MANUAL CONTROLS

New K Series modules bridge the gap between solid-state logic and manual controls. K Series now offers a convenient way to add lights, toggle switches, push buttons, thumb wheels, and timer controls to any K or M Series logic systems. New modular panel hardware is also available for these modules so that control panels can be designed for ease of use.

Cover illustration courtesy of Ex-Cell-O Corporation
K SERIES SOLID STATE CONTROL MODULES

LOGIC MODULES
K0XX to K3XX

INTERFACE MODULES
K4XX to K6XX

K SERIES HARDWARE
K7XX and K9XX

UNIVERSAL HARDWARE

APPLICATIONS

CONTROL AND DATA ACQUISITION SYSTEMS

K SERIES LOGIC LAB

INDAC-8

PDP-14

DEC PRODUCT SUMMARY
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FOREWORD

This third edition of the DIGITAL Control Handbook is for anyone who specifies, designs, manufactures or uses electronic or mechanical logic for instrumentation and control. Here you will find a wealth of useful information on the latest techniques and products available for implementing faster, cheaper, more reliable solid state electronic control systems.

Featured in this edition is the greatly expanded K Series line of low cost logic and interfacing modules, designed especially to operate in the electrically noisy surroundings that are unavoidable around electrical machinery. Over thirty K Series applications notes are included to help you easily design custom systems from these easy-to-use modules. Here are presented designs for four kinds of sequencers, digital comparators, thumbwheel switch multiplexers, annunciators, shaft angle pickup logic, memories for preset codes or limits, and many more. In addition to the Applications section, there are also dozens of useful design notes to be found in product descriptions scattered through the book. They are accessible from the regular index at the back or by using the thumb index on page 1.

Also described in this edition are compatible analog/digital conversion modules, standard analog/digital conversion subsystems, and complete systems for data acquisition (INDAC), N/C tape preparation (Quickpoint) and the PDP-14 machine controller. This edition also contains information on a broad selection of the latest PDP computers and other equipment for control and data acquisition systems. The DIGITAL Control Handbook will let you take advantage of the latest advances in solid-state control equipment.

DIGITAL sales engineers in over sixty offices around the world and our home office applications engineering staff are ready to help you put your control designs into action. They are all listed on the inside back cover. After you have scanned the book, give us a call.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>THUMB INDEX</td>
<td>1</td>
</tr>
<tr>
<td>FOREWORD</td>
<td>III</td>
</tr>
<tr>
<td>PART I — K SERIES SOLID STATE CONTROL MODULES</td>
<td></td>
</tr>
<tr>
<td>INTRODUCTION TO SOLID STATE LOGIC FOR INDUSTRIAL USE</td>
<td>1</td>
</tr>
<tr>
<td>K SERIES GENERAL SPECIFICATIONS</td>
<td>7</td>
</tr>
<tr>
<td>LOGIC SYMBOLOGY</td>
<td>14</td>
</tr>
<tr>
<td>LOGIC MODULE DATA SHEETS</td>
<td>16</td>
</tr>
<tr>
<td>Gating Modules, K0XX and K1XX</td>
<td>16</td>
</tr>
<tr>
<td>Flip-Flops and Memories, K2XX</td>
<td>33</td>
</tr>
<tr>
<td>Timers, K3XX</td>
<td>48</td>
</tr>
<tr>
<td>Manual Control Modules, K4XX</td>
<td>59</td>
</tr>
<tr>
<td>INTERFACE MODULE DATA SHEETS</td>
<td>68</td>
</tr>
<tr>
<td>Inputs, K5XX</td>
<td>69</td>
</tr>
<tr>
<td>Outputs, K6XX</td>
<td>85</td>
</tr>
<tr>
<td>K SERIES HARDWARE AND ACCESSORIES</td>
<td>99</td>
</tr>
<tr>
<td>Accessories Containing Electronics, K7XX</td>
<td>100</td>
</tr>
<tr>
<td>Mounting Hardware, K9XX</td>
<td>118</td>
</tr>
<tr>
<td>ANALOG/DIGITAL MODULES</td>
<td>125</td>
</tr>
<tr>
<td>UNIVERSAL HARDWARE</td>
<td>134</td>
</tr>
<tr>
<td>APPLICATIONS</td>
<td></td>
</tr>
<tr>
<td>Construction Recommendations</td>
<td>152</td>
</tr>
<tr>
<td>Relay Logic to K Series</td>
<td>158</td>
</tr>
<tr>
<td>Sequencers, Introduction</td>
<td>166</td>
</tr>
<tr>
<td>Timer Sequencers</td>
<td>168</td>
</tr>
<tr>
<td>Counter Sequencers</td>
<td>170</td>
</tr>
<tr>
<td>Shifter Sequencers</td>
<td>172</td>
</tr>
<tr>
<td>Polyflop Sequencers</td>
<td>173</td>
</tr>
<tr>
<td>Using K303 Timers for Frequency Setpoint</td>
<td>174</td>
</tr>
<tr>
<td>Estimating K303 Time Jitter</td>
<td>175</td>
</tr>
<tr>
<td>Combining K with M Series Modules</td>
<td>176</td>
</tr>
<tr>
<td>Combining K with A Series Modules</td>
<td>178</td>
</tr>
<tr>
<td>Combining K with R Series Modules</td>
<td>180</td>
</tr>
<tr>
<td>Pulse Generator From NAND Gates</td>
<td>181</td>
</tr>
<tr>
<td>K531 Quadrature Decoder</td>
<td>182</td>
</tr>
<tr>
<td>Sensor Converters</td>
<td>184</td>
</tr>
<tr>
<td>DC Drivers</td>
<td>188</td>
</tr>
<tr>
<td>Using K210s For Long Odd-Modulus Counters</td>
<td>190</td>
</tr>
<tr>
<td>Parallel Counters</td>
<td>191</td>
</tr>
<tr>
<td>Annunciators</td>
<td>192</td>
</tr>
<tr>
<td>Multiplexing Thumbwheel Registers with K581</td>
<td>194</td>
</tr>
<tr>
<td>Fixed Memory Using K281</td>
<td>196</td>
</tr>
</tbody>
</table>
Table of Contents (cont.)

APPLICATIONS (Continued)
  Jamming Data into K220 or K230 .............................................. 197
  Pulse Rate Multiplier ........................................................... 198
  Pulse Rate Squarer ............................................................... 201
  Pulse Rate Accelerator/Decelerator .......................................... 202
  Serial Adder ............................................................................ 204
  Stepping Motors, Introduction .................................................. 206
  Basic Two Way Shift Register .................................................... 208
  SLO-SYN¹ Bifilar Motor Drive .................................................... 208
  Responsyn² Motor Drive ............................................................ 209
  Fujitus Motor Drive ................................................................. 210
  Voltage to Frequency Converter Using A207 .................................. 212
  Current to Frequency Converter Using K303 ............................... 213
  Using K604, K614 with 240 V ..................................................... 214

K SERIES LOGIC LAB ............................................................... 216

PART II — CONTROL AND DATA ACQUISITION SYSTEMS

CONTROL SYSTEMS ................................................................. 224

COMPUTERS AND NUMERICAL CONTROL ................................... 226

INDAC-8 .................................................................................... 228
  Hardware ................................................................................. 228
  Software .................................................................................. 240

PDP-14 ...................................................................................... 246
  System Components .................................................................. 251
  System Example ....................................................................... 261

DEC PRODUCT SUMMARY .......................................................... 266
  PDP-8/L and 8/I ....................................................................... 266
  PDP-9/L and 9/I ....................................................................... 268
  PDP-10 ..................................................................................... 270
  PDP-12 ..................................................................................... 272
  PDP-15 ..................................................................................... 274
  COMPUTER LAB ..................................................................... 276
INTRODUCTION

Control system complexity and demands on reliability are rising with ever-increasing automation. More and more, control system designers are looking to solid state electronics for new answers to the old problems of reliability, complexity, and economy. Some of the answers are provided by solid-state digital logic designed for the industrial environment, and solid state analog-digital conversion to link analog sensors and actuators to digital control.

Why Solid State?
The time-honored way to do control logic is with the deceptively simple-looking relay. The metal-to-metal contact area sees physical and chemical actions of remarkable complexity. Even the mechanical-magnetic interactions are involved enough to cause problems now and then. Still, relays sometimes respond beautifully to simple maintenance. If the contacts stick, force them apart; if they are dirty, clean them.

Railway signaling relays, operating perhaps a hundred times a day, accumulate 25 years and a million operations without failure. And modern sealed-contact relays can do 10 billion operations under the right conditions without wearing out. So why abandon well-proven, reliable components? Don’t, unless it is necessary! But it is becoming necessary in a growing number of applications.

Reliability
As profit margins grow tighter, and maximum process efficiency becomes a necessity rather than an ideal, control system reliability assumes greater importance. Faulty operation and machine downtime can swiftly and disastrously cut into the profit picture. With a highly complex control system, check-out can easily become a very costly and time consuming operation. Many factors affect the reliability of a control system. A major consideration is the speed at which the logic control elements must operate. At 1KHz, near the maximum rate for dry reed delays, 100 million operations accumulate in about 30 hours. Longer-lived mercury-wetted contacts, operating 100 times per second, accumulate 10 billion operations in about four years. Even if a four year component life is enough, there are applications where 100 operations per second are not. Solid state logic, with nothing to wear out, stick, or corrode, can operate almost indefinitely at 100,000 operations per second.

Complexity is another factor. Demands for more automation, more efficiency, more safety, more accuracy all result in increased control system complexity. As a result, the sheer numbers of logical decisions demand component reliability far greater than that acceptable in a small system. Solid state logic provides the degree of reliability needed in a large system, at reasonable cost.

Size
Even the tiniest-contact reed relay coil is enormous alongside a transistor, or a complete integrated circuit. And most small control systems are not built with reed relays: to get the advantage of ruggedness or standardization, usually all the relays used are built to 300 volt or even 600 volt specifications whether they drive external loads or just relay coils. But a single small printed circuit board can easily accommodate a half dozen or more relay equivalents in logic capability, in a small fraction of the space of one 300 volt relay.
Computer Tie-In
There are several levels of computer involvement possible, extending from incorporation of a computer as a part of an individual control system to the use of a central computer to monitor the performance of many independent control systems. Regardless of the level at which the computer interacts, its presence demands an interface between solid-state circuitry and the controlled machine or process. If such an interface is forced into existence by the present or projected future use of a computer, why not put solid state control logic behind it and gain the benefits of solid state speed, compactness, and reliability throughout the entire system?

Also solid-state logic can communicate with existing analog sensors and actuators through solid-state analog-to-digital (A/D) and digital-to-analog (D/A) converters.

All of these factors tend to make solid state control systems increasingly attractive, particularly as their costs come down.

Who Should Be Designing For Solid State Controls?
Broadly speaking, the decision between conventional relay controls and the new solid state controls, like most engineering decisions, hinges on comparative overall costs. Where three or four or a half dozen relays can do the whole job, the cost of a solid-state interface will seldom be justified unless high speeds are required. Very large or computer-oriented systems leave little justification for the use of relays.

For intermediate systems, the comparison is more complicated. The tabulation below can serve as a framework for a systematic review of factors you should consider before you specify your next control system.

<table>
<thead>
<tr>
<th>Considerations</th>
<th>Factors Suggesting Relays</th>
<th>Factors Suggesting Solid State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability</td>
<td>Control system failure causes no panic. Temporary manual control acceptable. Simple system, easy to trouble shoot.</td>
<td>Downtime cuts quickly into process profitability. Quick check-out of entire system in case of trouble desirable, instead of on-the-spot checking. Lives and property might be endangered by failure.</td>
</tr>
<tr>
<td>Cost</td>
<td>Low cost relays acceptable. Maintenance costs need not be considered. Personnel training costs important. System failures will not cause significant secondary costs.</td>
<td>High quality relays used for comparison. Costs of failure high. Installation space costly. Cost of future modifications must be considered. Maintenance costs over life could be important.</td>
</tr>
<tr>
<td>Complexity</td>
<td>Small systems, perhaps a half dozen relays or fewer.</td>
<td>Complicated systems, which would require fifteen or more relays to implement.</td>
</tr>
<tr>
<td>Sophistication</td>
<td>Traditional performance still acceptable.</td>
<td>New levels of performance are needed, calling for increased control system complexity to remain competitive.</td>
</tr>
<tr>
<td>Considerations</td>
<td>Factors Suggesting Relays</td>
<td>Factors Suggesting Solid State</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Familiarity</td>
<td>Controls must be serviced by electricians who can not be retrained.</td>
<td>Environments already include other solid-state components or they will soon be added. Also, multi-system installations where a few controls technicians will cover a lot of equipment.</td>
</tr>
<tr>
<td>Growth</td>
<td>No foreseeable use of computers. Little likelihood of important modifications.</td>
<td>Added performance or safety features may be wanted later without tearing the system down. Computer tie-in might become desirable or is planned already.</td>
</tr>
<tr>
<td>Size</td>
<td>Plenty of space available.</td>
<td>Relay equipment might require separate balconies, restrict maintenance of machinery, or block aisles. Features added later must fit original enclosure.</td>
</tr>
<tr>
<td>Speed</td>
<td>Control system delays of tens of milliseconds acceptable. Operating rate is low, relay wearout no problem.</td>
<td>Compatibility with pulse tachometers, photoelectric pickups, electronic instruments required. Closed-loop stability demands quick response. High repetition rate that would cause wearout of moving parts.</td>
</tr>
</tbody>
</table>

**Why Digital?**

Relays, solenoids, switches, fuses, locks, counters, annunciators, panel lights and panic buttons all have one thing in common: they are digital. All these devices (when working properly) are up, down, on, off, in, out; but never in-between. Strictly speaking, of course, you cannot get from on to off without passing through in-between. But digital devices pass through in-between at maximum speed, and without waiting around for doubt to creep in.

Non-digital devices like panel meters, potentiometers, and slide rules work in the “in-between” area, producing outputs that are proportional to the input. The angular position of a panel meter pointer is the analog of the magnitude of the electrical input. A potentiometer’s voltage output is the analog of mechanical shaft position. In a slide rule, position is the analog of magnitude.

In a slide rule, accuracy is limited by the thickness of the calibrating marks and the difficulty of estimating values between them. Each space is an area of uncertainty. The same kind of uncertainty exists in every proportional electrical system, in the form of noise. In all but the most expensive analog equipment, the amount of noise, like slide rule error, limits accuracy to two or three significant figures.
Noise taken in this broad sense affects every proportional device. Noise is a major reason for the dominance of digital computers over analog computers where complex calculations are required. Small amounts of noise contributed by each analog input or computing element add up to degrade the accuracy of the answer. In digital circuits, the noise can be disregarded as long as it is below an “off” or “on” threshold level.

Analog controllers and servo systems, chart recorders, panel meters, and small analog computers are often simpler and cheaper than their digital equivalents, and should be used wherever they can do the job. But since so many commonly used control devices (from relays to panic buttons) are digital anyway, all-digital control is convenient. For complex control situations, digital methods can deliver accuracy and perform types of control beyond the ability of an analog system at any cost. And using solid state digital control, analog and digital devices can work together through A/D and D/A conversion. Better still, noise-free direct digital sensors and actuators can be used in the design of new process equipment.

Noise Immune Control Modules

Because of their high sensitivity and speed, solid state components can respond to noise that relays would safely ignore. To use solid state logic with freedom from noise problems in the neighborhood of arcing contacts, brushes, welders, etc. requires special design considerations.

Unlike analog devices, digital circuits have a noise “threshold” above which a noise or signal must rise to cause any change in the output of the circuit. It is this threshold that accounts for the superiority of digital circuits in processing information through complex manipulations without loss of accuracy.

In the design of solid state logic for industrial use, this basic-threshold feature of digital circuits can be exploited. By adding external capacitance, the speed, and thus the sensitivity, of the circuit can be lowered.

Noise

Suppose that on the basis of the above, you find you should be using solid-state digital logic. But will the system “drop bits,” or otherwise go haywire in your environment? How well can noise trouble be anticipated, and what measures should be taken? How can you compare the noise immunity of competing manufacturers’ circuits? These questions need some kind of answer before you can feel confidence in taking the step.

A logical starting point is the noise itself. What is its amplitude? Its frequency distribution? How does it vary with time? With temperature? How many pico-farads of coupling capacitance between the noise sources and the logic wiring? How many nanohenries of shared inductance in the logic and noise ground return paths?
Right away you suspect these questions are going to be difficult to answer. You may be able to say that typical noise source voltages are "measured in kilovolts" and are "strongest in the Megahertz frequencies." But going beyond such hazy estimates will require detailed knowledge of the physical conditions that interact to produce electrical noise. You'll need to know the materials used in all metal-to-metal contacts, and the condition of the contact surfaces. You'll need the inductance and capacitance of the wires connecting them. And the inductance and capacitance of the loads they drive. And the gases in the atmosphere surrounding the contacts. Even the exact routing of the wires will have to be examined.

Is solid-state out of the question after all, because analysing the noise environment is impractical? No, solid-state can still be used; provided you use circuits designed specifically for noisy environments, where the focus is on qualitative rather than quantitative factors.

**Engineering For the Unknown**

Engineers prefer to deal in quantities: "how big," "how many," and "how much." Success in dealing with noise requires a different approach because very few if any accurate numbers about noise will be forthcoming. Qualitative considerations, those that affect the overall character of circuit behavior rather than specific numerical details, are central to this approach.

We can group the qualitative tools available for dealing with electrical noise into two groups: those that keep noise out of the solid-state logic, and those that minimize the influence of noise that gets in. Keeping noise out is cheaper than electrically rejecting it, since primarily mechanical and packaging considerations rather than electronic aspects are involved. Here are some of the ways you can keep noise out:

1. Segregate logic wiring from field wiring. Don't design input converters and output drivers so field wiring goes through the same connectors used to carry logic signals. Arrange to use opposite ends of printed boards for logic and field wiring connections, and never allow the two kinds of wiring to lie side-by-side or be bundled together.

2. Don't mix logic ground with field ground. This doesn't mean logic ground should float; on the contrary. But heavy currents should not pass through the logic ground system on their way back to a power supply. An excellent scheme is to switch the AC line with isolated triacs. DC solenoid drivers might seem difficult to isolate, but judicious use of ground isolating resistors and auxiliary chassis tiepoints can force most of the load current outside of the logic ground system.

3. Use high-density packaging. Computer type modular construction minimizes lead lengths in the logic, minimizing the capacitive coupling between logic wiring and nearby field wiring. Dense packing also cuts resistance and inductance in the logic grounding system, minimizing interference from any residual noise currents that may flow there.

4. Where logic and power circuits must be adjacent, use shielding. For example, a group of printed boards carrying field circuits can be shielded from general purpose logic modules simply by inserting un-etched copper clad boards in the sockets that separate the two groups. (Logic power must skip these sockets to avoid shorting the supply). A single ground connection to the shield board is perfectly adequate, since the noise currents it carries will be limited by the small capacitance involved.
5. Filter the line voltage where it enters the logic power supply, or at supply output terminals. Supplies for panel lamps should also be filtered, if their wiring approaches logic wiring. Do not use logic power for any other function or carry supply output wires into the field for any reason.

The above five measures may suffice to allow even fast, computer-speed logic to be used in the vicinity of severe noise. Often, however, some forgotten loophole in the noise exclusion plan will spoil the dependability of an otherwise noise-tight system. All it takes is one such leak to cause real headaches if the logic itself is sensitive to noise. A good belt-and-braces approach will include not only these noise isolation qualities, but several noise desensitizing qualities as well:

1. Slow speed of response. Noise is usually most intense at high frequencies (in the Megahertz). Metal-to-metal contacts are nearly ideal step generators, and wiring resonances often dictate high-frequency noise peaks. A circuit that can't be switched for five microseconds is deaf to all but the biggest and slowest of noises, and usually will be entirely undisturbed. But be careful to use discrete capacitors, not sluggish semiconductors to obtain circuit slowdown. Semiconductor manufacturers "improve" their products regularly, often by increasing their speed.

2. Good current threshold and voltage thresholds. By "good" is meant "measured in milliamperes and volts." The bigger the better, but guard against falling in love with numbers. A factor of two in voltage threshold means little if you can't predict noise amplitudes to the nearest order of magnitude.

3. Risetime independence. Circuits that don't care what risetime you feed them give you an important insurance policy. If all else fails, you can hang a capacitor to ground at any troublesome point, without worrying about the effect this has on risetime. Even more than the other qualities, risetime independence is a prime example of engineering for the unknown.

4. Special care in timer and flip-flop design. These are the circuits that stretch a noise spike to damaging length. A system that has noise-immune, risetime-independent flip-flops and timers will for most purposes be as noise immune with ultra-fast gates as with slow gates.

Looking Ahead
Many of the factors listed above cost nothing more than forethought. All are applicable regardless of choices between discrete components, integrated circuits, or a combination. As the qualitative approach to noise avoidance is more widely understood and applied, solid-state logic will become more accepted, more universal. Fears will disappear. Should your next control system be solid-state?
K SERIES
CONTROL MODULES

Computer-oriented logic, by its very nature, is high speed (1 MHz and above), and provides noise immunity far below that required in a process control environment. The upper frequency range of the K Series modules is 100 KHz, with provision for reduction to 5 KHz for maximum noise immunity. These modules incorporate all silicon diodes, transistors, and integrated circuits, deliberately slowed through the use of discrete components.

Either English (non-inverting) logic or NAND/NOR logic is compatible with K Series. The hardware for this series is specifically designed for standard NEMA enclosures. FLIP CHIP™ mounting hardware can likewise be used for rack-mounting, inasmuch as K Series modules fit standard DEC sockets.

Proven FLIP CHIP™ connectors, used for years in applications from steel mills to lathe controls, provide modularity. Even the connection between terminal strips and electronics can be plugged for installing the logic after field wiring is complete, and removing it quickly for modifications or additions.

Checkout and trouble shooting is easy with K Series logic. Wherever possible, every system input and output has an indicator light at its screw terminal. A special test probe provides its own local illumination and built-in indication of transients, as well as steady states. Every point in the system is a test point, and consistent pin assignments reduce the need to consult prints.

Construction materials and methods are the same as for other high-production FLIP CHIP™ modules, including a computer-controlled operating test of each complete module. K Series modules further offer the size reduction, reliability, flexibility, and low cost of solid state logic, with an added bonus of easy interconnection. FLIP CHIP™ industrial modules are ideal for interfacing high speed M Series or computer-systems to machinery and processes. Sensing and output circuits can operate at 120 vac for full electromechanical capability. Inputs from contact devices see a moderate reactive load to assure normal contact life. Solid state ac switches are fully protected against false triggering. Voltages from the external environment are excluded from the wire-wrap connections within the logic.

K SERIES SPECIFICATIONS

SUMMARY
Frequency range: DC to 100 KHz. Control points on the modules allow reduction to 5 KHz for maximum noise immunity for critical functions.

Signal levels: 0v and ±5v, regardless of fanout used.

Fan-out: 15 ma available from all outputs; typical inputs 1-4 ma.

Waveforms: Trapezoidal. No fast transients to cause cross talk. External capacitive loading affects speed only; no risetime dependence.

Temperature range: −20°C to +65°C, using all-silicon diodes, transistors, and monolithic integrated circuits (0° to 150°F). (Limited to 0°C on the module types: K201, K202, K210, K211, K220, K230, K596).
Noise immunity: False “1”: 30 mA at 1.6V for 1.5 \( \mu \)sec typical. False “0”: 3 mA at 3V for 1.5 \( \mu \)sec typical. Time thresholds can be increased by a factor of 20 for critical points by wiring the slowdown control pins.

Simple power requirements: Single voltage supply, \( \pm 5V \pm 10\% \). Dissipation typically 200 mw per counting or shifting flip-flop, 30 mw per control flip-flop, 10 mw per two-stage diode gate.

Control system voltage: 120 VAC, 50 or 60 hertz.

Mounting provisions: Standard NEMA industrial enclosures. May also be used in 19” electronics cabinets.

**GENERAL SPECIFICATIONS**

**Construction Features**

K-Series modules include the quality features of older lines of FLIP CHIP modules: flame-resistant epoxy-glass laminates, all-silicon semiconductors, gold plated fingers and solid gold connector contacts. Thorough testing of each module is by computer operated automatic tester for most modules, or by specialized equipment for those which are not amenable to automatic test. A test specification sheet or data sheet is packaged with each module, including a circuit schematic for that type. Monolithic or hybrid integrated circuits are included wherever they can improve the performance-cost ratio. Versatile mounting hardware imposes as few physical constraints as practicable. Outline drawings below show nominal module dimensions.

**STANDARD MODULE SIZES**

**SINGLE - WIDTH FLIP CHIP MODULE**

[Diagram showing specifications for a single-width flip chip module]

**SINGLE - HEIGHT FLIP CHIP MODULE**

[Diagram showing specifications for a single-height flip chip module]
Logic Signals
There are no ultra-fast transients at any K Series output. Logic signal "1" and "0" levels are essentially independent of fanout. Rise and fall transitions have controlled slopes which are not strongly influenced by normal changes in fanout, lead length, temperature, or repetition rate. The fastest K Series trapezoidal logic signal can be fully analyzed with a 500KC oscilloscope. Logic "1" or "true" is +5 volts and logic "0" or "false" is zero volts except where redefined by logic designer. Counters and shift registers advance at the "1" to "0" transition and are cleared by a "0" level. Any unused input may be left open.

M Series Compatibility
M Series outputs can drive K Series logic gates and output converters directly, and any K Series input after passing through a K Series gate, provided they meet timing requirements. See Applications Notes.
Fanout and Fanin
K Series fanout capabilities are sufficient to relegate fanout calculations to the final checking phases of logic design. Logic outputs from any module type can drive up to 15 milliamperes. Logic gate inputs consume 1 milliampere per input. Other loadings range from 1 to 4 milliamperes as indicated by the loading numbers enclosed in squares on each specification diagram.

Expandable gates give K Series a fanin capability well beyond typical logic requirements. The most restrictive fanin condition in K Series logic concerns the wired AND configuration, for which several logic outputs are simply wired in common: the wired AND fanout capability is reduced to three milliamperes when the maximum of 4 outputs are tied together. The second level of logic (the OR node) within K113 and K123 gates is limited to less than 10 OR inputs to preserve output falltime control. The input AND gates of K113 or K123 modules may be extended with K003 expanders up to a maximum of 100 inputs, well beyond any practical requirement. The AND and OR function may be expanded at the same time on the K113 and K123 gate.

Operating Temperature
K Series modules are designed for operation in free-air ambient temperatures between −20°C and +65°C (0°F to 150°F) except the following types which are restricted to 0°C (32°F) minimum: K201, K202, K210, K211, K220, K230, K596.

Speed
Many applications for K Series modules involve operation at rates lower than relay speeds. Even at speeds many times faster than relay capabilities, timing need not be considered unless the logic includes a "loop". A flip-flop constructed of logic gates is such a loop, in which the output at a given point feeds back to influence itself, thus demanding input durations longer than total loop delay. Proper operation of such loops should be verified by calculation using the specifications below. For a complex loop an experiment should be made if possible to look for flaws in the calculations.

When anticipated repetition rates will be of the same order of magnitude as rated logic frequency, more care is required in timing design. K Series circuits are intentionally slowed to the maximum extent practicable for 100 KHz operation, and the resulting propagation delays can limit complex logic systems to 50 KHz or 30 KHz repetition rates. Timing loops must be examined just as carefully in slow logic as in fast logic. If K Series speed appears marginal or insufficient for the job at hand, use M Series high speed logic modules.
## K SERIES TIMING

| Timing Characteristics for K113, K123, K124, K202, K210, K211, K220, K230 | Time (\(\mu\)sec) |
|---|---|---|---|
| Logic Gate Propagation Delay. Time Delay for output to rise to 2.5v after input is sensed. | Min. | Typ. | Max. |
| Output D only, when connected to pin B | 7.5 | 40 | 180 |
| Logic Gate Propagation Delay. Time Delay for output to fall to 2.5v after input is sensed. | Min. | Typ. | Max. |
| Output D only, when connected to pin B | 4.5 | 20 | 180 |
| As above, but pin B grounded to pin C | 10 | 30 | 100 |
| Count/Shift Input Propagation Delay, Output Fall | Min. | Typ. | Max. |
| As above, but pin B grounded to pin C | 10 | 30 | 100 |
| Rise time, all unslaved outputs, K113, K123, K124. (0v to +5v) | Min. | Typ. | Max. |
| Pin D output only, when connected to pin B | 30 | 140 | 240 |
| Falltime, all unslaved outputs, K113, K123, K124 (+5v to 0v) | Min. | Typ. | Max. |
| Pin D outputs only, when connected to pin B | .5 | 1.5 | 4.0 |
| Minimum time between successive input transitions on any module which has one or more Count/Shift inputs. | Min. | Typ. | Max. |
| As above, but pin B grounded to pin C | 4 | | |

 Exceptions:
 Input transitions at pins J and K may follow other input transitions with delays down to zero; For characteristics not listed above, see timing information on individual data pages.

NOTE: Count/Shift inputs are included in types K202, K210, K211, K220, and K230

### Noise Immunity

Two properties of electrical interference often overlooked in evaluating logic noise immunity are its source impedance and its frequency distribution. Unless the digital logic is spread over several feet or yards so that high potentials can be induced in the ground system, most noise will be injected via very small stray capacitances and hence will have a high source impedance. The voltages at the noise source itself are usually measured in thousands of volts. Consequently, voltage thresholds alone cannot provide adequate noise rejection. The noise appears to come from a current source, so that logic circuit current thresholds are also an important measure of noise immunity.
Capacitance-coupled interference is strongest at the highest frequencies. Logic circuits which respond slowly can reject high frequency interference peaks that exceed dc current and voltage thresholds. K Series modules get their outstanding noise immunity from a balanced combination of current, voltage, and time thresholds.

Although good noise thresholds are important, noise environments are only vaguely predictable, so the following design features are probably still more important:

1. All field wiring is isolated from K Series logic wiring pins.

2. Logic power is not transmitted outside the logic environment for contact sensing, etc.

3. W994 electrostatic shields may be plugged in to further isolate pilot circuit noise: see Construction Recommendations (first Applications Note)

4. Plug-in module compactness keeps logic wiring short, to reduce noise injection capacitance, and confines the ground mesh for reduced ground noise.

5. Every third logic gate has optional slowdown control, ample for slowdown of all control flip-flops.

6. If all else fails, lack of risetime dependence permits any K Series output to be loaded with 0.01 mfd to ground to further reduce impedance and speed of response. Each K003 diode expander has such a capacitor available at pin B.

K Series Typical Noise Thresholds
To be falsely interpreted as a high level, a low (zero volts) K Series logic level would have to be raised 1.6 volts and held there for 1.5 microseconds; to do this would require 30 milliamperes to be supplied somehow from the noise source to the K Series output in question for this period of time. To be falsely interpreted as a low level, a high (+5V) K Series logic level would have to be reduced 3 volts and held there for 1.5 microseconds; to do this would require 3 milliamperes to be supplied somehow from the noise source to the K Series output in question for this period of time.

Power Requirements
A simple 5 volt supply operates any K Series system. Tolerance at room temperature: ±10%. K Series regulators K731 and K732 have a built-in temperature coefficient of approximately minus 1% for 3°C(5°F) to obtain full logic fanout over a wide temperature range and to minimize the temperature coefficient of K303 timers. Both regulators run from a nominal 12.6 volt center-tapped transformer secondary, with hash removed. See Construction Recommendations for information about alternate sources of logic power. Logic power is not used for contact sensing; 120 VAC is specified to provide full compatibility with silver contacts and noisy environments.
K SERIES LOGIC SYMBOLS

Symbols used in K Series diagrams are based on standard IC1-1965-15B for industrial controls issued by the National Electrical Manufacturers’ Association ("NEMA"). For those not familiar with this standard, the basic symbols are defined below, along with equivalent symbols from U.S. Military Standard Mil STD-806B. K Series modules are designed to allow a logical “1” to be identified with the positive voltage level, and logical “0” with zero volts. The diagrams shown below follow this convention. Notice that except for timers, the two symbol standards are one-for-one interchangeable. For relay logic symbol conversion, see second Applications Note.

<table>
<thead>
<tr>
<th>K-SERIES SYMBOL</th>
<th>LOGIC FUNCTION</th>
<th>MIL SYMBOL</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="AND Diagram" /></td>
<td><img src="image" alt="AND Truth Table" /></td>
<td><img src="image" alt="AND MIL Symbol" /></td>
</tr>
<tr>
<td><img src="image" alt="OR Diagram" /></td>
<td><img src="image" alt="OR Truth Table" /></td>
<td><img src="image" alt="OR MIL Symbol" /></td>
</tr>
<tr>
<td><img src="image" alt="NOT Diagram" /></td>
<td><img src="image" alt="NOT Truth Table" /></td>
<td><img src="image" alt="NOT MIL Symbol" /></td>
</tr>
</tbody>
</table>

**NOTE:** OVERBAR MEANS NEGATION IF A IS FALSE A IS TRUE AND VICE-VERSA.
<table>
<thead>
<tr>
<th>K SERIES SYMBOL</th>
<th>LOGIC FUNCTION</th>
<th>MIL SYMBOL</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Binary Counter Diagram" /></td>
<td><img src="image" alt="Logic Function Diagram" /></td>
<td><img src="image" alt="Binary Counter Diagram" /></td>
</tr>
<tr>
<td><strong>BCD Counter</strong> (Binary-Coded Decimal)</td>
<td><img src="image" alt="Logic Function Diagram" /></td>
<td><img src="image" alt="Binary Counter Diagram" /></td>
</tr>
<tr>
<td><strong>OFF DELAY</strong> (With Gated Input)</td>
<td><img src="image" alt="Logic Function Diagram" /></td>
<td><img src="image" alt="OFF DELAY (With Gated Input) Diagram" /></td>
</tr>
<tr>
<td><img src="image" alt="Converter Diagram" /></td>
<td><img src="image" alt="Converter Diagram" /></td>
<td><img src="image" alt="Converter Diagram" /></td>
</tr>
</tbody>
</table>
K003 AND expander: May be connected to the AND expansion node of any K Series module.

K003 AND/OR expander: May be connected to the OR expansion node of any K Series module.

K012 OR expander: May be connected to the OR expansion node of any K Series module.

K026 AND/OR expander: May be connected to the OR expansion node of any K Series module.
K028 AND/OR expander: May be connected to the OR expansion node of any K Series Gate.

These inexpensive gate expanders offer great logic flexibility and versatility without a proliferation of module types. Logic functions performed by expanders are illustrated in combination with the K113 and K123 gates in several pages that follow the data sheet for the gates themselves.

Each K003 expander module has a .01 uf capacitor available at pin B which may be used to implement logic delays as shown in the Application notes or to further reduce the speed of a K Series output.
LOGIC GATES
K113, K123, K124

K113 INVERTING GATE
K123 NON-INVERTING GATE
K124 AND/OR GATE

K113
K123
K124

Together with the K003, K012, K026 or K028 expanders, these gates perform any desired logic function, including AND, OR, AND/OR, NAND, NOR, exclusive OR, and wired AND.

Logic gate type K123 is an AND/OR non-inverting gate subject to expansion at either the AND or the OR node. Logic symbols and equivalent schematics are compared in the following illustrations. Typical pin connections are shown.

The AND input can be expanded up to 100 inputs total. The OR input can be expanded by any of the expanders, up to 9 inputs total. More OR inputs can be added if faster fall times are acceptable. Both the AND and OR functions can be expanded at the same time.

Expansion of the K113 inverting gate is identical. The equivalent circuit is the same except for inversion in the output amplifier.

The K124 provides a convenient way to implement non-inverting gate control flip-flops, exclusive ORs, and two term OR logic equations without the need for expanders. The module is electrically the same as a K123 gate with a K003 expander.

All three gate types include a slowdown capacitor that can be connected to the output of one circuit to increase its noise rejection when gates are interconnected to make control flip-flops. Use of this capacitor increases rise and fall time by approximately a factor of 20.

K113 — $11
K123 — $12
K124 — $14
LOGIC SYMBOL

NEMA
- 1/3 K123
- 1/3 K003

MIL
- 1/3 K123
- 1/3 K003

SIMPLIFIED SCHEMATIC

K003 AND/OR EXPANSION
(K026 MAY ALSO BE USED)

NEMA
- 1/3 K123

MIL
- 1/3 K123

K012 OR EXPANSION
The basic types of logic functions obtainable by expansion are shown below for the K123 non-inverting gate. Logic functions for the expanded K113 inverting gate are identical except for inversion of the output. Letters refer to logic signal names rather than module pin numbers.

LOGIC FUNCTIONS WITH GATE EXPANSION
NAND, NOR, EXCLUSIVE OR

The K113 inverting gate performs the NAND function directly, and performs the NOR function when combined with a K003 expander.

With proper input connections, the K124 non-inverting gate performs the exclusive OR function.

NAND FUNCTION OF BASIC INVERTING GATE

NOR FUNCTION OF BASIC INVERTING GATE WITH EXPANDER

EXCLUSIVE OR CONNECTION OF BASIC NON-INVERTING GATE WITH EXPANDER
WIRED AND
Wired AND functions can be obtained by connecting K123 outputs to other K124, K123 or K113 outputs as shown below. Any K Series output with a fanout of 15 may be wired ANDed.

WIRED AND EXAMPLES

SUMMARY OF GATE-EXPANDER
LOGIC COMBINATIONS

<table>
<thead>
<tr>
<th>Logic Function</th>
<th>No. of Inputs</th>
<th>Expanders</th>
<th>Gates</th>
</tr>
</thead>
<tbody>
<tr>
<td>AND</td>
<td>2</td>
<td>none</td>
<td>1/3 K123</td>
</tr>
<tr>
<td></td>
<td>3-5</td>
<td>1/3 K003</td>
<td>1/3 K123</td>
</tr>
<tr>
<td></td>
<td>6-8</td>
<td>2/3 K003</td>
<td>1/3 K123</td>
</tr>
<tr>
<td>OR</td>
<td>2</td>
<td>1/3 K003</td>
<td>1/3 K123</td>
</tr>
<tr>
<td></td>
<td>3-5</td>
<td>1/3 K124</td>
<td>1/3 K123</td>
</tr>
<tr>
<td></td>
<td>6-9</td>
<td>2/3 K012</td>
<td>1/3 K123</td>
</tr>
<tr>
<td>NAND</td>
<td>2</td>
<td>none</td>
<td>1/3 K113</td>
</tr>
<tr>
<td></td>
<td>3-5</td>
<td>1/3 K003</td>
<td>1/3 K113</td>
</tr>
<tr>
<td></td>
<td>6-8</td>
<td>2/3 K003</td>
<td>1/3 K113</td>
</tr>
<tr>
<td>NOR</td>
<td>2</td>
<td>1/3 K003</td>
<td>1/3 K113</td>
</tr>
<tr>
<td></td>
<td>3-5</td>
<td>1/3 K012</td>
<td>1/3 K113</td>
</tr>
<tr>
<td></td>
<td>6-9</td>
<td>2/3 K012</td>
<td>1/3 K113</td>
</tr>
</tbody>
</table>

FOR ZERO VOLTS DEFINED AS
LOGIC ZERO
standard definition

<table>
<thead>
<tr>
<th>Logic Function</th>
<th>No. of Inputs</th>
<th>Expanders</th>
<th>Gates</th>
</tr>
</thead>
<tbody>
<tr>
<td>AND</td>
<td>2</td>
<td>none</td>
<td>1/3 K123</td>
</tr>
<tr>
<td></td>
<td>3-5</td>
<td>1/3 K003</td>
<td>1/3 K123</td>
</tr>
<tr>
<td></td>
<td>6-9</td>
<td>2/3 K003</td>
<td>1/3 K123</td>
</tr>
<tr>
<td>OR</td>
<td>2</td>
<td>1/3 K003</td>
<td>1/3 K123</td>
</tr>
<tr>
<td></td>
<td>3-5</td>
<td>1/3 K012</td>
<td>1/3 K124</td>
</tr>
<tr>
<td></td>
<td>6-9</td>
<td>2/3 K012</td>
<td>1/3 K123</td>
</tr>
<tr>
<td>NAND</td>
<td>2</td>
<td>none</td>
<td>1/3 K113</td>
</tr>
<tr>
<td></td>
<td>3-5</td>
<td>1/3 K003</td>
<td>1/3 K113</td>
</tr>
<tr>
<td></td>
<td>6-8</td>
<td>2/3 K003</td>
<td>1/3 K113</td>
</tr>
<tr>
<td>NOR</td>
<td>2</td>
<td>1/3 K003</td>
<td>1/3 K113</td>
</tr>
<tr>
<td></td>
<td>3-5</td>
<td>1/3 K012</td>
<td>1/3 K113</td>
</tr>
<tr>
<td></td>
<td>6-8</td>
<td>2/3 K012</td>
<td>1/3 K113</td>
</tr>
</tbody>
</table>

FOR ZERO VOLTS DEFINED AS
LOGIC ONE
(inverted definition)
CONTROL FLIP-FLOPS FROM GATES

Control flip-flops can be formed by interconnection of gates as shown below.

NON-INVERTING GATE CONTROL FLIP-FLOP

The output of the flip-flop above is set to a ONE when the two SET inputs are both ONES. A ZERO at the RESET input returns the output to ZERO, provided at least one of the SET inputs is also ZERO.

INVERTING GATE CONTROL FLIP-FLOP

The flip-flop above, made from two inverting gates, provides complementary 1 and 0 outputs. A truth table is shown below.

<table>
<thead>
<tr>
<th>SET</th>
<th>RESET</th>
<th>1 OUTPUT</th>
<th>0 OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>NO CHANGE</td>
<td></td>
</tr>
</tbody>
</table>
K134 and K135 INVERTERS

Four flip-flop functional modules such as K210, K220, K230 can conveniently be augmented by a K134 or K135 to get “0” as well as “1” outputs. The K134 is also provided with expansion and inhibit inputs for use as the readout element of read-only memories using K281 diode memories (See Application Notes). A common input at pin K can force all four outputs high on both the K134 and K135.

The K134 inverters may also be AND expanded by K003 gate expanders, providing an efficient way to obtain 4-input NAND or inverted NOR gates.

The K135 inverters may be AND/OR expanded with the K003 or OR expanded with the K012 expander modules. No more than nine OR expansions should be connected to a given K135 gate.

The loading on pin K is initially 6 with no “OR” expansions and increases by “1” unit load for each “OR” input that is added to the module. For example, if a K012 expander was added to each of the four inverters, the total pin K load would be 22 unit loads.

K134 — $13
K135 — $13
Three-bit binary numbers at the input to the K161 will be decoded into eight one-at-a-time outputs. Both inputs and outputs are high for assertion. The inhibit input allows BCD to ten line decoders to be built, or permits several decoders to be interconnected for sixteen, twenty-four, thirty-two outputs, etc. The inhibit may be left open if unused, even though high is the inhibit state. When the K161 is being used with M series, all input signals must be buffered with K series gates. This is necessary due to the 3 volt thresholds in the K161.

Standard K Series slowdown circuits on each output minimize and for most purposes nullify the splinter pulses that all decoders emit during input transitions. Additional slowdown available on the zero output can usually suppress the larger splinter that may occur there. But since splinter size is ultimately determined by input timing tolerances, it is cleanest to avoid logic designs in which a decoder output is used as a source of pulses.

The diagrams below show how to connect decoders for 8, 10, 16 and 32 outputs. Much larger decoders are possible, and in fact up to 256 outputs or even more can be obtained by inhibiting all but one of several decoders.
8 STATE DECODER

1/3 K123

1/3 K123

BINARY-CODED-DECIMAL (BCD) DECODER

16 STATE DECODER

28
K174 DIGITAL COMPARATOR

Numerical comparisons such as those required in digital positioning controls are facilitated by the K174. Performing the same function as the comparator in closed-loop analog systems, the K174 tells which of two quantities is larger.

Fundamentally, the K174 performs a subtraction to determine whether a “borrow” would be needed to obtain a positive result. The magnitude of the difference is not available; only the sign.

Note in the example below that the output on pin K will be low only if the magnitude of the number in the K210’s is less than the thumbwheels.

If more than four bits are to be compared, several comparators may be cascaded as shown below. Note use of K003 to control the state of the output for the case of equal input numbers.

TWO DIGIT COMPARISON OF THUMBWHEELS AGAINST K210, ETC.
If the numbers being compared are not multiples of 4 bits then one of the inputs on each unused comparator position must be connected to +5 and the other one to ground.

The K174 can also be used to obtain three independent outputs for full-greater-than, equal-to, less-than capability. The application below takes advantage of the fact that if A is equal to B, K will go high if J goes high and K will go low if J goes low. By inverting the output at pin K and feeding it back to pin J, the K174 will oscillate if \( A = B \). If the timers are adjusted for a delay longer than the period of oscillation, the three possible output states can be obtained (High for assertion). With the values shown, the frequency will be approximately 50 KHz. Outputs respond to new conditions in 100 \( \mu \)sec.
If the four outputs of a K210 counter are wired to the K184 "F" inputs, and a four bit binary fraction is presented in reverse order to the corresponding "G" inputs, a pulse train is emitted at an average rate equal to the product of the K210 input rate and the binary fraction. Each transition from "0" to "1" at an FF input produces a 5 μsec output pulse to ground, if the corresponding "G" input has been high for 5 microseconds or more. Inputs are not rise-time sensitive. Outputs from several rate multipliers may be combined to give any desired precision.

Rate multipliers are primarily useful in numerical control applications, such as those described in the following magazine articles:

"Linear Interpolation" Control Engineering, June '64, p. 79
"Curvilinear Interpolation" Control Engineering, April '68, p. 81
"Many Digital Functions Can Be Generated With A Rate Multiplier" Electronic Design, Feb. 1, '68, p. 82.

In addition, the K184 can provide several other useful functions that take advantage of its internal complexities, shown below. Examples of both classes of use can be found among the applications notes.
This superslow memory simplifies sequencing of machine motions, and finds other applications where the ultimate in noise isolation is needed and speed is no problem. Its 1 KHz maximum repetition rate makes this flip-flop noticeably more resistant to extremely noisy surroundings than faster types like K202, K210, etc. So noise immune, in fact, that several yards of wire may be connected to K201 outputs even in severely noisy areas without errors.

The K201 flip-flop input gating is designed to respond to the time sequence of two inputs rather than to their simple AND function. Level inputs D, F, L, and N must be high at least 400 $\mu$s before the pulse inputs E, H, M, and P makes a high to low transition. The flip-flop will compliment if the S and R inputs are pulsed at the same time. The input minimum noise rejecting time thresholds are 100 $\mu$s. Successive input transitions must not be closer than 400 $\mu$s.
K202 flip-flops do shifting, complementing, counting, and other functions beyond the capabilities of simple set-reset flip-flops built up from logic gates. They also may be used to extend K210 counters or K230 shift registers.

When the output of the clock gate falls from high to low, the information at the OR input (pins D-J, L-P) is transferred into the flip-flop. Pin J (or P) is ORed with the pin D (or L) input. Like pins J and P of a logic gate, these pins can be driven only from a K003, K012, K028, or K026 expander.

Time is required for flip-flops and delayed inputs to adjust to new signals. The clock gate output must not fall to zero sooner than 4 μsec after its own rise, the end of a clear signal, or a change on associated data input pins.

A K202 flip-flop is cleared by grounding the clear input pin. The flip-flop is held in the zero state as long as the clear input is zero volts, regardless of other inputs.

When using a K202 flip-flop to extend the length of a K230 shift register, pins B on both modules must be left open (unslowed). Pin B slows the clock inputs of the K202 for complementing correctly at slow speeds in very noisy surroundings; but the data inputs are not affected by pin B.
Complementing: Below is shown a complementing application. Here the information stored at the data input is the opposite of the flip-flop’s present state. Each time the clock gate output changes from “1” to “0”, the opposite of the current state is read in.

![Complementing Pulse Diagram]

K202 COMPLEMENTING

Shift Register: The diagram below shows two flip-flops connected as a two-stage shift register. At each step the incoming signal, whether high or low, is set into the first stage of the register, and the original content of the first stage is set into the second stage. The input to each flip-flop must be stable for at least 4 microseconds before another shift pulse occurs, for reliable shifting.

![Shift Pulse Diagram]

K202 2-STAGE SHIFT REGISTER

Note: In older systems of logic, most flip-flop functions had to be performed by general-purpose flip-flops like the K202. The K Series, however, includes functional types K210, K211, K220, and K230 which are both less expensive and easier to use than the K202 for most applications. Think of the K202 primarily as a complementing control flip-flop and register extender.
The four set-reset flip-flops in the K206 are arranged for convenient addressing from the outputs of a K161 Binary to Octal Decoder. The flip-flop outputs can then be wired to control and maintain the state of corresponding output drivers, providing addressable output conditioning from teletypes, computers, or fixed-memory sequence controllers.

In addition, the same decoder may be used to address a particular K578 input sampler by grounding the K206 enable input when flip-flop changes are not desired. Pin E enable fanin on the K206 is reduced to 2 milliamperes when K161 addressing is used.

Since most control systems have about half as many digital outputs as inputs, it is convenient to use the least significant bit of the K161 address to determine which flip-flop state is wanted. Odd addresses allow for setting; even addresses, resetting. All flip-flops may be reset together by grounding the clear input, pin K.

When pin E is high, a logic “1” at an S input will set the output to a logic “1” and a logic “1” at an R input will reset the output to a logic “0”. S and R inputs should not be allowed to go high at the same time while the flip-flop is enabled. Any one or all flip-flops may be changed when pin E is high.
The K210 is a binary or BCD counter that can be wired to return to zero after any number of input cycles from 2 to 16. Count-up occurs when the COUNT gate output steps to zero. Decimal counting logic is built in; when pin D is unused, the counter resets to zero on the next count after nine. When pin D is grounded, the counter overflows to zero, after a count of 15. (Pin D is not intended for dynamic switching between binary and BCD counting.)

The counter is reset by grounding the clear input for 4 microseconds or more. A positive level at the J input from a K003 expander also resets the counter on the next high to low transition of the COUNT gate output. Counts of 10 or 16 DO NOT require the use of a K003 expander since they can be obtained with pin D.

Wire the K003 as a decoder to detect one count less than the desired modulus. (Detect 5 for a count-of-6 counter, etc.). Use the K424 Thumbwheel Decoder if manual reset control is desired.

K210 CONNECTED FOR COUNT OF 6

To count above 10, ground pin D. Combine two K003 expanders as shown below, where three counter outputs must be sensed (to divide by 8, 12, 14 or 15).

K210 — $27
K210 CONNECTED FOR COUNT OF 15

Time is required for flip-flops and pin J reset logic to adjust to new inputs. The count gate output must not step to zero sooner than 4.0 \(\mu\)sec after its own rise, a change at pin J, or the end of a clearing signal at pin K. **When pin B is grounded for slowdown, allow 50 \(\mu\)sec.**

Larger counters are obtained by cascading K210’s or adding K202 flip-flops. To cascade K210 modules, wire the most significant output of one counter to the input gate of the next. Inputs to the least significant stage can be either pulses or logic transitions to ground; risetime is not important.

Any transducer such as a switch, photocell, pulse tachometer, thermistor probe, or other compatible with K508, K522 or K524 input converters can generate the signal which is to be counted. The lack of input risetime restrictions may allow transducer outputs to drive K210 counters directly if damaging transients can be avoided, as when the transducer shares the logic system environment.

For visual readout of binary-coded decimal counters, the four outputs from each K210 may be connected to corresponding input pins on a K671 decoding driver and display.

K210 AUGMENTED WITH K202 FOR COUNT OF 32
The K211 is a binary counter that can be wired to produce a high to low output transition on pin V after any number of input cycles from 2 to 16. Count-up occurs on the high to low transition of the count gate output.

The counter is programmed by connecting pin L to pins M, P, S, and U to select the binary number that is one count less than the desired modulus. (Detect 7 for a count-of-8 counter, etc.).

The counter is reset by grounding pin K for 4 microseconds or more. Time is required for flip-flops to adjust to new inputs. The count gate output must not step to zero sooner than 4.0 μsec after its own rise or at the end of a clearing signal at pin K. When pin B is grounded for slowdown, allow 50 μsec.

K211 — $20
Larger dividers can be obtained by cascading K210's, K211's or adding K202 flip-flops. To cascade K211 modules, wire pin V to the input gate of the next module. Inputs to the least significant stage can be either pulses or logic transitions to ground; risetime is not important. Any transducer such as a switch, photocell, pulse tachometer, thermistor probe, or others compatible with K508, K522, or K524 input converters can generate the signal which is to be counted. The lack of input risetime restrictions may allow transducer outputs to drive K211 modules directly if damaging transients can be avoided, as when the transducer shares the logic system environment.

K211 modules can be used to build real time clocks and frequency dividers when only the most significant output is required.

REAL TIME CLOCK
Four flip-flops and all the gates needed for binary or binary-coded decimal up counting, down counting, presetting, and clearing are built into the K220. Up-down counters are useful for many digital position readout and feedback applications.

The direction of counting is established by the signal at pin L, high for up counting and low for down counting. Pin L count direction changes should finish no later than 4.0 \( \mu \)sec. before the next count input.

When K220 counters are cascaded, a single connection from Pin V of one K220 to the count input gate of the next establishes both carry and borrow propagation.
Up-counts occur when the count gate output makes a transition from high to low (+5V to 0V), as in the K210 and K230. Down-counts, however, take place on the transition from low to high (0V to +5V). Thus both carry and borrow signals propagate via the simple connection from pin V to the count gate of the next counter stage. ONEs present at the read-in gate pins U, S, P or M are read into the respective flip-flops when pin D makes the transition from low to high. The transition at pin D should finish not later than 4.0 μsec before the next count input. The transition from low to high at pin D should also begin no sooner than 4.0 μsec after any previous transition at pins D, J, K, L, M, P, S, U, or the count gate output. Ground any unused read-in gate inputs to prevent the read-in of undesired ONEs.

Grounding pin J or K forces all flip-flops to zero for as long as either clear input remains low.

Time is required for flip-flops, counting logic, or read-in gates to adjust to new inputs. Except clear inputs, neither the count gate output or any other counter input may be changed within 4 μsec of a transition at any other input. When pin B is grounded for slowdown, allow 50 μsec. All connections are made on the upper connector, except two: binary UP/DOWN counting may be obtained by grounding pins D and E on the lower connector.

Below is shown a means for accepting up and down pulse-trains from two separate sources. For this application input pulse spacing should be at least 20 μsec and input pulse width should be at least 10 μsec.

UP/DOWN COUNTER
FOR SEPARATE PULSE SOURCES TO 50Kc
Information presented to pin L of this four stage flip-flop register is shifted toward pin V with each transition from "1" to "0" at the shift input gate.

ONES present at the read-in gate input pins M, P, S or U are read into the respective flip-flops when pin D makes the transition from low to high. The pin D transition should finish no later than 4.0 $\mu$sec before the next count input. Transition from low to high at pin D should also begin no sooner than 4.0 $\mu$sec after any previous transition at pins D, J, K, M, P, S, U or the shift gate output. Ground any unused read-in gate inputs to prevent read-in of undesired ONEs.

Grounding pin J or K forces all flip-flops to zero for as long as either clear input remains low.

Shift registers of any length can be formed by tying pin V of one K230 to pin L of the next, and operating all shift gates together. Supply all shift pulses from the same device to maintain synchronism. The propagation delay of even one gate is too large a difference between two shift inputs on the same register. For every 20 bits that are required, duplicate the last stage of the shift-generating logic and tie the outputs in parallel to all K230 shift gate inputs.

Time is required for flip-flops, shifting logic, or read-in gates to adjust to new inputs. Except clear inputs, neither the shift gate output nor any other register input may be changed within 4 $\mu$sec after a transition at any other input. When pin B is grounded for slowdown, allow 50 $\mu$sec.
The K271 is a magnetically latched mercury wetted contact relay flip-flop. A logic one output from the SET gate will set the flip-flop, and a logic one output from the RESET gate will reset the flip-flop. The state of the memory will be unknown if the SET and RESET gate outputs are both logic one at the same time. Since time is required for the relay to change state, inputs must be high for at least five milliseconds.

Pin K must be held low or the memory can not be set or reset. Normally, the OK level output from a K731 source module drives pin K. When a line voltage failure is detected, pin K rises and the relay mechanically stores the last valid data until full power returns. Logic design must be provided for pin K to ensure that it remains high after power is restored until the system has returned to its proper state.
Three magnetically latched mercury wetted contact relays in the K273 follow logic-level input information at rates up to 100 Hz, when pin E is grounded. Normally the OK level output from a K731 source module drives pin E. When a line voltage failure is detected, pin E rises and each relay mechanically stores the last valid input data until full power returns. Logic design must be provided for pin E to ensure it will remain high after power is restored until the system has been returned to its proper state.
K281 FIXED MEMORY

The K281 is designed to be used with the K161 (Binary to Octal Decoder), the K681 (8-30 ma drivers) and the K134 (4 inverters), to build a read-only memory. Each K281 initially contains eight four-bit words consisting of only "1's". The user selects the codes he desires by cutting out diodes in the bit positions that are to be "0's". Additional K281 and K134 modules may be added to the system to generate more words and longer words. See Application Notes for diagram of memory configuration.

CODING THE K281 DIODE MEMORY

When the K281 is used to build a K Series Read Only Memory, the codes are stored by cutting out diodes where zeros are desired. The diode map below shows the physical location of the diodes on the K281 and how they are connected to the module pins.

Component side up

E, H, K, M are the four output pins.
D, F, J, L, N, R, T, V are the eight drive lines.

K281 — $8
The K301 Basic Timer can be used as an OFF DELAY (like the K303), ON DELAY or ONE SHOT (like the K323). Time delays from ten microseconds to 30 seconds can be obtained with either fixed or adjustable delays. Calibrated controls are available (K374, K376 and K378) for mounting directly on the K301. Remote controls can be added if desired. Mounting holes are provided on the module for different size timing capacitors and a trimpot or fixed resistor.

The output delay is controlled by the value of R and C connected to pin J. The timer recovery begins when either pin M or N is low or both F and H are high. Allow a recovery time of at least 300C (C in farads), in order to guarantee 95% repeat accuracy in timing. The timer delay period is equal to .7 RC. Any value of C may be used as long as R remains between 1 K and 250 K ohms. The following diagrams demonstrate how the K301 may be used to provide different types of timing. Pins P and S must be connected together to form the one shot circuit.

OFF DELAY (like K303)
ONE SHOT (like K323)

A positive pulse at the input will not terminate the timeout if the inverted output is connected to one input to the overshot. Pins M and N should be left open.

ON DELAY — K301

The K301 circuit is similar to the K303 Timer and uses the same techniques of noise rejection. For further information on resistors, capacitors and construction recommendations for external pulse width controls, please refer to the K303 module.

K301 — $13
K303 timers provide time delays from 10 microseconds to 30 seconds and can be interconnected to form clocks with periods covering the same intervals. Fixed or adjustable delays and frequencies are obtainable. Calibrated controls are available (K371 through K378) for mounting directly on the K303. Remote controls can be added, if desired. A simplified schematic of the K303 is shown below. The comparator has hysteresis, increasing the rejection of false “1” noise peaks at the input.
When a K303 input gate steps to zero, the uninverted output falls after a controlled interval, while the inverted output rises. The interval can be as little as 10 µsec or as long as 30 seconds depending on the size of the R and C connected to pin J, P, or V. Recovery begins when the input gate output rises to a logic "1". In order to guarantee 95% repeat accuracy in the delay time, a recovery time of at least 300 C should be used. (C is in Farads, Time is in seconds). Be sure to include the 2.2 nf capacitor as part of the value for C. The delay interval in seconds is equal to .7RC (R in ohms, C in farads).

Any value of C may be used as long as R remains between 1 K and 250 K ohms.

1/3 K303 AS OFF DELAY

A positive step at the input gate output resets the K303 timer outputs. If the step occurs before a timeout is complete, the timeout is terminated and no change appears at the outputs. This property is sometimes convenient for establishing a pulse repetition rate threshold (Frequency Setpoint).

A built-in 2.2 nanofarad timing capacitor assures adequate noise rejection when external capacitors are mounted several inches from the timer. Time threshold for resetting is always several percent of rated recovery time, so that noise rejection time increases in proportion to the size of the timing capacitor. Remote rheostats and timing capacitors may be used, but noise rejection will be degraded. If several timing capacitors will be switch selected, wire in the smallest near the module and switch the others in parallel with it.

Variable or fixed timing resistors used with K303 timers may be any carbon composition, film, or wirewound rheostat or potentiometer. Delay time is linearly proportioned to resistance from 250KΩ down to a few thousand ohms, falling to zero (reset inhibited) below a few hundred ohms. Momentary shorting to ground of control pins will not cause damage, but a padding resistor of at least 300Ω in series with variable controls is advisable both to prevent continuous grounding and to avoid confusion which may arise if resetting in inhibited.

Timing capacitors may be any ordinary mica, paper, ceramic, or low leakage electrolytic type. For delays above a few seconds, wet slug tantalum electrolytic capacitors are advisable to avoid leakage-induced drift at high temperatures. Temperature coefficient of delay has been optimized for the carbon composition potentiometers and tantalum electrolytic capacitors used in the controls described below, and is typically less than ±1% in 5°C (9°F) using K731 and K732 regulators for power.
K323 one shots provide output pulse widths from 10 microseconds to 30 seconds with either fixed or adjustable delays. Calibrated controls are available (K374, K376 and K378) for mounting directly on the K323. Remote controls can be added, if desired.

When either input to the K323 gate steps to zero the uninverted output rises and stays positive for a time equal to .7 RC. The pulse width is controlled by the value of R and C connected to pin J, P, or V. C can be any value, but R should be between 1 K and 250 K ohms. The one shot recovery begins when both signals at the input gate rise to logic 1. A recovery time of at least 300 C should be allowed to ensure 95% repeat accuracy in the output pulse width. (C is in farads, R is in ohms, time is in seconds).

K323 — $35
When both signals at the input gate are high, the uninverted output is forced low. If this occurs before a timeout is complete, the timeout is terminated and the pulse width will be unknown. This premature resetting can be eliminated by connecting the inverted output of the one shot to one of its inputs. This will make the one shot insensitive to input transitions during the timeout period.

A positive pulse at the input will not terminate the timeout if one input is connected to the oneshot inverted output.

The K323 circuit is similar to the K303 Timer and uses the same techniques of noise rejection. For further information on resistors, capacitors and construction recommendations for external pulse width controls, please refer to the K303 module.
Calibrated controls for timers, one-shots, and clocks are available in several ranges. They mount to the K301, K303, or K323 module on the side opposite the components by two screws per circuit, providing both mechanical and electrical connections. Each control includes a logarithmic potentiometer for easy settling over the full 30:1 calibrated range. Calibrations are approximate, meant for quick setup and easy control identification. Accurate time settings require the use of an oscilloscope, stopwatch, or other reliable time standard. These controls are intended for use at the end of K941 mounting bars.

Note: Time delay jitter is proportional to supply voltage ripple if times of the order of 1 msec are selected. For critical applications, use light loading on separate K731 or use H710 supply.
TIMER K303

Two K303 sections can be interconnected to make a free-running oscillator if one of the timing capacitors is about 100 times smaller than the other. The circuit with the larger capacitor will predominantly control the frequency. The diagram below shows the interconnections.

NOTE: K373, K375 PROVIDE TIMING COMPONENTS FOR THIS CIRCUIT

$18.00
Plus: 2 resistors
2 capacitors

2/3 K303 AS CLOCK BELOW 1 KHz

The 100 to 1 ratio of timing capacitors required limits this method to frequencies to 1 KHz or less, due to the 2.2 nanofarad capacitor built into each circuit. Three K303 circuits may be connected together for higher frequencies, as shown on next page.

K371 — $8
K373 — $8
K374 — $7
K375 — $8
K376 — $7
K378 — $9
LONG DELAYS
Longer delays than 30 seconds using large electrolytic capacitors would suffer from increased drift due to capacitor leakage. Moreover, there are some applications in which moisture and contamination cannot reliably be excluded from the electronics environment, making 250KΩ timing resistance impractical due to leakage along board surfaces. For either situation, two techniques are available: either cascade several timer circuits, or combine a clock-connected K303 with one or more K210 counters. The clock may be gated off at an unused input to avoid synchronizing errors. The diagram below shows both techniques combined, using one K210 and all three sections of a K303 to obtain a 22-minute delay.
TIMER FOR UP TO 22 MINUTES
K303 WITH K373 AND K378

SMALL K-SERIES CONTROL INSTALLED IN NEMA 12 ENCLOSURE.
MANUAL CONTROL MODULES

K410, K420, K422, K424, K432

K-Series, in addition to providing a wide range of versatile logic and AC or DC interface modules, also contains in the K4XX module grouping a series of manual control modules. The modules may be used with or without the K950 modular panel hardware to enter data into or to display data from a logic control system.

The module types and general characteristics are listed in the following table.

<table>
<thead>
<tr>
<th>Module</th>
<th>Use</th>
<th>No. of Circuits</th>
<th>Can Be Used Directly With M Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>K410</td>
<td>Indicator lights</td>
<td>5</td>
<td>Yes</td>
</tr>
<tr>
<td>K420</td>
<td>Toggle or push button switches</td>
<td>3</td>
<td>Yes</td>
</tr>
<tr>
<td>K422</td>
<td>Thumbwheel encoder</td>
<td>2</td>
<td>No</td>
</tr>
<tr>
<td>K424</td>
<td>Thumbwheel decoder</td>
<td>2</td>
<td>No</td>
</tr>
<tr>
<td>K432</td>
<td>Timer Controls</td>
<td>2-3</td>
<td>Yes</td>
</tr>
</tbody>
</table>

USING THE K4XX MODULES

All of the K4XX modules are double height single thickness modules. The manual controls are mounted where the A connector pins are normally located and all pin connections are made on the B connector half of the module. The modules, however, are always inserted in the A socket locations (upper row) in the logic mounting panel.

A minimum of 3½ inches of space must be left directly above the logic socket mounting panel (K943, etc.) to allow enough room for the manual controls. A K950 modular hardware panel may be used to cover the 3½ inch space, if a neat, closed-front panel is desired for the controls.

Any module may be plugged into the socket adjacent to any other module with the one following exception. The socket location directly to the left (facing the controls) of a K422 or K424 thumbwheel module may only be used for another K422 or K424 module.

The following pages explain the operation and characteristics of the individual module types.
The K410 indicator lamp module provides a convenient way to build binary, decimal, octal, or bi-quinary displays. Lamps and lamp drivers get their supply voltage from an internal supply that operates from any 12.6 V c.t. transformer.

The K410 may be used in a K943 mounting panel with or without the K950 panel hardware. Inputs are located on the B connector half of the module. Two modules plugged side by side on 1/2 inch centers provide 10 lamps for decimal, octal, or bi-quinary displays. More modules may be plugged in to provide five horizontal binary registers. Lamps turn on when both inputs are high or left unconnected.

Please see the write up on the previous page before using this module.
The K420 uses three 3-position Toggle switches. Only when the Toggle is in the center position will pins D, K, and R be high. The switch acts like a SPST Toggle in one direction and a spring returned push button in the other direction. Built in switch filters and Schmitt Triggers remove all switch contact bounce. Both inverted and uninvited outputs for each switch can drive 15 unit loads. Outputs are unslowed and may be used to drive M Series inputs directly.

The K420 may be used in a K943 mounting panel with or without the K950 modular panel hardware. All connections are made on the B connector half of the module.

Please see the write up preceding the K410 before using this module.
The K422 dual thumbwheel encoder used with the K134 inverters allows BCD data to be entered into the logic system from a K950 control panel.

K422 modules can be plugged in adjacent socket locations to build dual registers of up to 30 digits in width. Because of the width of the K422, the socket position directly to the left of the thumbwheel register may not be used for any K4XX module.

The four outputs from each thumbwheel should be connected to the four AND expansion modes of a K134. Switch outputs have no noise filters and should never be used as a source of pulses.

Switches may be multiplexed by wiring the 1, 2, 4, and 8 outputs from the K422 to the K134 “AND” expansion Nodes and connecting pins E and P to the outputs of separate gates. The desired thumbwheel is selected by causing a logic “0” at pin E or P. Logic “1” must be supplied to pins E and P of all the unselected switches. Groups of thumbwheels may be selected by connecting pins P and E to the same gate.

The K422 may be used in a K943 mounting panel with or without the K950 modular panel hardware. All connections are made on the B connector half of the module.

The K422 may be used directly with the K174 comparitor without the K134 inverters. Connect the output pins D, F, J, L or N, R, T, V directly to the K174 pins M, P, S, and U. As before, since the K422 has no noise filters, the comparitor output should only be a sensed logic level and not a source of pulses.
Pins U and K provide a convenient way to design an automatic defective switch detector. The K301 "on" delay should be set for about .5 seconds. If the thumbwheel switch does not make contact, the inverted timer output will go high after .5 seconds.

Please see the write-up preceding the K410 before using this module.
The K424 thumbwheel decoder module is designed to be used with the K210 BCD up counter to allow the counter modulus to be selected manually from 1 through 10. For this application the decoder output is connected to pin J of the K210. The counter will reset to zero on the next high to low clock transition following the number that is manually selected.

If the thumbwheel is set to the number 4, the counter will count 0, 1, 2, 3, 4, 0, 1, 2, etc.
Since the K424 is designed to be used only with up counters starting from a count of zero, the K422 must be used with the K174 comparator if specific numbers are to be decoded.

Up counter of more than one decade in length may also be manually controlled. The one-shot pulse width should be long enough to allow all carry pulses to propagate to the end of the counter. Pins B, E and P, M are not wired together for this application.

The K424 may be used with or without the K950 modular hardware panel. All pin connections are made on the B connector half of the module. Please see the write-up preceding the K410 before using this module.
The K432 Timer Control module used with a K301, K303, or K323 allows timer delays to be adjusted from a front panel by rotating a knob-pot. Timing ranges are selected by connecting the desired capacitor as shown in the table below either with wire wrap or 913 grip clip patch cords.

The board is predrilled and etched to provide space for a screw driver adjustable trimpot and capacitor to be mounted to obtain a third timer control. Each capacitor on the board may only be connected to one RC timer circuit at a time, however, any capacitor or resistor may be connected to form an RC.

The capacitor on pin L may be used with either the upper or lower knob-pot to obtain a range of 1 to 30 seconds.

Pins J, P, or V are connected to the RC time pins on the timer modules.

<table>
<thead>
<tr>
<th>Connect to Pin J or V</th>
<th>RC Time Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min.</td>
</tr>
<tr>
<td>None</td>
<td>10 µs</td>
</tr>
<tr>
<td>D or R</td>
<td>100 µs</td>
</tr>
<tr>
<td>E or S</td>
<td>1 ms</td>
</tr>
<tr>
<td>F or T</td>
<td>10 ms</td>
</tr>
<tr>
<td>H or U</td>
<td>100 ms</td>
</tr>
<tr>
<td>L</td>
<td>1 sec</td>
</tr>
</tbody>
</table>

Pin connections for selecting time ranges.

The K432 is designed to be used with or without the K950 modular hardware panel. All connections are on the B connector half of the module. Please see the write-up preceding the K410 before using this module.

K432 — $33
ACCESSORIES CONTAINING ELECTRONICS

On the following pages is a broad selection of interface modules. To help you get acquainted with the range of capabilities they offer, here is a summary table. Grouping by type of use to aid selection is not rigid. Maximum compatibility has been preserved to permit any combination of modules to be put together in the same system.

<table>
<thead>
<tr>
<th>Logic-to-Interface Connection and Type of Use</th>
<th>Module Type</th>
<th>Compatible Accessories</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Module Type:</td>
<td>K716 Interface Block</td>
</tr>
<tr>
<td>Integral 30” Flat cable connector. For small controls with heavy-duty field wiring</td>
<td>120 VAC input: K508</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>120/240 VAC output: K604</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Transducer input: K524</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>2.5 Ampere DC Driver: K644</td>
<td>X</td>
</tr>
<tr>
<td>Integral Terminals for larger systems</td>
<td>120 VAC input: K578</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>120/240 VAC output: K614</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>250 Volt DC Driver: K656</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>4 Amp Driver: K658</td>
<td>X</td>
</tr>
<tr>
<td>Solder Lugs with strain relief. For indicators, control panels, and nearby transducers</td>
<td>Transducer Input: K522 Dry circuit switch filter: K580 Inverted switch filter: K581 Low power indicator driver: K681 Indicator/Relay driver: K683</td>
<td>X</td>
</tr>
<tr>
<td>Integral 12” flat cable with NIXIE® tubes</td>
<td>Decimal Display: K671</td>
<td>X</td>
</tr>
</tbody>
</table>

68
The K501 can be used with the K580, K581, or K578 to provide simultaneous true and complement signals with full K series drive. Built in hysteresis and slowed outputs insure reliable operation in noisy signal environments.

Schmitt Triggers can also be used to speed up signals with very slow rise or fall times for input into pulse formers or logic circuits where timing considerations are critical.

The K501 is not designed to be connected directly to unfiltered contacts or other noisy signal sources. The Schmitt Triggers have standard K-Series outputs and their rise time is on the order of 7\(\mu\)s. Minimum hysteresis between upper and lower Thresholds is 1 volt.
The K508 AC input converter, operating through the K716 interface block, is designed for use with ordinary silver contacts in limit switches, pressure switches, pushbuttons and the like. Each input terminal presents a reactive load of 1 volt-ampere, which together with an external 120 volt AC pilot circuit voltage inhibits contamination buildup at the contact surface.

Electrical noise riding on pilot circuit wiring is attenuated in the input transformers and by hash filters at the K508 module. Contact bounce filtering is designed to respond to the first signal, and to leave the logic output in the "1" state in spite of skips lasting up to 100 milliseconds.

K508 output circuits have hysteresis, so that no intermediate output state can result from an ill-defined input condition. No separate Schmitt-triggers are required. Outputs are at ground for no input, at +5 volts when energized. All connections use upper connector.
The K522 Sensor Converter can take signals from photoconductive cells, thermistors, and other variable-resistance sensors and convert them to logic levels. Its built-in $\pm 1.8$ volt reference, programmable hysteresis, and noise cancelling ability make it simple to use. The K522 does not, however, provide the tolerance to high level noise or accidental application of line voltage which is obtainable from the K524.

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>K522</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of circuits</td>
<td>2</td>
</tr>
<tr>
<td>Module size</td>
<td>single</td>
</tr>
<tr>
<td>Input connections</td>
<td>solder lugs</td>
</tr>
<tr>
<td>Inputs accessible at module connector</td>
<td>yes</td>
</tr>
<tr>
<td>DC differential mode possible</td>
<td>no</td>
</tr>
<tr>
<td>Provision for adding transducer biasing trimpots in predrilled holes on board</td>
<td>yes</td>
</tr>
<tr>
<td>Noise cancellation range (common mode)</td>
<td>$\pm 1$ volt</td>
</tr>
<tr>
<td>Maximum $+$ input range for correct output</td>
<td>0 to $+5V$</td>
</tr>
<tr>
<td>Tolerance to overvoltage (no damage)</td>
<td>$\pm 3$ volts</td>
</tr>
<tr>
<td>Minimum hysteresis (deadband)</td>
<td>10mv</td>
</tr>
<tr>
<td>Maximum hysteresis</td>
<td>160mv</td>
</tr>
<tr>
<td>Maximum switching rate</td>
<td>50KHz</td>
</tr>
<tr>
<td>Minimum transducer resistance (at threshold)</td>
<td>400Ω</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Maximum transducer resistance (at threshold)</td>
<td>200KΩ</td>
</tr>
<tr>
<td>Noise Cancellation ratio at Line Frequency (CMR)</td>
<td>10:1</td>
</tr>
<tr>
<td>Noise Cancellation ratio at 1 KHz</td>
<td>20:1</td>
</tr>
<tr>
<td>Temperature Coefficient of Threshold (typical)</td>
<td>±1mv/°C (0.1%)</td>
</tr>
</tbody>
</table>

The minus input to each converter is AC coupled to the internal +1.8 volt reference to provide common mode noise rejection (CMR). In order to be effective, it must be connected to the same ground point to which the Transducer is connected. Twisted pair wiring should be used between the Transducer and Converter to help insure that any noise pick up will be the same on both wires (this is common mode noise). The outputs are high when the plus inputs are greater than +1.8 V. Predrilled holes are provided on each circuit for a three prong Trimpot to be mounted if switching point adjustment is desired when variable resistance transducers are used.

In general, the K522 is suited to laboratory and light machinery use where transducers are nearby and there is little danger of high voltage being applied to them accidentally. This is especially important when low resistance transducers are used with board mounted trimpots, since the trimpot provides a path from the transducer leads back to the logic supply. If high voltage (such as 120 VAC) were to get to the logic supply, all modules in the system would be destroyed.

The hysteresis of each K522 circuit can easily be selected in increments of 10 mv from a minimum of 10 mv (no connection) to a maximum of 160 mv by connecting one or more programming pins to the output.

Below is a table of pin connections for programming the hysteresis of each circuit.

<table>
<thead>
<tr>
<th>Table of Hysteresis Programming Pins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value when wired to converter output</td>
</tr>
<tr>
<td>Circuit 1 (Pin D)</td>
</tr>
<tr>
<td>Circuit 2 (Pin K)</td>
</tr>
</tbody>
</table>

Example: To add 30 mv hysteresis to the basic 10 mv hysteresis for a total of 40 mv hysteresis, connect pins E and F or L and M to the circuit outputs.

See application notes for further information on the use of sensor converters.

K522 — $22
Basically a noise-rejecting, threshold sensing differential voltage amplifier, the K524 is readily adapted to sensing threshold points in DC analog signals, AC signals, and pulses. It can also be biased to sense resistance thresholds. The differential amplifying technique permits flexible grounding and shielding methods to accommodate floating signal generators and minimize noise.

The K524 Sensor Converter senses voltage transitions or resistance thresholds by noise-rejecting differential amplification. A choice of AC or DC coupling is provided.

Output transitions occur when input voltage differentials are within 0.3 volts or less. When the "+" input is more positive, the output is a ONE. When the "+" input is more negative, the output is a ZERO.
Because of the complex input network in the K524, allowing true DC differential operation if desired, an additional connection is required. The simplified schematic below shows that the minus input to the internal comparator must be connected either to the DC-coupled or to the AC-coupled input attenuator via the model connector pins.

K524 EQUIVALENT CIRCUIT

Predrilled mounting holes for each circuit are provided for a three prong Trimpot to be added if switching point adjustment for variable resistance devices is desired. When Trim pots are used, pin BB (pin B on lower connector) must be connected to an independent bias supply, such as a separate K731 operated from a separate transformer, to insure against damaging currents through the bias circuits to the logic in case of accidental high voltages at K524 inputs. This precaution is most essential in systems containing K604 or K644 output converters, since inadvertent use of the wrong K716 socket is possible. This problem does not arise with self-generating sensors or where bias is supplied externally to variable-resistance sensors.

The following table shows the auxiliary pin connections on the lower module connector for the various applications of the K524.

<table>
<thead>
<tr>
<th>APPLICATIONS</th>
<th>COUPLING</th>
<th>PIN CONNECTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>As low performance analog comparator, for comparing two photocells etc., or</td>
<td>DC</td>
<td>BD to BE, BJ to BK, BN to BP, BT</td>
</tr>
<tr>
<td>wherever reference is supplied externally.</td>
<td></td>
<td>to BV</td>
</tr>
<tr>
<td>Photocells, thermistors, pulse tachometers, pressure transducers or wherever</td>
<td>AC</td>
<td>BD to BF, BJ to BL, BN to BR, BT</td>
</tr>
<tr>
<td>it is convenient to use the internal 2.5 volt reference.</td>
<td></td>
<td>to BV</td>
</tr>
</tbody>
</table>

Signals up to 25 KHz, suitable for counting by K210, K211 or K220 counters, can be obtained with symmetrical input signals having at least 1 volt excursions past the switching point. Maximum output rates can be limited to approximately 5KHz by tying together pins AM and AN, AP and AR, etc.
### CHARACTERISTICS

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number or circuits</td>
<td>4</td>
</tr>
<tr>
<td>Module size</td>
<td>double</td>
</tr>
<tr>
<td>Input connections</td>
<td>cable connector</td>
</tr>
<tr>
<td>Inputs accessible at module connector</td>
<td>no</td>
</tr>
<tr>
<td>DC differential mode possible</td>
<td>yes</td>
</tr>
<tr>
<td>Provision for adding transducer biasing trimpots in predrilled holes on board</td>
<td>yes</td>
</tr>
<tr>
<td>Noise cancellation range (common mode)</td>
<td>±7.5 volts</td>
</tr>
<tr>
<td>Maximum ± input range for correct output</td>
<td>±30V</td>
</tr>
<tr>
<td>Tolerance to overvoltage (no damage)</td>
<td>140 VAC</td>
</tr>
<tr>
<td>Minimum hysteresis (deadband)</td>
<td>10mv</td>
</tr>
<tr>
<td>Maximum hysteresis</td>
<td>10mv</td>
</tr>
<tr>
<td>Maximum switching rate</td>
<td>25KHz</td>
</tr>
<tr>
<td>Minimum transducer resistance (at threshold)</td>
<td>400Ω</td>
</tr>
<tr>
<td>Maximum transducer resistance (at threshold)</td>
<td>100KΩ</td>
</tr>
<tr>
<td>Noise Cancellation ratio at Line Frequency (CMR)</td>
<td>10:1</td>
</tr>
<tr>
<td>Noise Cancellation ratio at 1 KHz</td>
<td>20:1</td>
</tr>
<tr>
<td>Temperature Coefficient of Threshold (typical)</td>
<td>±1mv/°C (0.1%)</td>
</tr>
</tbody>
</table>

**K524 — $98**
All incoming components are 100% tested. Here, diodes are being tested automatically.
The K531 is a quadrature decoder that provides the proper direction and count controls for a K220 UP/DOWN counter register of up to 10 decades in length. Two or four counts per quadrature period can easily be selected and UP/DOWN counting can be done at frequencies up to 80 KHz. Either BCD or 2's compliment binary counting can be selected. The K531 also contains the necessary logic for + and − sign control for BCD displays. Counting can pass through zero at the full 80 KHz count rate. Sign control can be suppressed if desired.

Quadrature inputs can be from any encoder whose logic “0” voltage is .5V or less and logic “1” voltage is between +2.4V and +15 VDC. Each encoder output must be able to sink at least 3 ma in the logic “0” state. These are quite common and are available from companies such as Baldwin, Trump-Ross, and Data Technology.

Pin J is connected to K012 “OR” expansion gates to complete the zero detect logic if sign control is desired for BCD Nixie displays. One third of a K012 is required for each K220 module in the UP/DOWN register.
Pin B must be grounded if sign control is desired for BCD counting. Sign control is suppressed if pin B is left floating as shown in the table below for a 3 decade counter that is counting down from 999. For 2’s compliment binary counting, Pin B must be left floating and the most significant bit in the K220 binary UP/DOWN register is used for the sign. The bit will be a “1" for minus and a “0” for plus.

<table>
<thead>
<tr>
<th>K220 BCD UP/DOWN Register Grounded</th>
<th>Pin B: Open</th>
<th>Pin B: Open</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 999</td>
<td>+ 999</td>
<td>0011 1110 0111</td>
</tr>
<tr>
<td>+ 003</td>
<td>+ 003</td>
<td>0000 0000 0011</td>
</tr>
<tr>
<td>+ 002</td>
<td>+ 002</td>
<td>0000 0000 0010</td>
</tr>
<tr>
<td>+ 001</td>
<td>+ 001</td>
<td>0000 0000 0001</td>
</tr>
<tr>
<td>+ 000</td>
<td>+ 000</td>
<td>0000 0000 0000</td>
</tr>
<tr>
<td>- 001</td>
<td>+ 999</td>
<td>1111 1111 1111</td>
</tr>
<tr>
<td>- 002</td>
<td>+ 998</td>
<td>1111 1111 1110</td>
</tr>
<tr>
<td>- 999</td>
<td>+ 000</td>
<td>1100 0001 1001</td>
</tr>
</tbody>
</table>

Pins U and V are connected to pin A to provide 2 or 4 counts per quadrature period.

<table>
<thead>
<tr>
<th>Connect To Pin A</th>
<th>Counts Per Period</th>
<th>Maximum Input Freq.</th>
<th>Maximum Output Count Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>4</td>
<td>20 KC</td>
<td>80 KC</td>
</tr>
<tr>
<td>U, V</td>
<td>2</td>
<td>40 KC</td>
<td>80 KC</td>
</tr>
</tbody>
</table>

The output on pin N denotes the sign of the number in the UP/DOWN register. It will be a logic “1" for a plus sign and a logic “0” for a minus sign. The number zero always causes a logic “1" at pin N so that a minus zero can not be displayed. The K671 NIXIE display can be used with a Burroughs B-5442 “±" Tube. Pins N and V on the K671 must be grounded and Pin N on the K531 must be connected to pin T on the K671.

See Application Notes for detailed information on using the K531 with Nixie displays and computer interfacing.

K531 — $54
120 VAC INPUT CONVERTER
K578

Screw Terminals

120 VAC

1

2

3

4

5

6

7

8

9

120 Volt Indicators

AB (BU)

AD (BR)

AE (BR)

AF (BP)

AH (BN)

AJ (BM)

AK (BL)

AL (BJ)

AM (BJ)

AN (BH)

AP (BF)

AR (BE)

AS (BD)

AT (BC)

AU (BB)

AV (BA)

(BA)

(BB)

(BH)

(BK)

(BL)

(BM)

(BN)

(BP)

(BS)

(AU)

NOTE: PINS IN ( ) ARE USED IF MODULE IS REVERSED IN SOCKET.

K578 AC INPUT CONVERTER

K578 — $80
The K578 input converter, when mounted in a K724 or K725 interface shell, provides logic levels from 120 VAC signals from limit switches, relays etc. The 1VA reactive load provided by the K578 isolation transformers insures sparking at pilot contacts. Together with the ample circuit voltage used, this reactive load assures maximum contact reliability.

Electrical noise riding on pilot circuit wiring is attenuated both by the input transformer and by RC filtering. Bounce filtering is designed to pick up by the end of the first full cycle of contact, and to drop out (return to “zero” output state) by the end of three full cycles after the input is removed. (About 50 milliseconds.) This speed of response is desirable in large sequential scanning-type control systems, even though occasionally a heavy contact may be observed to produce more than one output transition due to very long bounce duration. If necessary, response speed may be cut in half by tying 150 mfd from the offending logic output to ground. However since no Schmitt triggers are included in the K578 (unlike the K508), a K184 or K501 must be used if it is important to know exactly how many contact closures have occurred in a given period. Note that these circuits may not be paralleled to obtain the wired OR or AND function, and that fanout is limited to 2 ma.

Gating circuits equivalent to four K026 sections are included for contact scanning applications using the K161, or to facilitate forming the logical OR of many inputs. Direct outputs are from circuits similar to the K580, and may not be wired together.

Clamp-type terminals on the K578 take two wires up to size 14. Neon indicators are included. The K578 can also be used in the K943 mounting panel, however some mechanical means of support must be provided to hold the K578 in its socket if vibration is a consideration.
These filters convert signals from dry circuit or wiping contacts to logic levels. Primarily they are used with gold contacts such as the new encapsulated reed limit switches, thumbwheel switches, and the like. Those push-buttons or slide switches that provide good wiping action will also operate reliably with these filters, but silver contacts designed for long life on heavy duty loads are likely to give trouble. For them, use interfaces designed for such application like K508-K716 or K578, or at least switch a high voltage. (see K580 voltage table.)

Access to K580 and K581 inputs is by solder lugs only. Strain relief holes are provided in board (near handle) for a 9-wire cable. The avoidance of contact connections on the logic wiring panel combined with heavy filtering guarantees noise isolation and protects modules by preventing accidental short circuits. Below is a summary of other characteristics:

<table>
<thead>
<tr>
<th></th>
<th>Contact Current</th>
<th>Contact Voltage</th>
<th>Output for Contact Closed</th>
<th>Time Delay on Closure</th>
<th>Time Delay on Opening</th>
</tr>
</thead>
<tbody>
<tr>
<td>K580</td>
<td>22ma</td>
<td>See Table</td>
<td>high</td>
<td>10msec</td>
<td>30msec</td>
</tr>
<tr>
<td>K581</td>
<td>22ma</td>
<td>5V</td>
<td>low</td>
<td>20msec</td>
<td>20msec</td>
</tr>
</tbody>
</table>

(Time delay figures above are nominal, and assume connection to the input of a standard gate such as K113 or K123.)

The contact current for the K581 comes from the logic supply, making it very important to assure freedom from accidental high voltages on K581 inputs, which could damage many logic modules by getting through to the system power supply. This hazard is not present with the K580, which uses an external source of +10 volts or more. The table below shows how external dropping resistors may be added to provide higher voltage operation.

**TABLE OF K580 VOLTAGE DROPPING RESISTANCES**

<table>
<thead>
<tr>
<th>CONTACT SUPPLY VOLTAGE</th>
<th>10</th>
<th>12</th>
<th>15</th>
<th>24</th>
<th>28</th>
<th>48</th>
<th>90</th>
<th>100</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dropping Resistance</td>
<td>0</td>
<td>82Ω</td>
<td>220Ω</td>
<td>620Ω</td>
<td>820Ω</td>
<td>1.8KΩ</td>
<td>3.6KΩ</td>
<td>3.9KΩ</td>
<td>4.7Ω</td>
</tr>
<tr>
<td>Dissipation</td>
<td>—</td>
<td>0.05W</td>
<td>0.11W</td>
<td>0.3W</td>
<td>0.4W</td>
<td>0.85W</td>
<td>1.8W</td>
<td>2.0W</td>
<td>2.5W</td>
</tr>
</tbody>
</table>

When using dropping resistors and higher voltage supplies, total tolerance of resistors and supply should be ±10% to insure high levels between +4V and +6V at the logic. Also observe that a handful of dropping resistors in 90V or 120V systems may dissipate more power than the entire logic system, and must be located so as not to cause excessive temperature rise in the K series environment.

Note that these circuits may not be paralleled to obtain the wired OR or wired AND function, and that fanout is limited to 2 milliamperes in order to maintain the low (zero) output voltage within normal K-Series specifications. Fanout to ordinary logic gates and diode expanders may be raised to 4 milliamperes if some noise and contact bounce rejection can be traded off; but hysteresis inputs such as those at counter inputs, rate multiplier, etc., may not switch properly if the logic zero is allowed to rise much above +0.5V.

See application note for thumbwheel register multiplexing using K581.
Any bipolar input signals with amplitudes between $\pm 3$ volts and $\pm 25$ volts will be transformed by this non-inverting converter into standard K-Series or M-Series logic signals with driving capabilities of 5 ma or 3 unit loads, respectively. Load for paralleling (wired OR): 1 milliampere. Input impedance stays between $3K\Omega$ and $6K\Omega$ for full capability with both the American EIA and the European CCITT standards for data transmission. Built-in noise filtering causes transition delays of several microseconds, limiting the maximum baud rate that can be handled.

Open-circuit inputs will produce low (zero-volts) outputs on the lower three circuits. The output stage of the first three circuits if inputs are open is controlled by pin B, which must be grounded for outputs low or connected to pin A (+5 volts) for outputs high. This last provision allows type 33 or type 35 current switching teletypes to be converted and wired ORed with modem interfaces. Pin B must be connected either to pin A or pin C: if it is left open, there may be crosstalk between circuits.

<table>
<thead>
<tr>
<th>Input</th>
<th>Pin B Connection</th>
<th>Pins D, F, J</th>
<th>Pins L, N, R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>C</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Circuit</td>
<td>A</td>
<td>+5</td>
<td>0</td>
</tr>
<tr>
<td>+3 to +25V</td>
<td>A or C</td>
<td>+5</td>
<td>+5</td>
</tr>
<tr>
<td>−3 to −25V</td>
<td>A or C</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0V</td>
<td>A or C</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Please observe that noise and interference can enter a digital system through any wires that pass through a noise field. K596 modules should be located at the edge of the system, and communication wiring should not be allowed to lie close to logic wiring for more than a few inches.
Operating in conjunction with the K782 or K716 Interface Block, the K604 permits AC operated valves, solenoids, small motors, motor starters and the like to be controlled directly from K Series logic. Each circuit can handle up to 250 volt-amperes continuously. Total for any module, however, should not exceed 500 volt-amperes averaged over one minute. Ratings below include maximum horsepower based on use of Allen-Bradley type K* motor starters. Less sensitive starters or relays may have significantly reduced capacity.
<table>
<thead>
<tr>
<th>Condition</th>
<th>Continuous V.A.</th>
<th>Inrush V.A.</th>
<th>Motor Direct</th>
<th>Type K Starter Max. H.P.</th>
<th>208/220 Max. H.P.</th>
<th>480/600 Max. H.P.</th>
</tr>
</thead>
<tbody>
<tr>
<td>With Fuse</td>
<td>250</td>
<td>600</td>
<td>1/20 H.P.</td>
<td>Size 3</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>No Fuse</td>
<td>250</td>
<td>1800</td>
<td>1/10 H.P.</td>
<td>Size 4</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

Littelfuse® type 275005 fuses provide fault protection for the triac output circuits. The fuses are mounted by clips on the connector board for easy replacement. Without the fuses, short circuits will destroy the module. The no-fuse information above is for reference only, and operation without fuse protection cannot be recommended. Circuits cannot be paralleled to increase ratings.

AC switch turnon takes place within 500 microseconds after input logic gate goes high. Turnoff takes place at zero crossings of the current. Maximum "off" leakage: 10 ma RMS at 140 VAC. Line voltage rating: 100 to 140 VAC, 50 to 60 Hz. Each triac output circuit has 400-volt breakdown rating. Shunt capacitor and shunt clipping devices inhibit false triggering on line transients.

Where very small devices such as pilot lamps, light duty relays, or AC input converters constitute the sole load, an auxiliary load such as a 12KΩ 2 watt resistor may be required to absorb sufficient holding current for full voltage output.

Two special precautions are made necessary by the presence of AC line voltages on the K604 module. First, always disconnect the ribbon cable connector before inserting or removing a K604 or an adjacent module, to avoid shocks or component damage. Second, W993 copper-clad boards ($4 each) should be installed between K604 modules and all other types except K508 or K644. With the pin 'A connection cut away, on either the board or the socket, the W993 copper clad board acts as an electrostatic shield. If this added interface protection is later found to be unnecessary, the sockets reserved for shield boards can be used to add logic features, modifications, etc. Refer to Construction Recommendations.

If desired, a K782 terminal board instead of the K716 may be used to obtain connections to field wiring. No indicators are provided on the K782, however. Photo and connection diagram on next page.

For 240 volt operation, refer to the application note on this topic.
K604 CIRCUIT IN USE
This module uses the K604 circuit and behaves in most respects the same. However, the K614 is designed to fit a K724 or K725 interface shell. Accordingly, the K614 has built-in clamp-type terminals for wires to size 14, interchangeable indicators, and output ratings boosted to 500VA per circuit by the larger heat sink area available in this configuration.

See Applications Notes for information on 240 volt operation
K614 TERMINALS AS VIEWED LEFT TO RIGHT ARE NUMBERS 1 THROUGH 9
Operating through the K782 or K716 Interface Block, the K644 DC Driver permits stepping motors, dc solenoids, and similar devices rated up to 2.5 amperes at 48 volts to be driven directly from K series logic. Built-in clamping diodes protect switching transistors from transient over-voltage.

Total output circuit current for the K644 module must not exceed 4 amperes averaged over any 1 minute period. The ribbon connector should be unplugged before inserting or removing a K644 module.

Moving the parts of a magnetic device changes the winding inductance. To equalize magnetic field turnoff and turnon times, the ratio of inductance to total circuit resistance must be held constant. This demands more resistance in the circuit during turnoff, when the inductance is higher. Resistance may be inserted between K716 terminal 15 (or 16) and the load supply to achieve this, provided the K644 output voltage will not exceed 55 volts. Whether resistance is added or not, these clamp return terminals must be connected to the plus side of the load supply to protect the module from overvoltage during turnoff.

The K644 may be used with a K782 instead of a K716 to obtain the screw terminals needed for connecting heavy duty field wiring.

See applications section for logic diagrams of several stepping-motor applications.
DC DRIVER
K656

Each circuit of this versatile driver can deliver up to 1 ampere at up to 250 volts, making it ideal for driving heavy-duty brakes and clutches or for high speed operation of other inductive loads. Like the K578 and K614, this module has integral clamp-type terminals and replaceable indicator lamps. (Lamps are effective only at 90 volts and above.) This driver module is designed to be used with K724 or K725 interface shells. Positive side of load supply must be connected to protect output transistors from damage during turnoff transient.

K656 — $80
K658 4 AMP DRIVER

Each circuit of this versatile driver can deliver up to 4 amperes at up to 125 volts. Like the K578, K656 and K614, this module has integral clamp-type terminals and neon indicator lamps. (Lamps are effective only at 90 volts and above.) This driver module is designed to be used with K724 or K725 interface shells. Positive side of load supply must be connected to protect output transistors from damage during turnoff transient.
This module has two parts separated by a 1-foot ribbon cable. One part plugs into any module socket, the other contains a side-viewing Burroughs type B-5440 long life NIXIE glow tube on a mounting board. Four connections to corresponding module socket pins of a K210 or K220 binary-coded decimal counter completes the input wiring. The display tube board attaches with two screws to a K771 supply for both mechanical mounting and power supply electrical connections. Displays up to 6 digits long can be stacked on each K771 supply. Stacked digits have 0.8" mounting centers. See Construction Recommendations before assigning module locations. A Burroughs Type B-5442 NIXIE + and − glow tube can also be used in the K671. Ground pins N and V. Let pin R float and put input on pin T. Pin T is high for +, low for −.
DEC thoroughly tests all finished modules, performing 100 ac and dc tests in less than 5 seconds. Most testing is done automatically on one of three computer-operated test stations like this one.
These eight-circuit modules drive external loads through 9-conductor cable soldered to split lugs at the handle end by the user. Strain relief holes are prepunched in the board. Logic “0” turns the driver off, logic “1” turns it on.

Pin connections via diodes to outputs facilitate production automatic module testing while isolating system wiring from high voltages. Circuits are not slowed, and these connections are not recommended as output tiepoints unless exceptional care is taken to prevent noise and damaging voltages from degrading system reliability. (See Fixed Memory application note.)

K681 — $15
K683 — $30
<table>
<thead>
<tr>
<th>MODULE TYPE</th>
<th>OUTPUT RATINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RESISTIVE</td>
</tr>
<tr>
<td>K681</td>
<td>18V, 30ma</td>
</tr>
<tr>
<td>K683</td>
<td>55V, 250ma</td>
</tr>
</tbody>
</table>

Note greatly reduced ratings on tungsten loads. Lamp filaments draw typically ten times more current at turnon than when hot, resulting in very high transistor dissipation if supply voltage is high. Series current limiting resistors or shunt preheat resistors could be used to limit surge in certain cases, but ratings above assume this would be awkward or impractical.
This bipolar non-inverting driver converts standard logic levels to either the American EIA or the European CCITT standard signals for data transmission. Power can either be 6.3 VAC ±10% 60Hz on pin B for EIA levels (at least ±5 volts) or 9.0 VAC ±10% 50Hz on pin B for CCITT levels (at least ±6 volts). Limited output current capability results in risetimes of several microseconds for capacitive loads of a few thousand picofarads, limiting the maximum baud rate to 5K baud. One ampere of AC can supply up to 32 K696 modules. Keep AC leads short to maintain voltage.

Please observe that noise and interference can enter a digital system through any wires that pass through a noise field. K696 modules should be located at the edge of the system, and communications wiring should not be allowed to lie close to logic wiring for more than a few inches. A high impedance probe may be used to monitor the half-wave rectified and filtered negative internal supply at pin T (5 KΩ series resistance).

K696 — $44
## HARDWARE SUMMARY TABLE

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>PRODUCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessories for Interface Modules (K5XX, K6XX)</td>
<td></td>
</tr>
<tr>
<td>Accessories for Interface Modules</td>
<td></td>
</tr>
<tr>
<td>Modules (K5XX, K6XX)</td>
<td>K716 Interface Block</td>
</tr>
<tr>
<td>K724 Interface Shell, Power wiring only</td>
<td></td>
</tr>
<tr>
<td>K725 Interface Shell, Pre-wired for scanning</td>
<td></td>
</tr>
<tr>
<td>K782 8 Terminals</td>
<td></td>
</tr>
<tr>
<td>K784 8 Terminals with Diodes</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td></td>
</tr>
<tr>
<td>1 Amp Regulator</td>
<td>K731 1 Amp Regulator</td>
</tr>
<tr>
<td>2 Amp Slave Regulator</td>
<td>K732 2 Amp Slave Regulator</td>
</tr>
<tr>
<td>2 Amp Transformer</td>
<td>K741 2 Amp Transformer</td>
</tr>
<tr>
<td>3 Amp Transformer with Auxiliary Winding</td>
<td>K743 3 Amp Transformer with Auxiliary Winding</td>
</tr>
<tr>
<td>5 Amp Low Ripple Supply</td>
<td>H710 5 Amp Low Ripple Supply</td>
</tr>
<tr>
<td>NIXIE Supply</td>
<td>K771 NIXIE Supply</td>
</tr>
<tr>
<td>Mounting Hardware and Connectors</td>
<td></td>
</tr>
<tr>
<td>64 Module 19&quot; X 5 1/4&quot; Mounting Panel</td>
<td>K940 Mounting Foot for K941</td>
</tr>
<tr>
<td>Mounting Bar</td>
<td>K941 Mounting Bar</td>
</tr>
<tr>
<td>64 Module 19&quot; X 5 1/4&quot; Mounting Panel</td>
<td>K943 64 Module 19&quot; X 5 1/4&quot; Mounting Panel</td>
</tr>
<tr>
<td>End Brackets</td>
<td>K980 End Brackets</td>
</tr>
<tr>
<td>Hold-Down and Cover</td>
<td>1907 Hold-Down and Cover</td>
</tr>
<tr>
<td>Cover Supports</td>
<td>H001 Cover Supports</td>
</tr>
<tr>
<td>Module Mounting Drawer</td>
<td>H920 Module Mounting Drawer</td>
</tr>
<tr>
<td>8-Connector Block</td>
<td>H800 8-Connector Block</td>
</tr>
<tr>
<td>Single Connector</td>
<td>H802 Single Connector</td>
</tr>
<tr>
<td>Wiring Aids</td>
<td></td>
</tr>
<tr>
<td>Grip Clip Logic Wiring Patchords</td>
<td>913 Grip Clip Logic Wiring Patchords</td>
</tr>
<tr>
<td>Power Wiring Jumpers</td>
<td>914 Power Wiring Jumpers</td>
</tr>
<tr>
<td>Bussing Strip</td>
<td>932 Bussing Strip</td>
</tr>
<tr>
<td>Wire for Wrapping</td>
<td>934 Wire for Wrapping</td>
</tr>
<tr>
<td>Pistol Grip Hand Wire-Wrap Tool</td>
<td>H810 Pistol Grip Hand Wire-Wrap Tool</td>
</tr>
<tr>
<td>Unwrapping Tool</td>
<td>H812 Unwrapping Tool</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
</tr>
<tr>
<td>Test Probe</td>
<td>K791 Test Probe</td>
</tr>
<tr>
<td>Module Extender</td>
<td>W980 Module Extender</td>
</tr>
<tr>
<td>Clad Board, Single Size</td>
<td>W992 Clad Board, Single Size</td>
</tr>
<tr>
<td>Clad Board, Double Size</td>
<td>W993 Clad Board, Double Size</td>
</tr>
<tr>
<td>Handle Riveting Tool for Clad Boards</td>
<td>H830 Handle Riveting Tool for Clad Boards</td>
</tr>
<tr>
<td>Perforated Board, Single Size</td>
<td>W994 Perforated Board, Single Size</td>
</tr>
<tr>
<td>Perforated Board, Double Size</td>
<td>W995 Perforated Board, Double Size</td>
</tr>
<tr>
<td>Cable Connector, Logic Only</td>
<td>W021 Cable Connector, Logic Only</td>
</tr>
<tr>
<td>Cable Connector, Logic and Power</td>
<td>W023 Cable Connector, Logic and Power</td>
</tr>
<tr>
<td>Cable Connector, Component Lugs</td>
<td>W028 Cable Connector, Component Lugs</td>
</tr>
</tbody>
</table>
An important hardware feature of the K Series system is the K716 Interface Block, which permits field wiring to be installed at ordinary screw terminals by electricians. The logic modules interconnect to the K716 by plug-in ribbon cables.

**TYPICAL CONTROL APPLICATIONS FOR K SERIES MODULES INTERFACED BY K716**

**Contacts:** Ordinary silver contacts of the kind found in limit switches, pressure switches, and pushbuttons work best when operated with healthy levels of both line voltage and load current. The sparking that results prevents buildup of contact surface contamination. To assure reliable switching, isolation transformers in the K716 provide a reactive load for switched 120 vac pilot voltages. The K508 AC Input Converter ignores contact bounce. Hash filters in the module, and attenuation in the isolation transformer built into the K716, reduce electrical noise. Built-in indicators permit quick maintenance checks.

The K716 Interface Block serves as an interconnection interface for those K Series modules that communicate with external equipment. External field wiring terminates at a 24-terminal screw connection block that accepts plain stripped wire up to 14 gauge. No separate crimped or soldered terminals are required.
K716 INTERFACE BLOCK
SCHEMATIC

Ribbon cables from the K Series interface modules connect to printed circuit board sockets on the K716. This allows the K716 terminal block to mount on the rear panel of a NEMA enclosure for the convenience of electricians, while the digital system itself mounts on the door for easy access to both modules and logic wiring. The ribbon cable makes neat, simple wiring layouts and easy flexing at the hinge.

The three sockets in the K716 terminal block contain the same module-connector system used for the modules themselves, permitting quick disconnect of the entire logic system without affecting reliability. This arrangement, together with the K940-K941 bolt-on mounting hardware, allows initial checkout of control systems away from the site, as well as minimizing downtime in case of failure. (See Construction Recommendations.) The cable sockets have the same reliable gold contacts as K Series module sockets.

Socket B, for use with the K508 AC input converter, is fed by eight isolation, stepdown and contact loading transformers contained within the aluminum shell of the K716. The transformer primaries receive 120-volt pilot signals from external contact closures. Each input is monitored by a neon indicator.

Sockets A and C are for use with K524, K604, and K644. Neon indicators are provided to monitor the outputs of the K604 Isolated AC Switch module.
The drawing above shows approximate dimensions of the K716. Mounting, slots clear no. 10 screws and allow compensation for mounting screw location tolerances. See first Application Note "Construction Recommendations."
All neon indicators are located within the K716 shell, visible at the rear of associated screw terminals.

Socket D, normally terminated by a shorting plug, runs all return lines from connector C to a common point. If the shorting plug is removed, independent wiring of connector C return leads for K524 or K604 modules is possible. A W033-06F-W033 cable connector ($15) must be installed between socket D and socket A. An extra 2-inch clearance is required by this connector board. Independent wiring provides connections for four two-wire circuits instead of 8 circuits with bussed returns.

Below is a recommended mounting pattern for combining many interface blocks. This pattern can be extended provided the 30” reach of ribbon is not exceeded.

---

**K716’S IN INDUSTRIAL ENCLOSURE**

103
Unlike the K716 interface block, these shells do not contain any electronic components. Instead, they provide the connectors and the mechanical support for self-contained interface modules K578, K614, K656, and K658. Up to four such modules may be installed, with eight module sockets remaining between them for simple logic functions. Convenient wiring channels are obtained between units if they are mounted on 12" centers vertically and 6" centers horizontally. This way a total of up to 32 input converters and 16 output converters fits in one square foot of panel space, along with up to 16 logic modules.

The K724 provides only logic power and ground connections between all but two sockets. It is primarily intended for very simple logic systems or for large systems where all input and output logic levels are connected to a separate logic unit by connector cables.

The K725 uses a printed backplane to make most of the connections required in a remotely scanned system. In this type of system, a few address lines transmitted to the interface shell on a single connector cable are decoded by a K161 decoder within the shell either to sample one particular K578 input, or else to set or clear a K206 flip-flop which in turn controls the state of one of the output converters. This type of system is convenient to use with a computer, and also lends itself to situations requiring remote contact sensing and switching at several scattered locations.

K725 Signal Flow

<table>
<thead>
<tr>
<th>K724</th>
<th>$55</th>
</tr>
</thead>
<tbody>
<tr>
<td>K725</td>
<td>$82</td>
</tr>
</tbody>
</table>
K725 CONNECTIONS
AT W023 SOCKETS

K206 Returns: Low if addressed output flip-flop holds a "1."
K578 Returns: Low if addressed input has 120VAC applied.
K206 Enable: If high, clears addressed output flip-flop when pin N is high, sets the flip-flop when pin N is low.
K206 Clear: If low, clears all output FFs.
K135 Enable: If low, forces both K206 return and K578 return high to allow wired OR of returns from up to sixteen K725 assemblies.
Address, Pin N: Least significant bit of input address; if K206 Enable is high, selected flip-flop forced to the state of pin N. For sampling the K206 state, pin N must be low because there are only 8 flip-flops.
K725

INTERFACE SHELL
These pantograph-controlled insertion machines position and crimp pre-tested components onto four module boards at a time. A press will cut the modules apart after assembly is completed, minimizing handling up to that point.
The K731 supplies ±5 volt dc power to pin A of all K Series modules and provides several specialized once-per-system control functions. Any source of center-tapped 12.6 volt (50 or 60 Hz) allows the K731 to deliver up to 1 amp dc, which is sufficient to operate most typical control systems of up to 32 modules. The K731 is short-circuit proof.

This module is normally plugged into one of the innermost sockets on a K941 mounting bar, where its large components occupy space otherwise unused.

The turn-on output goes to ground during the power-up transient, and remains at ground until after the supply voltage has fully reached its quiescent value. It may be used to initialize flip-flops to a known starting condition.

The OK level output goes to ground when the supply voltage reaches 90% of its final value, and returns positive when less than 90% of full voltage is available. It is normally used as an enabling input to the K273 Retentive Memory module.

The line sync output allows a K113 or K123 gate to switch in synchronism with ac supply zero-crossings. This permits the line frequency to drive a real-time clock, or serve as the standard in a phase-locked loop with K303 timers, where higher frequencies must be synchronized with the line. Line sync fanout is limited to 1 ma (for high fanout, use K113 or K123 for distribution). None of the K731 logic outputs may be used to obtain the OR function, and they may not be wired to any other output.

K731 delivers up to 1 ampere when used with a 12.6 volt transformer rated for 105-130 volt line. For 5% input voltage reduction (12.0v transformer or 100 volt line) the output current capability decreases 10%. Output voltage temperature coefficient is typically minus .33%/°C. See summary of module current consumption following K732 data.

K731 — $24
The H710 power supply is ruggedly built, low cost, regulated, floating output, five volt power supply that can be mounted in an H920 chassis drawer or used as a free standing unit. Remote sensing to correct for loss due to long lines is provided. When shipped from the factory, the remote sensing inputs are jumpered to their respective outputs. Especially useful in systems that require maximum repeatability from K303 timers in the millisecond region.

**INPUT VOLTAGE:** 105-125 VAC or 210-250 VAC 47-63 HZ  
**OUTPUT VOLTAGE:** 5 vdc.  
**P-P RIPPLE**  
Less than 20 mv.

**OUTPUT CURRENT:**  
0-5 amps. short-circuit protected for parallel supply operation.

**LINE AND LOAD REGULATION:**  
The output voltage will not vary more than 50 mv over the full range of load current and line voltage.

**OVERTENSION PROTECTION:**  
The output is protected from transients which exceed 6.9 Volts for more than 10 nsec. However, the output is not protected against long shorts to voltages above 6.9 Volts.

**POWER CONNECTIONS:**  
Input power connections are made via tab terminals which fit the AMP "Faston" receptacle series. Output power is supplied to solder lugs. All required mounting hardware is supplied with this unit. See 914 power jumpers.

Length: 8"  
Height: 6"  
Width: 5"  
Finish: Chromicoat  

H710 — $200
This module is normally tied to corresponding pins A, C, S, U, and V of a K731 Source. For each unit of current emitted by the K731, the K732 emits two. Up to three K732 slaves can be controlled by a single K731 for a total system current of 7 amperes.

In high-current systems, use short heavy wires for transformer secondary connections. Loss of 5% of secondary voltage in either ground return or transformer output leads will reduce regulator current ratings more than 10%.

Tabs near the handle end of the 732 may be connected to K741 or K743 transformers by using convenient 914 Power Jumpers. Then by wiring pins U and V to corresponding pins on K731, AC connections are provided through the K732 to the source module. To avoid loss of regulation, do not connect a K732 until enough modules have been plugged in to draw a reasonable current (several hundred milliamperes).

For self contained low-ripple supplies see H710 and H716.

CAUTION:
These modules lack overvoltage protection, and may damage M-Series modules in case of a supply failure. Not recommended for use with M series modules.
### SUMMARY OF MODULE CURRENT REQUIREMENTS

#### LOGIC MODULES

<table>
<thead>
<tr>
<th>Module</th>
<th>Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K003</td>
<td>3</td>
</tr>
<tr>
<td>K012</td>
<td>12</td>
</tr>
<tr>
<td>K026</td>
<td>6</td>
</tr>
<tr>
<td>K028</td>
<td>8</td>
</tr>
<tr>
<td>K113</td>
<td>17</td>
</tr>
<tr>
<td>K123</td>
<td>18</td>
</tr>
<tr>
<td>K124</td>
<td>21</td>
</tr>
<tr>
<td>K134</td>
<td>23</td>
</tr>
<tr>
<td>K135</td>
<td>22</td>
</tr>
<tr>
<td>K161</td>
<td>45</td>
</tr>
<tr>
<td>K174</td>
<td>12</td>
</tr>
<tr>
<td>K184</td>
<td>56</td>
</tr>
<tr>
<td>K201</td>
<td>130</td>
</tr>
<tr>
<td>K202</td>
<td>120</td>
</tr>
<tr>
<td>K206</td>
<td>50</td>
</tr>
<tr>
<td>K210</td>
<td>150</td>
</tr>
<tr>
<td>K211</td>
<td>60</td>
</tr>
<tr>
<td>K220</td>
<td>220</td>
</tr>
<tr>
<td>K230</td>
<td>150</td>
</tr>
<tr>
<td>K271</td>
<td>40</td>
</tr>
<tr>
<td>K273</td>
<td>50</td>
</tr>
<tr>
<td>K281</td>
<td>0</td>
</tr>
<tr>
<td>K301</td>
<td>15</td>
</tr>
<tr>
<td>K303</td>
<td>30</td>
</tr>
<tr>
<td>K323</td>
<td>35</td>
</tr>
<tr>
<td>K410</td>
<td>0</td>
</tr>
</tbody>
</table>

(Requires 12.6 V C.T. 50-60 cps)

<table>
<thead>
<tr>
<th>Module</th>
<th>Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K420</td>
<td>17</td>
</tr>
<tr>
<td>K422</td>
<td>0</td>
</tr>
<tr>
<td>K424</td>
<td>2</td>
</tr>
<tr>
<td>K432</td>
<td>0</td>
</tr>
<tr>
<td>K501</td>
<td>45</td>
</tr>
</tbody>
</table>

#### OTHER MODULES

<table>
<thead>
<tr>
<th>Module</th>
<th>Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K508</td>
<td>65</td>
</tr>
<tr>
<td>K522</td>
<td>Transducer bias plus 25</td>
</tr>
<tr>
<td>K524</td>
<td>Transducer bias plus 35</td>
</tr>
<tr>
<td>K531</td>
<td>0</td>
</tr>
<tr>
<td>K578</td>
<td>0</td>
</tr>
<tr>
<td>K580</td>
<td>(Uses separate supply)</td>
</tr>
<tr>
<td>K581</td>
<td>Per contact closed 22</td>
</tr>
<tr>
<td>K596</td>
<td>30</td>
</tr>
<tr>
<td>K604</td>
<td>All circuits off 40</td>
</tr>
<tr>
<td>K614</td>
<td>All circuits off 20</td>
</tr>
<tr>
<td>K644</td>
<td>All circuits off 20</td>
</tr>
<tr>
<td>K656</td>
<td>All circuits off 10</td>
</tr>
<tr>
<td>K658</td>
<td>All circuits off 10</td>
</tr>
<tr>
<td>K671</td>
<td>13</td>
</tr>
<tr>
<td>K681</td>
<td>16</td>
</tr>
<tr>
<td>K683</td>
<td>160</td>
</tr>
<tr>
<td>K696</td>
<td>(Also requires 6.3vac 60 Hz or 9.0 vac 50 Hz) 7</td>
</tr>
</tbody>
</table>
These hash-filtered, 50/60 Hz transformers supply K731 Source and K732 Slave Regulator modules. The K743 also provides an auxiliary winding for use with K902, K580 Dry Contact Filters and K681 or K683 Lamp Drivers (requires additional bridge rectifier). Type 914 Power Jumpers are convenient for connecting to tab terminals on these transformers and on the K732 and K943. Both transformers have holes at the corners of the chassis plate for mounting on K980 endplates or H002 brackets.

<table>
<thead>
<tr>
<th></th>
<th>PLATE DIMENSIONS</th>
<th>HOLE CENTERS</th>
<th>MATCHING K980 Ctrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>K741</td>
<td>3½&quot; x 5&quot;</td>
<td>2½&quot; x 3¾&quot;</td>
<td>2½&quot;</td>
</tr>
<tr>
<td>K743</td>
<td>5&quot; x 5&quot;</td>
<td>4&quot; x 3¾&quot;</td>
<td>4&quot;</td>
</tr>
</tbody>
</table>

The K741 is sufficiently light in weight to be mounted on one side only, as at the end of a K943 mounting panel.
The table below shows how to obtain various currents. Line voltages within ±10% from nominal and short, heavy secondary wires are assumed. One K731 is required in each case.

<table>
<thead>
<tr>
<th>60 Hz</th>
<th>50 Hz</th>
<th>K732</th>
<th>TRANSFORMER</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1-1A</td>
<td>0.1-0.8A</td>
<td>0</td>
<td>K741 or K743</td>
</tr>
<tr>
<td>0.5-2A</td>
<td>0.4-1.6A</td>
<td>1</td>
<td>K741 or K743</td>
</tr>
<tr>
<td>1-3A</td>
<td>0.8-2.4A</td>
<td>1</td>
<td>2 K741s or K743</td>
</tr>
<tr>
<td>2-4A</td>
<td>1.6-3.2A</td>
<td>2</td>
<td>2 K741s or 2 K743s</td>
</tr>
<tr>
<td>3-5A</td>
<td>2.4-4A</td>
<td>2</td>
<td>3 K741s or 2 K743s</td>
</tr>
<tr>
<td>4-6A</td>
<td>3.2-4.8A</td>
<td>3</td>
<td>3 K741s or 2 K743s</td>
</tr>
<tr>
<td>5-7A</td>
<td>4.5-6A</td>
<td>3</td>
<td>4 K741s or 3 K743s</td>
</tr>
</tbody>
</table>

When more than one transformer is required, the secondary windings must be connected in parallel. Care must be taken to ensure that the 12.6 vac windings are connected in phase and not 180 degrees out of phase. If a transformer is connected incorrectly, the secondary voltage will be lower than 10 vac. Simply reverse the secondary wires to bring the transformers back in phase.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>K741</td>
<td>$22</td>
</tr>
<tr>
<td>K743</td>
<td>$38</td>
</tr>
</tbody>
</table>

113
DISPLAY SUPPLY
K771

Shown above from the viewing side, the K771 supplies power and a convenient two-screw mounting for up to 6 K761 display tubes. Display tubes are stacked to the left, the first tube board being attached to the K771. The second tube board attaches to the first, and so on. Board mounting screws provide both mechanical mounting and electrical power connections. The two panel mounting screw locations dimensioned above have no. 6 steel threaded inserts. Several 1” high holes using a standard chassis punch may be cut on 0.8” centers for viewing display tubes. To seal opening against dust, a 3” by 3-6” piece of Lucite® or Plexiglas® may be assembled between display and mounting surface. Power 120 VAC enters the supply from a terminal strip at the rear. Total depth behind mounting surface: 4”.

K771 — $26

TEST PROBE
K791

K791 TEST PROBE

This pocket test probe contains two pulse-stretching lamp drivers for visual indication of both transient and steady-state conditions. Neither indicator lights on an open circuit. A built-in test point illuminator adds convenience. The probe introduces negligible loading of the point under observation. The black wire connects to any pin C. The red wire gets ac power from the system supply transformer, pin U or V of K731. Probe is hollow and fits unwrapped end of H800W pins for hands-off use if desired.

K791 — $27
Twenty module boards are drilled simultaneously from a computer-generated coordinate tape. Other pantograph-controlled machines drill up to 200 boards simultaneously from a computer-generated template.
These two double size modules offer an alternative to the K716 for obtaining field wiring connections in K series systems. The K782 has straight-through connections for use with K524, K508, K604, or K644 modules. The K784 includes 60 v clamp diodes for protection of K681 or K683 modules driving inductive loads. Strain relief holes and split lugs on both boards adapt them for such modules as K580 and K683 where 9-conductor ribbon or individual wires will be used.

Connector pins are also provided, so the connector board of types like K524 or K604 can be plugged into a shared H800-F block and bussed connections used.

The photo at right shows one way that these modules may be mounted, by bolting through the holes provided and mounting on K980 brackets. The attachment of a K743 transformer to the K980 is also shown here.

---

K782 — $12
K784 — $17
K782 TERMINALS WITH
K743 AND K980
This convenient mounting hardware permits logic connector pin wiring to be done before logic is installed in the enclosure.

K940 is a mounting support that attaches to the enclosure. K941 is a removable bracket that mounts up to four H800 connector blocks. Any connections to external equipment are made through the ribbon connectors of interface signal modules (K508, K524, K604, K644) to the K716 Interface Block.

An installation of K-Series equipment in a NEMA-12 Enclosure is illustrated on the next page.

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>K940</td>
<td>$3</td>
</tr>
<tr>
<td>K941</td>
<td>$6</td>
</tr>
</tbody>
</table>
K940, K941 WITH K716 IN A NEMA-12 ENCLOSURE, 16 IN. DEEP  TOP VIEW
19" MOUNTING PANEL
K943-R, K943-S

These low cost, 19" panels have 64 sockets with either wire-wrap (W) or solder fork (F) contact pins. Shipped with connector blocks installed and pins A and C bussed.

No terminal strips are included in the K943, since power regulators K731 and K732 will normally be plugged in to make power connections. If hold-down is required to prevent modules from backing out under vibration, order a pair of end plates K980. These assemble by means of added nuts on the rear of the rack mount screws. They accept the painted 1907 cover plate, making a hold-down system that contacts the module handles and can allow flexprint cables to be threaded neatly out the end. Rack space: 5 1/4".

---

Solder Fork K943R — $96
Wire Wrap K943S — $96

120
MOUNTING PANEL
H913, H914

The H913 panel houses a 5v regulated supply and four low density H808 connector blocks. This allows 16 of either A, K, M, or W series modules to be used. Electrical and mechanical characteristics are given below.

The H914 panel houses 8 low density H808 connector blocks. The panel will hold 32 of either A, K, M, or W series modules. It can be used for expanding slot capacity in conjunction with H913 or alone using other options of voltage supply, e.g. K731, K732 combinations. Mechanical characteristics are like those of K943.

ELECTRICAL CHARACTERISTICS

INPUT VOLTAGE:
105-125 VAC or 210-250 VAC
47-63 Hz
OUTPUT VOLTAGE:
5vdc

OUTPUT CURRENT:
0-5 amps. short-circuit protected for parallel supply operation

OVERVOLTAGE PROTECTION:
The output is protected from transients which exceed 6.9 volts for more than 10 nsec. However, the output is not protected against long shorts to voltages above 6.9 volts.

MECHANICAL CHARACTERISTICS

PANEL WIDTH: 19 in.
PANEL HEIGHT: 5¾ in.
DEPTH: 16¾ in.
FINISH: Chromicoat
POWER INPUT CONNECTIONS:
Screw terminals

Provided on transformer
MODULES ACCOMMODATED: 16
POWER OUTPUT CONNECTIONS:
Barrier strip with screw terminals and tabs which fit AMP "Faston" receptacle series 250, part no. 41774 or Type 914 power jumpers.

1945-19 HOLD DOWN BAR: Reduces vibration and keeps modules securely mounted when panel or system is moved. Adds ½ in. to depth of mounting panel.

H913 — $270
H914 — $125
The K950 Magnetic modular panel hardware provides a convenient way to build control panels containing lights, toggle and push button switches, timer controls, and thumbwheel switches. The lower connector half of the control modules K410, K420, K422, K424, and K432 are plugged into the upper connectors across a K943 mounting panel and the manual controls protrude through the K950 panel frame. The K410, K420, and K432 modules are supplied with a precut panel piece that fills the panel space for the module. The K422 and K424 modules do not require a panel piece. Since each module is covered independently of the next module, any module type can be plugged into any one of the available 32 panel socket locations. All panel hardware is supplied painted black, however, panel pieces may be individually repainted to give color coded meaning to panel controls. Thumbwheel modules are black plastic and can not be painted.

A control module can be inserted into any socket except the one directly to the left of a K422 or K424 thumbwheel module. For this reason it is recommended that all thumbwheel registers be grouped together in the same section of the panel to conserve panel locations. Metal spacers of single or double module width are available to cover unused panel locations.

The frame and panel pieces are made of steel and are held together with rivets and flexible strip magnets. The frame is mounted in a standard 19 inch rack directly above a socket mounting panel. After the control modules have been inserted into their chosen socket locations, the steel panel pieces are snapped into place to cover the modules and unused locations. After the panel is completely filled, a steel bezel is snapped into place over the panel pieces and the panel is complete.

The panel hardware can be disassembled at any time to allow controls to be added or removed.

When the panel is completely assembled, most of the magnetic lines of force are closed through the steel panel pieces. However, steel dust particles and filings will still be attracted to the panel surfaces. The magnetic force from the panel is not strong enough to damage a watch worn by the user. Each K950 is supplied with 8 single and 8 double spacers to cover up to 24 unused panel locations. The K950 is 3½ inches in height.

K950 — $39
END PLATES
K980

Pair of plates for supporting 1907 cover to hold modules in K943 panel under shock and vibration. (Note: If vibration is anticipated, care must be taken not to nick logic wires. Use a quality wire stripping device.) Also used for mounting K741, K743, K782, K784.

K980 — $6

COVER
1907

Blue painted or brown tweed painted aluminum cover with captive screws to mate threaded bushings in K980 and H001. Adds to appearance while protecting system against vibration and tampering.

1907 — $9
The K990 is a predrilled etched module for mounting up to six RC networks for K301, K303, or K323 timer controls. Any capacitor size up to a “D” case tantalum can be mounted in the space provided. A trimpot and series resistor can be mounted in the remaining space. Trimpot adjustments are accessible from the edge of the module. If the module is not mounted in the top row of modules in the system, a W980 extender module will be required to make trimpot adjustments. Etch layout is for trimpots with a staggered center pin. Connections to the module can be made either through the pins or through a cable soldered to split lugs.
ANALOG/DIGITAL MODULES

Many types of digital control systems can be interfaced to analog references or servos by means of the few versatile modules described here. The table below shows some of the many possibilities.

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>PRODUCTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital to Analog Converter 9 bits (511 steps)</td>
<td>A613- D-A Converter, A702 Reference, H704 Supply</td>
</tr>
<tr>
<td>Digital to Analog Converter, 12 bits (4095 steps)</td>
<td>A613 D-A Converter, A704 Reference, H704 Supply</td>
</tr>
<tr>
<td>BCD A to D Converter 3 decades (999 steps)</td>
<td>A613 D-A Converter, A704 Reference, H704 Supply</td>
</tr>
<tr>
<td>Analog to Digital Converter, 9 bits (See Applications Note)</td>
<td>A613, A702, H704, A207 Operational Amplifier, K210 Counters</td>
</tr>
<tr>
<td>Analog to Digital Converter, 12 bits (See Applications Note)</td>
<td>A613, A704, H704, A207 Operational Amplifier, K210 Counters</td>
</tr>
<tr>
<td>BCD A to D Converter, 3 decades (See Applications Note)</td>
<td>A613, A704, H704, A207 Operational Amplifier, K210 Counters</td>
</tr>
</tbody>
</table>
NOTE 1. Mounting holes are provided on the module so that input and feedback components can be added. Components shown with dashed lines are not included with the module.

NOTE 2. This jumper comes with the module. It may be removed to suit circuit requirements.

NOTE 3. Pins L & M can be connected together to improve settling time, but parameters such as drift and open loop gain are degraded.

The A207 is an economical Operational Amplifier featuring fast settling time (5 µs to within 10 mv), making it especially suited for use with Analog-to-Digital Converters. The A207 can be used for buffering, scale-changing, offsetting, and other data-conditioning functions required with A/D Converters. All other normal operational amplifier configurations can be achieved with the A207.

The A207 is supplied with a zero balance potentiometer. Provisions are made on the board for the mounting of input and feedback components, including a gain trim potentiometer. The A207 is pin-compatible with the A200 Operational Amplifier.
SPECIFICATIONS—At 25°C, unless noted otherwise.

<table>
<thead>
<tr>
<th>Pins L &amp; M Differences with Pins Connected L &amp; M Not Connected</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Settling Time</strong></td>
</tr>
<tr>
<td>Within 10 mv, 10v step input, typ:</td>
</tr>
<tr>
<td>3 μsec</td>
</tr>
<tr>
<td>6 μsec</td>
</tr>
<tr>
<td>Within 10 mv, 10v step input, max:</td>
</tr>
<tr>
<td>5 μsec</td>
</tr>
<tr>
<td>8 μsec</td>
</tr>
<tr>
<td>Within 1 mv, 10v step input, max:</td>
</tr>
<tr>
<td>7 μsec</td>
</tr>
<tr>
<td>10 μsec</td>
</tr>
<tr>
<td><strong>Frequency Response</strong></td>
</tr>
<tr>
<td>DC open loop gain, 670 ohm load, min:</td>
</tr>
<tr>
<td>15,000</td>
</tr>
<tr>
<td>100,000</td>
</tr>
<tr>
<td>Unity gain, small signal, min:</td>
</tr>
<tr>
<td>3 MHz</td>
</tr>
<tr>
<td>Full output voltage, min:</td>
</tr>
<tr>
<td>50 KHz</td>
</tr>
<tr>
<td>Slewing rate, min:</td>
</tr>
<tr>
<td>3.5v/μsec</td>
</tr>
<tr>
<td>Overload recovery, max:</td>
</tr>
<tr>
<td>8 μsec</td>
</tr>
<tr>
<td><strong>Output</strong></td>
</tr>
<tr>
<td>Voltage, max:</td>
</tr>
<tr>
<td>±10v</td>
</tr>
<tr>
<td>Current, max:</td>
</tr>
<tr>
<td>±15 ma</td>
</tr>
<tr>
<td><strong>Input Voltage</strong></td>
</tr>
<tr>
<td>Input voltage range, max:</td>
</tr>
<tr>
<td>±10v</td>
</tr>
<tr>
<td>Differential voltage, max:</td>
</tr>
<tr>
<td>±10v</td>
</tr>
<tr>
<td>Common mode rejection, min:</td>
</tr>
<tr>
<td>10,000</td>
</tr>
<tr>
<td><strong>Input Impedance</strong></td>
</tr>
<tr>
<td>Between inputs, min:</td>
</tr>
<tr>
<td>100 K ohms</td>
</tr>
<tr>
<td>Common mode, min:</td>
</tr>
<tr>
<td>5 M ohms</td>
</tr>
<tr>
<td><strong>Input Offset</strong></td>
</tr>
<tr>
<td>Avg. voltage drift vs. temp, max:</td>
</tr>
<tr>
<td>60 μV/°C</td>
</tr>
<tr>
<td>30 μV/°C</td>
</tr>
<tr>
<td>Initial current offset, max:</td>
</tr>
<tr>
<td>0.5 μa</td>
</tr>
<tr>
<td>Avg. current drift vs. temp, max:</td>
</tr>
<tr>
<td>5 na/°C</td>
</tr>
<tr>
<td><strong>Temperature Range</strong></td>
</tr>
<tr>
<td>0°C to +60°C</td>
</tr>
<tr>
<td><strong>Power</strong></td>
</tr>
<tr>
<td>+15v (pin D), quiescent:</td>
</tr>
<tr>
<td>6 ma</td>
</tr>
<tr>
<td>−15v (pin E), quiescent:</td>
</tr>
<tr>
<td>10 ma</td>
</tr>
</tbody>
</table>

If the Output is accidentally shorted to ground, the amplifier will not be damaged.

*Gain of 1, inverting or non-inverting configuration.
ANALOG GND (PIN AF) & DIGITAL GND (PIN AC) MUST BE CONNECTED TOGETHER AT ONE POINT IN THE SYSTEM.
The A613 is a 12-bit Digital-to-Analog Converter for moderate speed applications. The module is controlled by standard positive logic levels, has an output between 0v and +10v, and will settle within 50 µsec for a full scale input change. The input coding can be either straight binary or 3 decades of 8421 BCD with only simple connector jumpers required to take care of the change.

The A613 requires a −10.0v reference that can supply negative current, such as an A704. Provisions are made for adding up to 3 extra resistors to implement offsetting functions. Potentiometers are provided for zero balancing, and gain trim. The A613 is a double height board.

An input of all Logic 0’s produces zero volts out; all Logic 1's produces close to +10v out. The operational amplifier output can be shorted to Ground without damaging the circuit.

**SPECIFICATIONS**

**Inputs**
- Logic ONE:
- Logic ZERO:
- Input loading:

**Output**
- Standard:
- Optional, (requires Positive REF)
- Settling time, (10v step):
- Output current:
- Capacitive loading:

<table>
<thead>
<tr>
<th>Binary Dig. In.</th>
<th>Analog Out</th>
<th>BCD (8421)</th>
<th>Analog Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>000 — 00</td>
<td>0.0000v</td>
<td>000</td>
<td>0.000v</td>
</tr>
<tr>
<td>000 — 01</td>
<td>+0.0025</td>
<td>001</td>
<td>+0.010</td>
</tr>
<tr>
<td>100 — 00</td>
<td>+5.0000</td>
<td>050</td>
<td>+0.500</td>
</tr>
<tr>
<td>111 — 11</td>
<td>+9.9975</td>
<td>999</td>
<td>+5.000</td>
</tr>
</tbody>
</table>

Accuracy

- At +25°C:
- Temp. coef: ±0.015% of full scale
- ±0.001%/°C (plus drift of REF)
- BCD ±0.05% of full scale
- ±0.002%/°C (plus drift of REF)

**Board Size**
- 1 double height board, single module width

**Temperature Range**
- +10°C to +50°C

**Power**
- +15v at 35 ma at max. load
- −15v at 60 ma
- +5v at 60 ma
- −10.0v REF at −7 ma (reverse current)

If the Output is accidentally shorted to Ground, the output amplifier will not be damaged.

---

A613 — $250

129
## REFERENCE SUPPLIES
**TYPES A702, A704 (DOUBLE HEIGHT)**

![Image of REFERENCE SUPPLIES](image)

### A704 PRECISION REFERENCE SUPPLY
(Double size module)

<table>
<thead>
<tr>
<th>Module Type</th>
<th>Output</th>
<th>Current</th>
<th>Temperature Coefficient</th>
<th>Regulation</th>
<th>Ripple Peak to Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>A702</td>
<td>−10 V</td>
<td>±60 mA</td>
<td>1 mV/°C</td>
<td>30 mV, no load to full load</td>
<td>10 mV</td>
</tr>
<tr>
<td>A704</td>
<td>−10 V</td>
<td>−90 to +40 mA</td>
<td>1 mV/8 hrs 1 mV/15° to 35°C 4 mV/0° to 50°C</td>
<td>0.1 mV, no load to full load</td>
<td>0.1 mV</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Module Type</th>
<th>Adjustment Resolution</th>
<th>Input Power</th>
<th>Use</th>
<th>Output Impedance</th>
</tr>
</thead>
<tbody>
<tr>
<td>A702</td>
<td>5 mV</td>
<td>−15 V/100 mA +10 V (B)/10 mA</td>
<td>Load with 500 μF at load. May also be preloaded if desired</td>
<td>0.5 ohms</td>
</tr>
<tr>
<td>A704</td>
<td>0.01 mV</td>
<td>−15 ±2V/250 mA</td>
<td>See below for sensing and preloading</td>
<td>0.0025 ohms</td>
</tr>
</tbody>
</table>

**Remote Sensing:** The input to the regulating circuits of the A704 is connected at sense terminals AT (+) and AV (−). Connection from these points to the load voltage at the most critical location provides maximum regulation at a selected point in a distributed or remote load. When the sense terminals are connected to the load at a relatively distant location, a capacitor of approximately 100 μF should be connected across the load at the sensing point.
Preloading: The supplies may be preloaded to ground or −15v to change the amount of current available in either direction. For driving DEC Digital-Analog Converter modules, −125 ma maximum can be obtained by connecting a 270Ω±5% 1 watt resistor from the −10v AE reference output to pin AC ground (A704 only).

Pin Connections: The A704 is a double-sized module. The top pin letters are prefixed A.

Wiring: Digital-analog and analog-digital converters perform best when module locations and wiring are optimized. All Digital-Analog Converter modules should be side-by-side, with Type 932 bus strip used to bus pins E and pins F together on all converter modules. In an analog-digital converter, the comparator should be mounted next to the converter module for the bits of most significance. The reference supply modules should be mounted nearby, and if the A704 is used, its sense terminals should be wired to pins E and F of the most-significant-bits converter module. The high quality ground must be connected to the common ground only at pin AC of the reference supply module, and this point should also be the common ground for analog inputs to analog-digital converters. Do not mount A-series modules closer than necessary to power supply transformers or other sources of fluctuating electric or magnetic fields.

<table>
<thead>
<tr>
<th>Model</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>A702</td>
<td>$ 58</td>
</tr>
<tr>
<td>A704</td>
<td>$184</td>
</tr>
</tbody>
</table>
These supplies differ only in dimensions and output current capabilities: 400 ma and 1.5 Amperes respectively for the H704 and H707. May be mounted on the bars in an H920 drawer, taking the space of two connector blocks.

**MECHANICAL CHARACTERISTICS**

**DIMENSIONS:** 3\(\frac{1}{4}\) x 3\(\frac{3}{4}\) x 5 in. height (H704)

**DIMENSIONS:** 4" x 5" x 5\(\frac{1}{2}\)" height (H707)

**CONNECTIONS:** All input-output wires must be soldered to octal socket at the base of the power supply.

**OPERATING TEMPERATURE:** −20 to +71°C ambient

<table>
<thead>
<tr>
<th>Model</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>H704</td>
<td>$200</td>
</tr>
<tr>
<td>H707</td>
<td>$400</td>
</tr>
</tbody>
</table>
ELECTRICAL CHARACTERISTICS

INPUT VOLTAGE: 105 to 125 vac; 47-420 cps.
OUTPUT VOLTAGE: floating ±15v
OUTPUT VOLTAGE ADJUSTMENT: ±1v each output
REGULATION: 0.05% line, 0.1% load for both voltages
RIPPLE: 1 mv rms max for both outputs
OVERLOAD PROTECTION: The power supply is capable of withstanding output short circuits indefinitely without being damaged.

IF REMOTE SENSING IS NOT USED, CONNECT: 5 TO 4
6 TO 7
Digital manufactures a complete line of hardware accessories in support of its module series. Module connectors are available for as few as one module and as many as 64. A complete line of cabinets is available to house the modules and their connector blocks, as well as providing a convenient means for system expansion. Power supplies for both large and small systems and reference supplies are also available.

Coupled with the recent additions to the hardware line, Digital has made every effort to maintain or improve the high standards of reliability and performance of its present line. Through the availability of a wide range of basic accessories, DEC feels that it is offering the logic designer the necessary building blocks which he requires for complete system design.

50-CYCLE POWER

Because of the demand for Digital’s products in areas where 115-v, 60-cps power is not available, each of the power supplies with a frequency-sensitive regulating transformer is also available in a multi-voltage 50-cps version. All 50-cps supplies have the same input connections. The line input is on pins 3 and 4. Jumpers should be connected depending on the input voltage.

WIRING HINTS

These suggestions may help reduce mounting panel wiring time. They are not intended to replace any special wiring instructions given on individual module data sheets or in application notes. For fastest and neatest wiring, the following order is recommended.

1. All power & ground wiring and any horizontally bussed signal wiring. Use Horizontal Bussing Strips Type 932 or Type 933.

2. Vertical grounding wires interconnecting each chassis ground with pin C grounds. Start these wires at the uppermost mounting panel and continue to the bottom panel. Space the wires 2 inches apart, so each of the chassis-ground pins is in line with one of them. Each vertical wire makes three connections at each mounting panel.

3. All other ground wires. Always use the nearest pin C above the pin to be grounded, unless a special grounding pin has been provided in the module.

4. All signal wires in any convenient order. Point-to-point wiring produces the shortest wire lengths, goes in the fastest, is easiest to trace and change, and generally results in better appearance and performance than cabled wiring. Point-to-point wiring is strongly urged.

The recommended wire size for use with the H800 mounting blocks and 1943 mounting panels is 24 for wire wrap, and 22 for soldering. The recommended size for use with H803 block and H911 mounting panels is #30 wire. Larger or smaller wire may be used depending on the number of connections to be made to each lug. Solid wire and a heat resistant spaghetti (Teflon) are easiest to use when soldering.

Adequate grounding is essential. In addition to the connection between mounting panels mentioned above, there must be continuity of grounds between
cabinets and between the logic assembly and any equipment with which the logic communicates.

When soldering is done on a mounting panel containing modules, a 6-v (transformer) soldering iron should be used. A 110-v soldering iron may damage the modules.

When wire wrapping is done on a mounting panel containing modules, steps must be taken to avoid voltage transients that can burn out transistors. A battery- or air-operated tool is preferred, but the filter built into some line-operated tools affords some protection.

Even with completely isolated tools, such as those operated by batteries or compressed air, a static charge can often build up and burn out semiconductors. In order to prevent damage, the wire wrap tool should be grounded except when all modules are removed from the mounting panel during wire wrapping.

AUTOMATIC WIRING

Significant cost savings can be realized in quantity production if the newest automatic wiring techniques are utilized. Every user of FLIP CHIP modules benefits from the extensive investment in high-production machinery at Digital, but some can go a step further by taking advantage of programmed wiring for their FLIP CHIP digital systems.

While the break-even point for hand wiring versus programmed wiring depends upon many factors that are difficult to predict precisely, there are a few indications:

1. One-of-a-kind systems will probably not be economical with automatic wiring, even when the size is fairly large; programming and administrative costs are likely to outweigh savings due to lower costs in the wiring itself.

2. At the other end of the spectrum, production of 50 or 100 identical systems of almost any size would be worth automating, not only to lower the cost of the wiring itself but also to reduce human error. At this level of volume, machine-wired costs can be expected to be less than the cost of hand wiring.

3. For two to five systems of several thousand wires each, a decision on the basis of secondary factors will probably be necessary: ease of making changes, wiring lead time, reliability predictions, and availability of relevant skills are factors to consider.

The Gardner-Denver Corporation, and Digital can supply further information to those interested in programmed wiring techniques. At Digital, contact the Module Sales Manager, Sales Department.

COOLING OF FLIP CHIP MODULES

The low power consumption of K and M series modules results in a total of only about 25 watts dissipation in a typical 1943 Mounting Panel with 64 modules. This allows up to six panels of modules to be mounted together and cooled by convection alone, if air is allowed to circulate freely. In higher-dissipation systems using modules in significant quantities from the A series, the number of mounting panels stacked together must be reduced without forced-air cooling. In general, total dissipation from all modules in a convection-cooled system should be 150 watts or less.
The regulating transformers used in most DEC power supplies have nearly constant heat dissipation for any loading within the ratings of the supply. Power dissipated within each supply will be roughly equal to half its maximum rated output power. If power supplies are mounted below any of the modules in a convection-cooled system, this dissipation must be included when checking against the 150 watt limit.
Pairs of brackets. H001 provides 3/4" standoff to mount 1907 over K943 wiring. H002 provides a 2" setback so a control panel with switches, lamps, etc. can be mounted flush with mounting rack or cabinet in front of logic wiring. The H002 can also be used to mount the K741 and K743 transformers.

The H020 consists of a mounting frame casting. Components which can be mounted on this frame include, H800, H803, H808 connector blocks, power supplies such as H710 and others or customer components that are adapted to the frame mounting requirements.

The H021 consists of a pair of offset end plates which mount to the H020. These end plates provide a mount for the 1945-19 hold down bar, if required. H022 consists of a pair of end plates similar to H021 but provide a terminal block assembly for ease of parallel power wiring of adjacent panels.

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>H001-PR</td>
<td>$8</td>
</tr>
<tr>
<td>H002-PR</td>
<td>$8</td>
</tr>
<tr>
<td>H020</td>
<td>$15</td>
</tr>
<tr>
<td>H021</td>
<td>$7</td>
</tr>
<tr>
<td>H022</td>
<td>$20</td>
</tr>
</tbody>
</table>
CONNECTOR BLOCKS
H800-W, H800-F

This is the 8-module molded socket assembly used in FLIP CHIP mounting panels. Aside from its function as a replacement part, there may be times when a special mounting fixture with one or more H800 blocks must be made by a manufacturer who wishes to fit a few modules into a confined or irregular space. The drawings below show the pertinent dimensions.

REPLACEMENT CONTACTS TYPES H801-W, H801-F

These contacts are offered in packages of 18 for replacement purposes. In each package, nine straight and nine offset contacts are included, enough to replace all contacts in one socket.

H801-W is for wire-wrap connectors; H801-F is for solder-fork connectors.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>H800F</td>
<td>$8</td>
</tr>
<tr>
<td>H800W</td>
<td>$8</td>
</tr>
<tr>
<td>H801F</td>
<td>$2</td>
</tr>
<tr>
<td>H801W</td>
<td>$2</td>
</tr>
</tbody>
</table>
This is an 18 pin connector block for a single flip-chip module. The H802 can be used to fit a single module in a confined or irregular space. Often the H802 is used as a connector for a cable at some remote location. The H802 is only available with wire wrap pins.
The H808 is a relatively low density connector block for use with all modules in the catalog. This includes A, K, M, and W Series modules. The connector provides 4 module slots each having 36 pins. On A, K and W Series modules only the 2 side pins, (A2, B2, etc.) will make contact. This connector adds a measure of convenience and versatility to the many uses to which these catalog modules can be applied. Hand wiring of connector pins is more easily accomplished for M Series prototype work. H800 and H808 connector blocks can be mixed for M and A, K, W module mixing purposes. Wire wrapping patterns can be maintained even though module letter series are mixed because H800 & H808 pin layout is identical. H809 is a package of 36 replacement pins, 18 left and 18 right.
WIRING ACCESSORIES
932, 933, 934, 935, 936
H810, H811, H812, H813, H814

932 BUS STRIP
Simplifies wiring of register pulse busses, power, and grounds. Same as used in K943 with H800 blocks.

933 — $0.60

933 BUS STRIP
Simplifies wiring of power, ground and signal busses on mounting panels using H803 connectors.

933 — $1

934 WIRE-WRAPPING WIRE
1000 ft. roll of 24 gauge solid wire with tough, cut-resistant insulation. (Use Teflon insulated wire instead for soldering.) For use with H800 connectors.

934 — $50
935 WIRE-WRAPPING WIRE
1000 foot roll or 30 gauge insulated solid wire for use with H803 connectors.

935 — $60

936 19 CONDUCTOR RIBBON CABLE
Use on W Series connector modules or split into 9-conductor cables for use with K580, K681, K683, etc.

936 — $0.60/ft.

H810 PISTOL GRIP HAND WIRE WRAPPING TOOL
The type H810 Wire Wrapping Tool is designed for wrapping #24 or #30 solid wire on Digital-type connector pins. The H810 Kit includes the proper sleeves and bits. It is recommended that five turns of bare wire be wrapped on these pins. This tool may also be purchased from Gardner-Denver Co. (Gardner-Denver part No. 14H-1C) with No. 26263 bit and No. 18840 sleeve for wrapping #24 wire. Specify bit #504221 and sleeve #500350 for wrapping #30 wire. When ordering from Digital specify the sleeve and bit size desired for #24 and #30 wire.

- H810(24) — $ 99
- H810A — $ 99
- H810B — $150
The Type H811 Hand Wrapping tool is useful for service or repair applications. It is designed for wrapping #24 solid wire on DEC Type H800-W connector pins. This tool may also be purchased from Gardner-Denver Co. as Gardner-Denver Part #A20557-12.

Wire wrapped connections may be removed with the Type H812 Hand Unwrapping tool. This tool may also be purchased from Gardner-Denver Co. as Gardner-Denver Part #500130.

The H811A and H812A are equivalent to the H811 and the H812 except that the A versions are designed for #30 wire. Both tools may be purchased from Gardner-Denver directly under the following part numbers: H811A A-20557-29; H812A 505 244-475. The H813 is a #24 bit; H813A, a #30 bit. The H814 is a #24 sleeve; H814A, a #30 sleeve.

None of the Wire Wrapping Tools will be accepted for credit under any circumstances.

<table>
<thead>
<tr>
<th>Tool Code</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>H811(24)</td>
<td>$21.50</td>
</tr>
<tr>
<td>H811A(30)</td>
<td>$21.50</td>
</tr>
<tr>
<td>H812(24)</td>
<td>$10.50</td>
</tr>
<tr>
<td>H812A(30)</td>
<td>$10.50</td>
</tr>
<tr>
<td>H813(24)</td>
<td>$30</td>
</tr>
<tr>
<td>H813A(30)</td>
<td>$30</td>
</tr>
<tr>
<td>H814(24)</td>
<td>$21</td>
</tr>
<tr>
<td>H814A(30)</td>
<td>$21</td>
</tr>
</tbody>
</table>

143
913 AND 915 PATCHCORDS
These patchcords provide slip-on connections for FLIP CHIP mounting panels and are available in color-coded lengths of 2, 3, 4, 6, 8, 12, 16, 24, 32, 48, and 64 inches. All cords are shipped in quantities of 100 in handy polystyrene boxes. Type 913 patchcords are for 24 gauge wirewrap and use AMP Terminal Type #60530-1. Type 915 patchcords are for 30 gauge wirewrap and use AMP Terminal Type #85952-3.

H820 AND H821 GRIP CLIPS FOR SHIP-ON PATCHCORDS
The type H820 and H821 GRIP CLIPS are identical to slip-on connectors used in respectively the 913 and 915 patchcords. These connectors are shipped in packages of 1000 and permit fabrication of patchcords to any desired length. H820 GRIP CLIPS will take size 24-20 awg. wire and may be purchased from AMP, Inc. as AMP part #60477-2. H821 GRIP CLIPS will take size 30-24 awg. wire and are AMP part #85952-3.

H825 HAND CRIMPING TOOL
Type H825 hand crimping tool may be used to crimp the type H820 GRIP CLIP connectors. Use of this tool insures a good electrical connection. This tool may also be obtained from AMP, Inc. as AMP part #90084.

H826 HAND CRIMPING TOOL
Type H826 hand crimping tool may be used to crimp the type H821 GRIP CLIP connectors. This tool is identical to AMP part #9019-1.
914 POWER JUMPERS

For interconnections between power supplies, mounting panels, and logic lab panels, these jumpers use AMP "Faston" receptacles series 250. Specify 914-7 for interconnecting adjacent mounting panels, or 914-19 for other runs of up to 19 inches. 914-7 contains 10 jumpers per package; 914-19 contains 10 jumpers per package.

The 914-7 jumpers are 7 inches long and the 914-19 jumpers are 19 inches long.

913 — $18/pkg. of 100
914-7 — $4/pkg.
914-19 — $4/pkg.
915 — $33/pkg. of 100
H820 — $48/pkg. of 1000
H821 — $75/pkg. of 1000
H825 — $146
H826 — $210
The H920 Module Drawer provides a convenient mounting arrangement for a complete digital logic system. The H920 has space for 20 mounting blocks in addition to an H701, H710, or H716 power supply, or 24 mounting blocks without a supply. It accepts H800, H803, and H808 mounting blocks and fits standard 19” racks. Width of the H920 is 16½”, depth is 19” and height is 6¾” including an H921 front panel. The H920 is equipped with a bracket for power distribution within the drawer, or to other drawers and mounting panels. Mounting arrangements are provided for the H921 front panel and H923 slide tracks.

The H921 front panel is designed for use primarily with the H920 Module Drawer. It provides mounting space for switches, indicators, etc. The H921 is pre-drilled and ready to mount on the H920. Height of the H921 is 6¾”, width is 19”.

H923 chassis slides are intended for use with the H920 Module Drawer. The H923 allows the user to slide the drawer out of the rack and tilt the drawer for easy access.

<table>
<thead>
<tr>
<th>H920</th>
<th>$170</th>
</tr>
</thead>
<tbody>
<tr>
<td>H921</td>
<td>$10</td>
</tr>
<tr>
<td>H923</td>
<td>$75</td>
</tr>
</tbody>
</table>
The H925 Module Drawer provides mounting space for H800, H803, and H808 connector blocks accommodating as many as 144 modules. The connector blocks mount pins-upward on the H925 for easy access during system checkout.

The right side of the H925 is provided with three axial flow fans which are mounted internally. They provide cooling air flow across the mounted modules.

For ease of mounting, the H925 is provided with two non-tilting slides, similar to Grant type SS-168-NT. Considering possible servicing, the H925 should be mounted with enough height for using bottom access.

The H925 includes cover plates for its top and bottom along with an attractive bezel and front subpanel. The subpanel consists of a formidable 16-gauge material for mounting front panel controls and accessories. The bezel is designed for installing a customer-supplied dress panel. The dress panel should have a thickness of 1/8" and measure 8 1/4" x 18 3/4" with the corners radiused to 3/8". The H925 fits all DEC 19" racks.

H925 — $250
CABLE CONNECTORS
W021, W023, W028

The W021 and W028 provide cable connections to any module socket or mounting panel. The cable is a 19-conductor ribbon with nine signal leads and ten shields. The signal leads are connected to pins D, E, H, K, M, P, S, T and V. The shields are internally connected together and to pins C, F, J, L, N, R and U.

The W023 allows straight-through connections for all 18 pins. Pin A on this connector should not be used for logic signals, since it would be so easy to get power voltage on pin A by mistake. But W023 connector cables are convenient for supplying power and ground connections as well as signals to K724 and K725 interface shells.

TWO CONNECTOR STANDARD CABLES

<table>
<thead>
<tr>
<th>TYPES (connector type — cable inches — connector type)</th>
<th>LENGTH</th>
<th>PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>W021-36R-W021, W028-36R-W021, W023-36R-W023</td>
<td>3 Feet</td>
<td>$27.80</td>
</tr>
<tr>
<td>W021-60R-W021, W028-60R-W021, W023-60R-W023</td>
<td>5 Feet</td>
<td>$29.00</td>
</tr>
<tr>
<td>W021-84R-W021, W028-84R-W021, W023-84R-W023</td>
<td>7 Feet</td>
<td>$30.20</td>
</tr>
<tr>
<td>W021-120R-W021, W028-120R-W021, W023-120R-W023</td>
<td>10 Feet</td>
<td>$32.00</td>
</tr>
</tbody>
</table>

Cable connectors are also available separately, as is 19-conductor ribbon cable (936). Please include suffix letters as shown when ordering.

| W021RU — $4   |
| W023RU — $4   |
| W028RU — $4   |
| 936 — $0.60/ft |
The W980 Module Extender allows access to the module circuits without breaking connections between the module and mounting panel wiring.

For double size flip-chip modules use two W980 extenders side by side. The W980 is for use with A, K and W Series 18 pin modules.

W980 — $14
The W982 serves a function similar to the W980 except it contains 36 pins for use with M series modules. The W982 can be used with all modules in this catalog. A, K, and W series modules will make contact with only 2 side pins. A2, B2, etc.

For double size M Series modules use two W982 extenders side by side.

W982 — $18
These 10 blank modules offer convenient means of integrating special circuits and even small mechanical components into a FLIP CHIP system, without loss of modularity. Both single- and double-size boards are supplied with contact area etched and gold plated. The W990 Series modules provide connector pins on only one module side for use with H800 connector blocks. W970 series modules have etched contacts on both sides of the module for use with double density connectors Type H803, and low density Type H808.

<table>
<thead>
<tr>
<th>Type</th>
<th>Pins</th>
<th>Description</th>
<th>Handle</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>W990</td>
<td>18</td>
<td>Bare board, split-lug terminals</td>
<td>attached</td>
<td>$2.50</td>
</tr>
<tr>
<td>W991</td>
<td>36</td>
<td>Bare board, split-lug terminals</td>
<td>attached</td>
<td>$5.00</td>
</tr>
<tr>
<td>W992</td>
<td>18</td>
<td>Copper clad, to be etched by user</td>
<td>separate</td>
<td>$2.00</td>
</tr>
<tr>
<td>W993</td>
<td>36</td>
<td>Copper clad, to be etched by user</td>
<td>separate</td>
<td>$4.00</td>
</tr>
<tr>
<td>W998</td>
<td>18</td>
<td>Perforated, 0.052” holes, 18 with etched lands. The holes are on 0.1” centers, both horizontally and vertically</td>
<td>attached</td>
<td>$4.50</td>
</tr>
<tr>
<td>W999</td>
<td>36</td>
<td>Perforated, 0.052” holes, 36 with etched lands. The holes are on 0.1” centers, both horizontally and vertically.</td>
<td>attached</td>
<td>$9.00</td>
</tr>
<tr>
<td>W970</td>
<td>36</td>
<td>Bare board, no split lugs, similar to W990, contact both sides</td>
<td>attached</td>
<td>$4.00</td>
</tr>
<tr>
<td>W971</td>
<td>72</td>
<td>Bare board, no split lugs, similar to W991, contact both sides</td>
<td>attached</td>
<td>$8.00</td>
</tr>
<tr>
<td>W972</td>
<td>36</td>
<td>Copper clad, similar to W992</td>
<td>separate</td>
<td>$4.00</td>
</tr>
<tr>
<td>W973</td>
<td>72</td>
<td>Copper clad, similar to W993</td>
<td>separate</td>
<td>$6.00</td>
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<tr>
<td>W974</td>
<td>36</td>
<td>same as W998, contact both sides</td>
<td>attached</td>
<td>$9.00</td>
</tr>
<tr>
<td>W975</td>
<td>72</td>
<td>same as W999, contact both sides</td>
<td>attached</td>
<td>$18.00</td>
</tr>
</tbody>
</table>
K-SERIES CONSTRUCTION RECOMMENDATIONS

A high percentage of all failures in electronic systems result directly from hasty planning of nonelectronic aspects. Much time and trouble can be saved by planning mechanical assembly before construction begins. Wiring methods and lead dress, heat distribution and temperature control, power supply reliability and line fault contingencies, and the attitudes and habits of people working near the system all merit forethought. Important opportunities for reliability, maintainability, and convenience will be lost if early and consistent attention is not given the topics below.

Environment

a. Temperature

Module temperature ratings are \(-20^\circ\text{C to 65}\)\(^\circ\text{C (0°F to 150°F)}\) except K201, K202, K210, K211, K220, K230, and K596 which are limited to \(0^\circ\text{C (36°F)}\) minimum. These ratings are for average air temperature at the printed board, and take local heating by high dissipation components into account. Free, unobstructed air convection is required for reliable operation; the plane of each module must be essentially vertical for this reason.

Convection is required not only to remove heat but also to distribute it, and movable louvres or baffles used to obtain self-heating under frigid conditions must not interfere with air movement within and around modules.

b. Motion

Transport or use in trucks or aboard ships can vibrate modules sufficiently to work them out of their sockets. K271, K273, K604, K644, K731, K732, K303, K301 and K323 modules with K374 or similar controls attached are most subject to disturbance.

If modules are mounted in a K943 19-inch panel, use K980 endplates and a 1907 cover.

If modules are mounted on the hinged door of an enclosure, position the K941 so a support bolted to the side of the enclosure will contact the modules when the door is closed, taking care not to let the support interfere with ribbon cable on K508, K524, K604, and K644.

Mercury contact relays in K273 modules should be maintained within \(30^\circ\) of vertical while operating to insure correct logic output.

Controls such as K374, etc. will hold their setting in vibration, but are easily disturbed by repeated contact with loose wiring, etc.

Finally, take pains not to nick logic wires if vibration is likely to be encountered. Use a quality wire stripper. One of the new motor driven rotary types could easily pay for itself by reducing wiring time and avoiding vibration induced wire breakage.

c. Contaminants

Sulphurous fumes will attack exposed copper or silver; their presence demands the coating of ribbon connections and K731 heatsink cladding with suitable insulating varnish or plastic. A combination of high humidity and
contaminated atmospheres requires such treatment on all printed wiring of K301, K323, and K303 timers and controls, since at maximum settings even a few microamperes of leakage will affect their timing. Varnish or coatings are neither required nor recommended in less hostile conditions, and in any case it is desirable to exclude contaminants.

d. Convenience

Adjustments should be mounted so the least critical are easiest to reach. Calibrated controls such as K374, etc. should be positioned in a logical pattern before K303 sockets are wired. Ruggedness and feel should govern the selection of remote timer controls likely to be operated in moments of preoccupation or alarm.

Pluggable connections to K716, K724-K725, and (optionally) to K782-K784 allow electricians to complete their work while the logic itself is being built or checked elsewhere. Plan cable routing to simplify installation of electronics last. Take advantage of the ease with which a K941 mounting bar can be fastened to a pre-installed K940 foot.

Logic Wiring

a. General Information

Wire wrapping is the most suitable technique for the sockets used with K series modules. Some prefer AMP Termi-Point (trademark) but neither AMP nor DEC can guarantee full compatibility for this system. Solder fork connectors are optional; wrapped connections may also be soldered. For large volume repetitive systems using K943 mounting panels, DEC offers a machine-wrapping service.

Never solder or wire wrap with any tool if there are modules installed, unless the tool is grounded to the frame to drain static charges, and unless AC operated devices work from isolation transformers. It is safest to avoid AC operated wire wrap tools together. Hand-operated pistol-grip wire wrapping tools are surprisingly efficient and easy to use. If automatic machine wrapping is contemplated, plan for only two wraps per pin.

b. Wire Types

Teflon (trademark) insulation over size 22 tinned solid copper wire is best for soldering. Size 24 tinned solid copper wire must be used for wrapping H800 and K943 pins. Teflon (trademark) insulation may be used, but some prefer to sacrifice high temperature performance by using Kynar (trademark), to get greater resistance to cut-through where soldering is not involved.

Type 932 bussing strip allows module power and ground pins A and C to be connected conveniently, and is also helpful if several modules have common pin connections.

c. Procedures

First solder in all bussing strips. Next tie all grounds and grounded pins together. Finally point-to-point wire all other connections.

Run all wires diagonally or vertically. Do not run wires horizontally except to adjacent pins or along mounting bar between modules. Horizontal zig-zag wiring interferes with checking and is prone to insulation cut-through. Leave wires a bit slack so they can be pushed aside for probing. Cabling is definitely not recommended. Wires should be more or less evenly distributed over the wiring area.
When wrapping, avoid chains of top-wrap-to-bottom-wrap sequences which entail numerous unwrappings if changes must be made. Properly sequenced wraps require no more than three wires to be replaced for any one change in two-wraps-per-pin systems. Never re-wrap any wire. For best reliability, do not bend or stress wrapped pins, for this may break some of the cold welds. Follow tool supplier's recommendations on tool gauging and maintenance etc. As a convenience, DEC stocks three Gardener-Denver tools under numbers H810, H811, and H812. See specifications pages.

Field Wiring

a. AC Pilot Circuits

All screw terminals used in the K-Series have clamps so that wires do not need any further treatment after insulation is stripped. All terminals can take either one or two wires up to 14 gauge.

K716 terminals have been arranged so AC inputs all go to one end of the interface block, and AC outputs all go to the other end. The eight terminals nearest the center are typically connected only to each other and to a few return and AC supply wires. Input and output leads should be segregated so they do not block entry to the ribbon connector sockets. If sockets face to the left, AC inputs will be above and all other connections below. Wires should be routed down the connector side of K716 blocks to cable clamps or wiring ducts placed parallel with K716s. (See diagrams on K716 data page.)

Plan the logical arrangement of field wiring terminals and indicators before module locations are selected to avoid excessive folding or twisting of ribbon cables. (See recommendations on module locations below.)

b. DC and Transducer circuits

DC outputs from K644, K656, K681, and K683 and AC outputs from K604 and K614 are high level; wiring is noncritical. Low level inputs, however, may require special treatment to avoid false indications. Low level signals should at least be isolated from AC line and DC output signals throughout the field wiring system, and, as a minimum, individual twisted pairs should be used for signals and return connections.

For lower signal levels or longer wiring runs, shielded pairs may be required, with the shield grounded only at one point, preferably at the logic system end unless one side of the transducer is unavoidably grounded. Conduit which may be grounded indiscriminately is not an effective substitute for shielded, insulated wiring.

All signals except line voltage AC inputs use the straight-through connections of K716 terminals 15 through 24. Within the K716, leads are shortest to terminals 15, 17, 18, 19, and 20; use these terminals for minimum noise on K524 low level signals.

Module types K578, K614, K656, and K658 have their own terminal strips and do not require the use of a K716. Modules that do not have terminal strips may be connected to field wiring through the K782 or K784 module.
Module Locations

a. End Sockets (K941)

The first sockets to assign are those for K731 and K732 regulators, and for K301, K323, and K303 timers. If possible, mount regulators nearest the foot of a K941 mounting bar, so their extra bulk projects into the space between the mounting surface and the first H800 block on the bar. Controls mounted on the same mounting surface opposite K731 source modules may be as much as 5/8" deep without touching modules.

Sockets at the outer end of K941 mounting bars are the only locations where K303 timers can have integral controls mounted. Even where the use of K370-group controls is not initially planned, assignment of K303 modules to these outer locations is recommended. Also, these sockets should be the first reserved as spares if any unused locations are available. This way maximum flexibility will be preserved for possible design changes or additions.

b. Interface Modules

AC and DC interface modules such as K508, K524, K604, and K644 should be assigned locations that simplify cabling. Ribbon cables can be twisted by a succession of 45° folds, but a neat installation should be planned. Assign the location and position of K716 interface blocks first. Consider such features as logical arrangement of indicator lights for trouble shooting, ease of routing and tracing field wiring, and directness and length of ribbon cable runs back to the logic modules.

After K716 locations and assignments have been selected, assign socket positions for interface modules (K508, etc.). The order should be coordinated so the combined ribbon cables will lie flat together. Excess ribbon cable can be easily and neatly folded away. Lengths other than 30" are not available since these modules cannot be tested and stocked until cables are cut and soldered. This should cause no difficulty if module locations are assigned thoughtfully.

c. Display Modules

If K671 decade displays are required, select their locations after regulator and interface modules have been assigned sockets. The 12" cables on these modules are oriented for convenient assembly of displays above logic modules, to be viewed from outside the door or enclosure in which K940 and K941 hardware is mounted. Used this way, the digits of lower significance have cables below those of more significant digits.

For neatest cabling and quickest module wiring, counter and display modules should be arranged so the counter input will be nearest the K940 mounting surface. Notice that pin connections on K671, K210, and K220, and K230 modules are coordinated, so that a side-by-side pairing of flip-flop and associated K671 modules will result in short, neat, easy wiring. Ribbon cable passes easily between modules, so it is not necessary to restrict K671 modules to the topmost row. However, the limited cable length will usually restrict them to the top mounting bar in systems using more than one K941.

Do not fold or arrange ribbon cables so that they lie flat on the upper edges of modules, as this will restrict the flow of cooling air.
System Power

a. Supply Transformer

Any filament or "control" transformer rated at 12 v or 12.6 v RMS on nominal 120 v line voltage may be used to supply power to K series logic. However, use of a 12 v instead of a 12.6 v transformer reduces maximum current ratings from K731 and K732 by 15%, as does a 5% voltage drop from any other cause such as resistance in secondary wiring or line voltage below the nominal 10% tolerance.

Transformer current rating should be for capacitor-input filter, about 50% higher than the rating required for resistive loads. Thus a single K731 1 amp regulator requires a center-tapped transformer with \( \frac{3}{4} \) ampere rating on resistive loads at 12.6v, or with two 6.3v windings rated \( \frac{3}{4} \) ampere each.

These transformer selection considerations can of course be eliminated by using K741 or K743 transformers with noise filtering built-in.

b. Noise Filtering

Hash filter capacitors of 0.1 mf each are recommended from each side of the power transformer secondary to chassis ground. In environments where the AC line may carry unusually large amounts of noise, line filters such as Sprague Filterols (trademark) are advisable. K series systems must not share 12 volt power with any electromechanical device, since the transformer itself is the primary filter for medium-frequency line noise rejection.

c. Power Wiring

In systems not requiring full use of the quick-change features of the K716 and K940, transformer secondaries can be wired directly to pins U and V of regulator modules. If power connections are to be removed with maximum speed, a W021 connector board may be used to bring 12 VAC power into the system. It is best to limit current through any pin to about 2 amperes, so in large systems several W021 pins are needed for each side of the secondary.
d. Alternate Power Supplies

Any source of 5 VDC ± 10% may be used for K series systems at ordinary room temperatures, provided noise, hash, spikes, turnon-overshoot, etc. are reasonably well controlled. K series modules are far less sensitive to noise on power lines than computer-speed circuits, but it is still possible to cause malfunction or damage if extreme noise is present.

Temperature coefficient of the K731 regulator is selected to compensate for that of timers and other circuits, so operation over temperature extremes with constant-voltage supplies involves a sacrifice in timing consistency. Output fanouts are also degraded if constant voltage supplies are used at extreme low temperatures. Derate linearly from 15 ma at room temperature to 12 ma at -20°C (0°F) for constant-voltage power supplies.

e. Line Failure

When unscheduled shutdown of a K-series system cannot be tolerated in spite of AC power failure, some form of local energy storage is required. To withstand, short-term failures it is possible to add extra capacitance from pin A to pin C. However, manual grounding of pin D (turnon level) may be required to start the system, since the external capacitance will appear to the regulator as a short and output current will be limited to a low value. For each ampere-millisecond of dc power storage beyond the rise of K731 OK level, 10,000 mfd is required. The supply itself provides one half ampere-millisecond internally. K732 slave regulators each provide one ampere-millisecond internally. However, these survival times are only available when regulators are operating at or below 75% of their nominal ratings.

A 5 volt battery, or a 6 volt battery with series diode(s) to drop the voltage to 5 volts, may be used as an alternate source of power in case of line voltage failure. In very small systems (with some types of batteries) it may be practical to use the battery itself as a shunt regulator, charging it through a simple full-wave rectifier and dropping resistor circuit from the same kind of transformer used with K-series regulators. Unless the current is very low with respect to battery size, however, some means of switching the battery connection will be required. Below is shown a circuit which can be used for current requirements to 1 ampere. The same principle can be extended to larger systems with slightly more complex circuitry.

![Power Failure Switch for Emergency Battery Diagram](image-url)
### K SERIES

<table>
<thead>
<tr>
<th>MIL.</th>
<th>N.E.M.A.</th>
<th>GENERAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>![MIL Diagram]</td>
<td>![N.E.M.A. Diagram]</td>
<td>![GENERAL Diagram]</td>
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### ELECTRO-MECHANICAL

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<tr>
<th>J.I.C.</th>
<th>2-INPUT INCLUSIVE OR</th>
<th>5-INPUT INCLUSIVE OR</th>
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<td>![J.I.C. Diagram]</td>
<td>![2-INPUT INCLUSIVE OR Diagram]</td>
<td>![5-INPUT INCLUSIVE OR Diagram]</td>
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<td><strong>INVERTING FUNCTION</strong></td>
<td><a href="#">Diagram</a></td>
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<td><strong>2-INPUT NOR</strong></td>
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## Electro-Mechanical

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<th>K Series</th>
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<tr>
<td><strong>2-Input Exclusive OR</strong></td>
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**Diagram:***
- J.I.C.: [Diagram](#)
- General: [Diagram](#)
- N.E.M.A.: [Diagram](#)

**Diagram:**
- J.I.C.: [Diagram](#)
- General: [Diagram](#)
- N.E.M.A.: [Diagram](#)

| **Bistable (Flip-Flop)** | | | |

**Diagram:**
- J.I.C.: [Diagram](#)
- General: [Diagram](#)
- N.E.M.A.: [Diagram](#)

**Diagram:**
- J.I.C.: [Diagram](#)
- General: [Diagram](#)
- N.E.M.A.: [Diagram](#)

| **Off-Delay** | | | |

**Diagram:**
- J.I.C.: [Diagram](#)
- General: [Diagram](#)
- N.E.M.A.: [Diagram](#)

**Diagram:**
- J.I.C.: [Diagram](#)
- General: [Diagram](#)
- N.E.M.A.: [Diagram](#)
DECODER:
BCD TO
10 LINE
## ELECTRO-MECHANICAL

<table>
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<th>GENERAL</th>
</tr>
</thead>
</table>

### CROSSBAR SELECTOR

### HOME-TO-5

![Circuit Diagram](attachment:image.png)

- **STEP**
  - 0
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
  - 7

- **STEPPER SWITCH INDEX COIL**
  - M

- **STEP**
  - 0
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
  - 7

- **STEPPER INDEX COIL**
  - M
K SERIES SEQUENCERS — GENERAL

A fundamental part of many K Series systems is a sequencer that controls the progression from one state or operation to the next state or operation. Four logic elements are available to define the state or operation currently in effect, and there are also several choices of method for moving from each state to the next, and for deriving output signals that include any arbitrary set of states. This note considers each sequencer in a general way, so that their overall merits can be compared before starting detailed design with the 1 or 2 most appropriate. The simplest sequencer of all, consisting of logic gates alone, is not mentioned here; but of course if AND and OR functions by themselves can do the job, splendid.

1. TIMER SEQUENCER

Several independent K303 timers connected in cascade form a very flexible, completely adaptable sequencer. If each timer input is driven by the direct (non-inverted) output of the previous timer, removing logic “1” from the first will cause all the outputs to fall like hesitant dominoes. A pushbutton, limit switch, etc. can then reset all timers by restoring “1” at the first until the next cycle is wanted. Or by connecting the timers in a loop with an odd number of inversions a self-recycling sequencer can be obtained. The clock circuits shown on pages 93-94 of the Industrial Handbook are special cases of this latter technique.

The complete adjustability of timer sequencers can be a disadvantage in some applications. When more than 3 or 4 steps are needed, the sheer number of knobs to twiddle begins to lead toward possible confusion and perhaps “provocative maintenance.”

2. COUNTER SEQUENCER

One K210 counter provides up to 16 sequence states, and many more are obtainable by cascading. The counter may be stepped along by a fixed-frequency source such as the line frequency, or by a K303 clock. It is also possible to generate stepping pulses by completion signals from the processes being sequenced. K184 rate multipliers can be conveniently used to produce such pulses. Counter sequencers recycle without external aids at 9 or 15 (BCD or binary connections) and may be set to recycle at other steps as shown in K210 specifications.

Counter sequencers offer the most discrete states for the money, and the entire sequence can be scaled up or down in time simply by adjusting the input stepping rate. However, if many different output signals are to be derived from a counter sequencer, the gating can become complex unless the signals required happen to fit those available from K161 octal decoders or from the counter directly.

3. SHIFT SEQUENCERS

K230 shift registers can be connected as ordinary ring counters or as switch-tail ring counters. Specialized shift sequencers such as Barker
code (pseudo-random) sequencers are also possible. The most generally useful type is the switch-tail (Johnson code) ring counter, in which the last stage is fed back inverted into the first. This provides two states for every flip-flop, or 8 states if all four flip-flops in a K230 are utilized. The pattern achieved is the same falling-domino behavior obtained with the non-recirculating timer sequencer, except that the “dominoes” fall up one-by-one after they have finished falling down. Either fixed frequency or event-completion signals can be used to step a shift sequencer, just as for counter sequencers.

Shift sequencers cost more per state than counter sequencers. Their only advantage lies in the fact that any state or any collection of contiguous states can be detected by a simple 2-input gate. Not only does this feature simplify the derivation of many overlapping output signals, but it also offers excellent flexibility for modifications after construction. The need for only two connections to generate any once-per-sequence signal to start and end at any arbitrary state even permits practical patch-panel programming of output signals.

4. POLYFLOP SEQUENCERS

If the state or operation in progress is to be determined in many cases by a combination of external factors, instead of primarily by the sequencer itself, a polyflop may be the best solution. A polyflop is simply a multi-state circuit which will remember the last state into which it was forced until the next input comes along. Polyflops can have any number of states, though the practical limit is probably 8 or fewer. Set-reset flip-flops are a very common special case of the polyflop, having 2 states. If you want a name for the next six types you could call them tripflop, quadraflop, pentaflp, hexaflop, septaflop, and octaflop.

The general polyflop is built from as many K113 inverting gates as there are states required, each with input AND expansion sufficient to gate together all outputs by the one that gate controls. Thus any one low output will force all other outputs high. Polyflops do not establish any fixed order through the possible steps as the other three sequencers do, and so perhaps should be called state memories rather than state sequencers. However, there are some situations in which a polyflop is found to be a superior replacement for one of the ordered sequencers, such as where several different outside signals must be able to force the control into corresponding specific states immediately without passing through the normal sequence.

### SUMMARY

<table>
<thead>
<tr>
<th>Sequencer Type</th>
<th>Relative Cost per State</th>
<th>Modification Flexibility</th>
<th>Other Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timer</td>
<td>highest</td>
<td>easiest</td>
<td>Can be self-stepping</td>
</tr>
<tr>
<td>Counter</td>
<td>low-med</td>
<td>fair</td>
<td>Best for many states, few outputs</td>
</tr>
<tr>
<td>Shifter</td>
<td>medium</td>
<td>good</td>
<td>Suitable for patch panel setup</td>
</tr>
<tr>
<td>Polyflop</td>
<td>medium</td>
<td>fair</td>
<td>States may be forced in any order</td>
</tr>
</tbody>
</table>
The simplest and most obvious way to sequence operations or states on a machine or in a control system is to use several timers in cascade. Below is shown a simple three-state timers sequencer.

A pushbutton, clock, or another sequencer can provide signal A that resets all timers and begins the sequence. Any number of timers may be cascaded, but if many steps are needed one of the less flexible sequencers should be considered as a means of reducing the number of adjustments and the cost.

Outputs other than those available directly from the timers can be obtained by a two-input gate connected to appropriate direct or inverter timer outputs. For example, a signal true during both T₂ and T₃ can be obtained by ANDing output D with the inversion of output B. The possibility of deriving any once-per-cycle output from this type of sequencer with two-input gates only is a virtue shared with switch-tail shifting sequencers.
The inverted output from the last timer in the chain may be used to provide the initiate signal resulting in self-recycling. However, sufficiently large timing capacitors must be in use to allow the initiate signal to rise all the way to $+5\,\text{V}$ if normal relations between timing RC and time delays are to be maintained. Pages 51 and 52 of this Handbook show short self-recycling timer chains usable at high recycle rates. Three inversions, or any odd number of inversions must be contained within a self-recycling loop.

Many variations are possible by combining timer sequencers with other types of sequencers, branching to auxiliary sequencer chains, gating timer inputs from external devices, etc.

Finished wiring has a neat appearance and is easy to trouble shoot if wired point-to-point as recommended.
APPLICATION

COUNTER SEQUENCERS

Counter sequencers offer the largest number of discrete steps for the money, since for \( N \) flip-flops up to \( 2^N \) states are obtainable. A single K210 counter, for example, offers up to 16 states for $27.

A source of timing signals, such as the “line sync” output from the K731 or a K303 clock may be used to advance a counter sequencer at uniform increments of time. In addition, event completion signals may be used to gate, augment, or substitute for the uniform time signal. One way to sub-

Event completion signal gates the time signal if the latter is a normally low, relatively higher frequency signal. Event completion signal augments the time signal if the latter is a normally high, relatively lower frequency signal.

A substitute for time signals is to use a K184 Rate Multiplier as if it were four separate differentiating pulse generators with ORed outputs.

USING K184 TO GENERATE EVENT COMPLETION PULSES

The principal disadvantage of counter sequencers is gating complexity, if many outputs must be derived which are not simply the flip-flop outputs themselves. Counter sequencers are most suitable for high-resolution sequencing of relatively few outputs whose relationship to sequencer states is unlikely to be modified after construction.

A crosspoint matrix offers reasonably low cost and good flexibility for developing counter sequencers with large numbers of states. For example, the 64 state sequencer shown here costs about $100 before any 2-input state detectors are added.
The desired states may be detected one-by-one using any two-input AND gate such as those of gates K113, K123, or K134, or two-input gates on other modules like K210 counters, K230 shift registers, K303 timers, K604 or K614 AC switches, K644 or K656 DC drivers, etc. Or several states may be combined by ORing the outputs of several two-input AND gates as shown below.
APPLICATION

SHIFTER SEQUENCERS

An alternate to the Counter Sequencer for generating many outputs, especially where some of the output sequences may be revised after construction, is the switch-tail shift ring.

Any one state can be detected by a single 2 input gate. For example, state 2 is true if B is high and C is low; state 4 is true if A and D are both high, etc. Moreover, any contiguous array of states may be detected by a gate of only two inputs. For example, state 2, 3, and 4 can be combined by a two-input gate that looks for A and B both high. This convenient characteristic not only reduces the cost and complexity of output gating, but also makes last minute changes easy since no new gates have to be added to modify the steps to which a given output gate responds, so long as they are contiguous. Also, notice that state 0 is on an equal footing with the others so that "contiguous" states may include or span the zero or home state.

The two input gating rule could be exploited to permit patch-panel coding of a general-purpose sequencer. One possible arrangement for such a panel is shown here, for a four flip-flop sequencer. In use, one would simply AND start and finish signals that span the desired state or states.

<table>
<thead>
<tr>
<th>START</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Ā</th>
<th>Ā</th>
<th>Ā</th>
<th>Ā</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINISH</td>
<td>Ā</td>
<td>Ā</td>
<td>Ā</td>
<td>Ā</td>
<td>Ā</td>
<td>Ā</td>
<td>Ā</td>
<td>Ā</td>
</tr>
<tr>
<td>STATE</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>0</td>
</tr>
</tbody>
</table>

PATCH PANEL

For the special case of four states to be spanned, only one connection is required. Observe that to span more than half the available states, it is necessary to detect their complement and invert.

Switch-tail shift rings can be driven from all of the same sources as counter sequencers, and may be extended to as many states as desired. If N is the number of shift register flip-flops, 2^N states will be obtained in the sequencer.
POLYFLOP SEQUENCERS

Just as a flip-flop can be set to one of two states and remember it, a logic circuit that has three, four, or more states will remember the last of its several states to which it has been set.

The fundamental principle of the polyflop is that each inverting AND gate must have an input from all other outputs but its own.

<table>
<thead>
<tr>
<th>POLYFLOP</th>
<th>K113</th>
<th>K003</th>
<th>MODULE COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRIFLOP</td>
<td>1</td>
<td>0</td>
<td>$11.00</td>
</tr>
<tr>
<td>QUADRAFLOP</td>
<td>1-1/3</td>
<td>1-1/3</td>
<td>$20.00</td>
</tr>
<tr>
<td>PENTAFLOP</td>
<td>1-2/3</td>
<td>1-2/3</td>
<td>$25.00</td>
</tr>
<tr>
<td>HEXAFLOP</td>
<td>2</td>
<td>2</td>
<td>$30.00</td>
</tr>
<tr>
<td>SEPTAFLOP</td>
<td>2-1/3</td>
<td>4-2/3</td>
<td>$44.33</td>
</tr>
<tr>
<td>OCTAFLOP</td>
<td>2-2/3</td>
<td>5-1/3</td>
<td>$51.00</td>
</tr>
<tr>
<td>NONAFLOP</td>
<td>3</td>
<td>6</td>
<td>$57.00</td>
</tr>
</tbody>
</table>

The table above shows the components needed to build polyflops in the practical range of sizes. Module cost figures refer only to module sections actually used, and there is a significant amount of wiring required for the larger polyflops. Nevertheless, there will be circumstances in which a polyflop is more efficient than either a more conventional sequencer or a collection of ordinary set-reset flip-flops. Through the OR-expansion capability of K113 gates, external signals can be readily gated into a polyflop using low cost gate expanders. Selected output is low; all others high.
USING K303 TIMERS FOR FREQUENCY SETPOINT

A K303 timer will reset to the start of its timing cycle when its inputs become high regardless of its previous state. This feature can be exploited to distinguish two pulse repetition rates, to detect a missing pulse in an otherwise continuous pulsetrain, or to close a frequency-regulating feedback loop. (Note: Where critical requirements are placed on K303 timing consistency in the millisecond range, consider the use of a low-ripple supply such as H710 to minimize modulation of the timing period at the ripple frequency.

![Diagram of pulse train and K303 timer operation]

Input signal can be a square wave or pulses of any width down to 0.3% of the maximum delay available with the timing capacitor used. (Pulsewidths down to 0.1% or less may be used if timing consistency can be sacrificed). Timer delay would normally be set 30% to 50% longer than the nominal pulse repetition rate to detect missed pulses in a train, or at the geometric mean between two pulse periods which are to be distinguished.

By cascading timers, pulses as short as 300 nanoseconds may be stretched to any length needed. However, pulses less than several microseconds in length do not produce consistent or predictable time delays from the K303, and are only recommended for pulse-stretching (using built-in 0.002 mf timing capacitor).
ESTIMATING K303 TIME JITTER

Repeat accuracy in the K303 can deviate as much as 8% of base time or frequency or even more if sufficient ripple is present on the voltage supply line. Jitter is related to frequency or time setting and may be estimated by the graph showing maximum jitter from a K731 power supply at 75% of its maximum output. (i.e. 1 ms period @ 500 mv. supply ripple yields 8% jitter.) Jitter at a given frequency is also proportional to supply ripple.

Reduction of ripple in applications requiring high accuracy may be accomplished by using a separate, lightly loaded K731 or by using the H716 or H710 Power Supply. Recovery times less than 300C will be additive to supply jitter. When used as a clock the timer controls K371, K373, or K375 will provide the proper recovery times.

If peak-to-peak ripple is held to 100 mv, 95% repeat accuracy may be expected from the K303 at all the settings.
COMBINING K WITH M-SERIES MODULES

There are several types of applications in which a combination of M and K Series modules is better than either one alone, such as interfacing a K Series system to a computer or interfacing an M Series system to electro-mechanical devices. Here are the things to consider and recommended designs for both pulses and levels in each direction.

TIMING

Timing considerations are important, but unfortunately are not reducible to simple rules: as in any other logic design task, interfacing K with M Series modules requires adherence to all timing constraints of the output device, the input device, and the logic loops (if any) as a whole. As a minimum, M Series signal driving K Series circuits must last long enough (at least 4 microseconds even if no propagation within the K Series is required) so that the K Series will not reject it as if it were noise; and as a minimum, K Series signals driving M Series circuits must be received by M Series inputs that will not be confused by ultra-slow risetimes.

K TO M SERIES LEVELS

K TO M-SERIES LEVEL CONVERTER

Note: Total lead length connected to input of first M Series gate should be less than 6 inches, to minimize any tendency toward oscillation while active region is being traversed. Do not use slowed K Series levels. If noise still gets through, a .001 capacitor from M Series input pin to ground can be added.

M TO K SERIES LEVELS

1. Diode gate inputs (K113, K123, etc.) and drivers with flexprint cables (K604, K644, K671) may be paralleled freely with M Series inputs.
2. M Series outputs should not be paralleled (wired AND) with K Series outputs.
3. K303 inputs, K220, K230 readin gate inputs, and K135 and K161 inhibit inputs require the full 5 volt K Series swing, and normally should not be paralleled with M Series inputs. Also in this category are clear inputs to K202, K210, K220, and K230. M Series gate outputs will rise all the way to +5V if no M Series inputs are paralleled with these points, except the K161 inhibit input.
4. Other K Series inputs generally may be driven directly, but in some cases heavy capacitive loading will slow the transitions.
K TO M SERIES PULSES

![Diagram of K to M Series Pulses]

NORMAL
(100 KHz)
K SERIES RISE
(2 ma LOAD)

Note: Same input restrictions as K to M Series level converter. M113 may be replaced by M602 circuit if desired.

M TO K SERIES PULSES

Use a type M302 delay multivibrator set for at least 5 \( \mu \text{sec} \) (capacitor pins H1-L2 or S1-S2). Observe same restrictions on K Series inputs to be driven as listed above under "M to K Series levels."

**Loading**

Driving M from K Series modules, each risetime-insensitive input should be regarded as a 2ma K Series load, and K Series inputs may be freely mixed with M Series inputs up to the total K Series fanout of 15 milliamperes. M Series inputs could be regarded as 1.6ma each if more complicated rules and qualifications concerning use with K303 timers and reduction in low-output noise rejection were established, but the 2 ma equivalence is simpler and safer.

Driving K from M Series, each milliampere of K Series load should be regarded as one M Series unit load.

For computer interfacing and other M-Series applications where K Series is used as a buffer to keep noise in the external environment from reaching high-speed logic, beware of long wires between the M and K Series portions. For full noise protection, all signal leads penetrating the noisy environment normally must have K-series modules at both ends. EIA converters (K596, K696) or lamp drivers may offer a helpful increase in signal amplitude or decrease in allowable line impedance for long data links. In any case, use all the slowdown connections or slant capacitors that the required data rates permit.
COMBINING K WITH A SERIES MODULES

The voltage breakdown ratings of K series gate module inputs (K113, K123, K134) is high enough to withstand the ±10 volt output swing of an amplifier such as A207, with correct gate output levels. This fact allows the A207 to be used not only as operational amplifier, but also as a comparator. A 12 bit slow speed analog-to-digital counter-type converter is made possible by using the A207 output directly as a logic signal.

In operation, the counter starts at zero and counts up until the D to A converter output just exceeds the analog input. As the comparator inputs reverse their polarity relationship, the comparator output switches and inhibits the clock. The counter is left holding a number representing the analog input voltage.

The 20 microsecond recovery time of the A207 used as a comparator restricts operation to below 50 KHz. In the system shown here, the comparator "done" signal forces the clock output to the high state. Operation is re-started by clearing the counter or by an increase in the analog voltage. If a control flip-flop were added between the comparator and the gate, action could be halted regardless of input voltage change until a new "start" signal. Maximum conversion time is 4095 times 30 microseconds, or about 120 milliseconds. (The extra 10 microseconds allows for counter carry propagation time and the time required for the A613 output to change one small step).
A faster converter may also be built using up/down counters or by building a successive-approximation type of converter.

12 BIT ANALOG TO DIGITAL CONVERTER
COMBINING K WITH R SERIES MODULES

For conversion from R series or other zero-and-minus levels to K series levels, the W603 (seven circuits, $23) may be used. When driving gate module or timer inputs, and most other K series inputs as well, pins B and V may be left open if desired (no +10 V supply). For conversion from K series to R series levels, use W512 (seven circuits, $25). For a more complete description of these FLIP CHIP modules, ask for the DIGITAL LOGIC HANDBOOK C-105.

There are two modules in the R series which can be used directly in the K series: The R001 and R002 gate expanders. The R001 is convenient for adding one extra input to a K-Series expandable AND gate, while the R002 can facilitate multiple inputs to several expandable AND gates from the same logic signal.

R001 DIODE NETWORK

- OUTPUT
- D
- E
- F
- G
- J
- L
- N
- O
- P
- R
- T

- INPUT
- O
- E
- H
- K
- M
- N
- O
- S
- U

R002 DIODE NETWORK

- OUTPUT
- D
- E
- H
- J
- L
- M
- P
- R
- T
- U

- INPUT
- F
- O
- K
- O
- N
- S
- V

R001 — $4
R002 — $5
PULSE GENERATOR FROM NAND GATES

An effective pulse generator is formed by adding a capacitor to the OR node of a K113 inverting gate, as shown below. The circuit converts positive level transitions to pulses for clearing flip-flops, etc. Pulse width is slightly greater than 1000 C: 1.0 microfarad produces 1.0 to 1.5 millisecond pulses, 0.01 microfarad produces 10 to 15 microsecond pulses. The input must remain low for several times the pulse width for reasonable pulse width consistency.

![Diagram of pulse generator]

PULSE GENERATOR

Each K003 gate expander module includes a 0.01 mf capacitor from pin B to ground, suitable for use in this circuit to obtain pulses approximately ten microseconds wide. This is essentially the same scheme used to obtain one-shot behavior with K303 timers.

Inverted output pulses for clearing flip-flop registers, etc. may be obtained by substituting a K113 for the K123 gate shown.

The input low to high transition must be from an unsloped K Series output. If a slowed risetime is used, such as from a K580, K581, or K578, the output will remain low. Use a K501 Schmitt Trigger if the risetime needs to be speeded up.
K531 QUADRATURE DECODER APPLICATIONS

The K531 can be used to provide all the necessary control signals to operate a K220 BCD up/down register for Nixie Displays or a K220 Binary up/down register for computer interfacing.

The same encoder can be used to operate two K531 modules so that a NIXIE display can be provided with the binary interface.

Total System Consists Of:

5  K220  $52.00  $260.00
1  K531  $54.00  $ 54.00
2  K012  $ 7.00  $ 14.00
6  K671  $43.00  $258.00
1  K741  $22.00  $ 22.00
1  K731  $24.00  $ 24.00

$632.00
Total System Consists Of:

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Component</th>
<th>Price</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>K220</td>
<td>$52.00</td>
<td>$260.00</td>
</tr>
<tr>
<td>1</td>
<td>K531</td>
<td>$54.00</td>
<td>$ 54.00</td>
</tr>
<tr>
<td>1</td>
<td>K741</td>
<td>$22.00</td>
<td>$ 22.00</td>
</tr>
<tr>
<td>1</td>
<td>K731</td>
<td>$24.00</td>
<td>$ 24.00</td>
</tr>
</tbody>
</table>

$360.00
SENSOR CONVERTERS — OPERATION AND APPLICATIONS

Sensor Converters are basically voltage comparators that compare an unknown variable input voltage against a fixed known internal or external reference voltage called the threshold voltage. If the unknown voltage is higher than the reference voltage, the comparator output will be a logic 1, and if it is less, it will be a logic 0. K-Series has two different converter modules, the K522 with a built in +1.8 Volt reference and the K524 with a +2.5 V reference. In most applications the inexpensive K522 module can be used, except where high common mode noise rejection, sensitivity, or 120 VAC input protection are required or where DC levels or signals are to be compared. The following application examples cover the major uses of sensor converters.

I. Signal comparison against the internal voltage reference

Use either the K522 or K524. Twisted pair wiring should always be used between the transducer and sensor converter.

A. Variable Resistance Devices. (Add trimpots to K522 and K524 module in predrilled mounting holes.)

1. CdS photoconductive cell
2. Thermistor
3. Rheostat (Pressure Transmitter)
4. CdSe, Si, or Se photo cells

All variable resistance devices require the use of a bias supply and trimpot in order to generate a voltage that will vary each side of the fixed internal reference supply. Predrilled trimpot mounting holes are provided on each circuit on both the K522 and K524 for this purpose. The K522 +3.6V bias supply is automatically connected when the trimpot is mounted on the board. On the K524 an external +5V bias supply must be connected to pin B on the B connector. This +5 supply can be the logic supply, but it is recommended that a separate K731 supply be used to protect the logic system from accidental contact with 120 VAC. If the logic supply were used for bias, all modules in the system would be destroyed if an accidental short to 120 VAC did occur. Only when the resistance of the transducer is greater than the resistance of the trimpot will the sensor converter output be high. The transducer and trimpot should be picked in the following manner.

Transducer
The resistance of the transducer at the desired sensing point must be greater than 400 ohms and less than 20K for the K522 and less than 100K for the K524.

Trimpot
The resistance of the trimpot must be adjustable to equal the transducer resistance at the desired sensing point.
B. Voltage generating devices (Trimpots or bias are not required)

1. Pulse tachometer
2. Potentiometer

Some types of voltage generating devices can be sensed directly by a K522 or K524 provided that the voltage will vary each side of the fixed internal reference voltage. If the voltage swing does not go above the internal reference supply voltage of either sensor module, the K524 will have to be used with an external reference supply. If it does not go below the internal reference supply voltage, voltage or current level sensing will have to be used.
C. Voltage or current level sensing.

(If the voltage swing at the sensor convertor + input will ever go negative, use the K524.)

1. Voltage level sensing

To sense a voltage level greater than the internal reference supply voltage, a resistor divider should be used to attenuate the signal as follows:

\[ V_{\text{in}} \rightarrow \frac{R_1}{R_1 + R_2} \]

\[ R_2 \text{ must be between 0 ohms and 20K for the K522, 0 and 100K for K524.} \]
\[ R_1 \text{ and } R_2 \text{ should be chosen so that } V_{\text{in}} \text{(max)} \text{ equal the maximum output} \]
\[ \frac{V_{\text{out}}} {R_1 + R_2} \]

current available or \( R_1 + R_2 \) equal the minimum allowed load resistance

and \( VR_2 \) equals the internal threshold voltage of the sensor converter. \( V \) is

the voltage level to be sensed.)

voltage level to be sensed.)

2. Current level sensing \( R_1 \) and \( R_2 \) should be chosen so that \( R_1 \) equals zero ohms, and \( IR_2 \) equals the internal threshold voltage of the sensor converter. \( I \) is the current level to be sensed.)

II. Signal comparison against an external voltage reference. Use the K524 only.

A. DC threshold comparison

When the K524 control pins are connected for DC coupling the output will switch when the + input is within .3V of the voltage level of the minus input. Zero crossings at the + input signal can easily be detected by grounding the minus input. DC levels between ±7.5V can be sensed by connecting an external supply of the desired voltage level to the minus input. Since the minus input can only accept voltage level between ±7.5V while the plus input is good for ±30 volts, CMR to noise spikes will be lost as the minus input voltage approaches + or −7.5 volts. A better method to use in sampling large voltages is with a voltage divider. To sense a positive voltage, use the method described under voltage level sensing. To sample a negative voltage level, use the same technique, but connect the minus input to a negative voltage reference. The resistor divider calculations are the same as described for positive voltage levels, except the module threshold voltage will now be equal to the negative voltage reference on the minus input.
B. DC signal comparison

If the signals to be compared are between $\pm 7.5$ volts the comparison can be made directly by connecting one signal to the $+$ input and the other one to the $-$ input.

If the signals are greater than $\pm 7.5$ volts or maximum common mode noise rejection is desired, a resistor divider should be used across each signal output to reduce the voltage swing. The same resistor values should be used for both dividers.
APPLICATION

DC DRIVERS
CURRENT PATH CONTROL

All K-Series DC drivers sink current to ground and they all have a terminal, connector pin, or split lug that is specified as the load supply ground. To help segregate high D.C. currents from the logic system ground, these special ground connections must be wired directly to the minus side of the load supply. Where more than one load supply is being used, the minus sides should be bussed together. Ground the minus side of the supply to the chassis ground where they are mounted.

By providing this direct connection from the module to the load power supply, heavy currents are forced to flow through the ground return wire and not through the chassis ground.

NOTE: If the ground return wire is not provided, current will have to flow through the chassis ground.

CLAMP DIODES

All K-Series DC driver except the K681 and K683 have clamp diode protection available if the module is being used to control inductive loads. Protection can be obtained for the K681 and K683 if they are used with the K784 module. These clamp diodes provide protection for the output transistors from high voltages during turn off and must be connected to the positive side of the load power supply. If different load supply voltages are being used on a given module, connect the diodes to the positive side of the highest voltage supply. For resistive loads or lamps, the diodes are not required, but as a standard practice they should be connected as a safety precaution.

DRIVER SELECTION

The individual data sheets state the maximum voltage or current capability of the modules. If, for example, the specification states a voltage of 125 volts at up to 4 amps, this means that any load supply voltage between 1 volt and 125 volts may be used and that the module will conduct current when it is turned on up to 4 amps maximum. If the load has a surge current rating of 3 amps and a holding current of 1 amp, the driver must have at least a 3 amp rating. For this application the K658 should be used.
In some applications it is desired to let the current fall rapidly in an inductive load. If the clamp diode is returned directly to the load supply, the current will fall slowly because it will circulate through the load until it is dissipated due to the resistance of the inductive load in the form of heat. The current decay rate can be increased by putting a resistor in series with the clamp diode return. The maximum resistor value allowed is given by the formula.

\[ R = \frac{V_{\text{max}} - V_p}{I_L} \]

- \( V_{\text{max}} \) = maximum voltage rating for module
- \( V_p \) = load supply voltage
- \( I_L \) = maximum load current

The peak power dissipated in the resistor will be \( I_L^2 R \). The actual watt rating of the resistor may be smaller than this if the inductance is small or the repetition rate is slow, but you will be safer if you use the maximum watt rating. As can be seen from the formula, the higher the voltage rating is for the module, the larger \( R \) can be, and the faster the current will decay. The K656 is useful for this application because of its 250 volt rating.

**DRIVERS IN PARALLEL**

The DC drivers may be connected in parallel to obtain greater current driving ability, however, there are two important considerations.

1. Paralleled drivers must all be on the same module.

2. The current handling capability increases as the square root of the number of drivers that are connected.

Example:

- 1 driver = 1 amp
- 2 drivers = 1.4 amps
- 3 drivers = 1.7 amps
- 4 drivers = 2 amps
USING K210s FOR LONG ODD-MODULUS COUNTERS

The pulse generator shown on the previous page can be incorporated with K210 counters to obtain counts at non-binary moduli above 16, the limit for a single K210. Below is shown a modulus 24 counter, as would be required for a digital clock.

The basic principle involved is to detect the largest number to be permitted, and to generate a clear pulse when it disappears due to the reception of one more count. The same method may be extended to counters of any length, provided the clear pulsewidth is wide enough to override any possible carry propagation.
PARALLEL COUNTERS

The counters shown elsewhere in this handbook are "serial" counters: that is, the input to a counter module of high significance is the simple output of the next less significant flip-flop, resulting in a time difference between groups of outputs (within any K210, K220, or K230 module all outputs switch essentially simultaneously).

If a long counter is driving a large decoder, or if flip-flop outputs from different parts of the counter are being gated together for any purpose, carry propagation time down a serial counter can give rise to false transients lasting several microseconds from the decoder or gating. In effect, the carry propagation time causes the counter to pass through one or more wrong counts on the way to the correct state.

The solution is to feed count pulses in parallel to all modules simultaneously, but gating the pulses to modules of high significance with the "1" outputs from all bits of lesser significance. The diagram below shows how this is done for an 8 bit (or two decade) K210 counter. Observe that modules of higher significance would need input gates expanded to 9, 13, or 17 inputs for 12, 16, and 20 flip-flop counters respectively.

Photoelectric shaft-angle transducers generate signals A and B in quadrature. Where maximum resolution and/or two-way counting is desired, the scheme below can be used to interface the amplified transducer outputs to the counter control shown on K220 data pages.

12 BIT PARALLEL BINARY COUNTER
ANNUNCIATORS

In the simplest type of annunciator, a single alarm device is triggered by any abnormal occurrence, and a lamp is lighted by the occurrence to identify it. An inexpensive annunciator of this type can be built by taking advantage of the four Schmitt triggers and differentiators in the K184 module as indicated below. If silver contacts are to be sensed, auxiliary load and higher voltage must be used, preferably 120 VAC with K604-K716 or K614. Any number of inputs may be handled by ORing K184 outputs (wired OR if possible for up to 5 K184s). The normal 5 μsec K184 pulsewidth should be stretched to 140 μsec for use with a slowed-down alarm flip-flop by putting a 0.1 mf capacitor from each K184 pin J to ground.

![Diagram of annunciator circuit]

SIMPLE ANNUNCIATOR FOR FOUR DRY CONTACTS

In larger systems or where an abnormal occurrence may be too brief to be identified from a simple direct driven indicator, flip-flop memory must be added to each line to set up this sequence of operations:

<table>
<thead>
<tr>
<th>ALARM STATUS</th>
<th>ANNUNCIATOR LAMP STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No Alarm</td>
<td>Off</td>
</tr>
<tr>
<td>2. Alarm — Unacknowledged</td>
<td>Flashing (2Hz)</td>
</tr>
<tr>
<td>3. Alarm — Acknowledged</td>
<td>Steady</td>
</tr>
</tbody>
</table>

1. No Alarm — Memory Cancelled Off

The Flash Supply is generated at a suitably low frequency by a K303 Clock with K375 Timer Control. This supply is available for distribution to other similar stages in a system.

The Alarm F.F. is set with an Alarm Input at Logic 1, the K580 controls the Alarm 0 to 1 response time. (See K580 data sheet) This allows the Lamp to flash. The Alarm F.F. is not cancelled, should the Alarm Input return to Logic 0. The initial Alarm must first be acknowledged manually before the Alarm F.F. is reset. Acknowledging the Alarm changes the Lamp from Flashing to Steady, and prepares the Alarm F.F. for Reset by the Alarm Input returning to Logic 0.
K Series Modules per Annunciator

<table>
<thead>
<tr>
<th>MODULE TYPE</th>
<th>NUMBER REQUIRED</th>
<th>NUMBERS OF CIRCUITS USED</th>
<th>COST PER LINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>K003</td>
<td>1 @ $4.00</td>
<td>3 of 3</td>
<td>$4.00</td>
</tr>
<tr>
<td>K113</td>
<td>1 @ $11.00</td>
<td>1 of 3</td>
<td>$3.60</td>
</tr>
<tr>
<td>K123</td>
<td>1 @ $12.00</td>
<td>3 of 3</td>
<td>$12.00</td>
</tr>
<tr>
<td>K134</td>
<td>1 @ $13.00</td>
<td>1 of 4</td>
<td>$4.33</td>
</tr>
<tr>
<td>K580</td>
<td>1 @ $20.00</td>
<td>1 of 8</td>
<td>$2.50</td>
</tr>
<tr>
<td>K681</td>
<td>1 @ $15.00</td>
<td>1 of 8</td>
<td>$1.80</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>$28.23</strong></td>
</tr>
</tbody>
</table>

The cost of common items, K303, K375, Power supplies etc., must be spread equally over the number of Annunciators in a system to get the true cost per stage.
THUMBWHEELS AND MULTIPLEXING THEM WITH K581

Binary-coded decimal thumbwheel switches of many sizes and types are available to provide convenient manual data entry into K220 and K230 reading gates via K580 switch filters. Below are listed some of the many types that can be used this way:

<table>
<thead>
<tr>
<th>MANUFACTURER'S TYPE</th>
<th>PANEL CUTOUT HEIGHT</th>
<th>WIDTH PER DIGIT*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digitran 315</td>
<td>1.380”</td>
<td>0.500”</td>
</tr>
<tr>
<td>Digitran 13015</td>
<td>2.000”</td>
<td>0.500”</td>
</tr>
<tr>
<td>Digitran 715</td>
<td>0.980”</td>
<td>0.500”</td>
</tr>
<tr>
<td>Digitran 8015</td>
<td>0.980”</td>
<td>0.500”</td>
</tr>
<tr>
<td>Digitran 9015</td>
<td>1.375”</td>
<td>0.600”</td>
</tr>
<tr>
<td>EECo 5305</td>
<td>0.960”</td>
<td>0.500”</td>
</tr>
</tbody>
</table>

*Note: Additional “zero digits” width generally required in panel cutout.

The simplest hookup uses one K580 for every two decimal digits as shown here.

Power for the unmultiplexed system can be obtained from a 10 volt DC power supply or by using the circuit shown here with the auxiliary 12.6v winding on the K743 transformer.

GETTING +10V FROM K743
Where more than one or two thumbwheel registers are needed it may be economic to multiplex several digits through the same K581 circuits as shown below. This scheme requires diodes to be mounted on the switches, as provided for by all of the types listed above. IN4001 diodes may be used.

To sequence through the registers, it is necessary to turn on one K683 circuit at a time; this can be done by a K161 binary to octal decoder. Since no BCD decade can draw more than 60 milliamperes, as many as four decades can be handled on any one K683 switch. Circuits may be paralleled for larger registers.

Notice that K581 outputs will be one diode drop above ground in the “low” state. This restricts multiplexing to use with K220 or K230 readin gates, or to K113, K123, or K134 inputs at 1 milliampere only. If the diode outputs (connector) on K683 are used, noise rejection will be reduced to levels that would normally be unacceptable. Direct (solder lug) connections are definitely recommended.
FIXED MEMORY USING K281

Switch registers such as those shown on the preceding page may be considered as memory devices. Very often a system that needs thumbwheel memory (or flip-flop memory) can also benefit from memory that is not readily changed. By using a K281 board with diodes cut out where “zero” is to be recorded, many types of sequence or character (symbol) codes may be permanently stored in a digital system.

Variations

More 4-bit words:
   a) Use same K161 and K681
   b) Duplicate K281 and K134, tying K134 outputs together
   c) Use pin K inhibit on K134s to select 8 words
   d) Up to 40 4-bit words may be obtained (fanout down to 3)
   e) For more 4-bit words use longer words and gate outputs

Longer Words:
   a) Use same K161 and K681
   b) Duplicate K281 and K134; two for 8 bits, three for 12 bits, etc
   c) Single K681 capable of word lengths to 28 bits
   d) Get more than 8 words as in getting more 4-bit words

Serial Scanout:
   a) Connect word address lines to scanning counter
   b) Tie together K134 outputs
   c) Select word at K134 pins N, R, T, V.
   d) Second K161 can select word at K134 inputs
   e) Scanning and word-address K161s may be swapped
   f) This system is expandable in two dimensions also

Note: The K681 Lamp Driver lacks the noise immunity and output slowdown designed into all of the general-purpose K-Series logic modules. For this reason it is important to take advantage of congruent pin assignments by assigning adjacent module slots to K161, K681, K281, and K134 modules used in memory applications.
JAMMING DATA INTO K220, K230

The "clear" and "read ones" inputs on these modules may be combined to obtain the effect of a "jam." That is, completely new data may be stored in a single operation regardless of previous flip-flop states. However, the "read ones" (pin D) input must wait to rise at least 4 microseconds after the clear input rises, to give the clearing action time to die away. A simple way to accomplish this delay is shown below.

DIODE AND CAPACITOR IN K003 AS RISE DELAY

This circuit gives about 10 microseconds of rise delay. The K003 capacitor discharges on jam input fall through the K003 diode, but the diode opens to force the pin D load current alone to recharge the capacitor, which takes time. The delay may be reduced if desired to about 5 microseconds by connecting another one milliampere pull-up (pin D to pin E on the K003 shown above).

Several "read ones" inputs may be driven from a single K003 section, provided the capacitance is multiplied by the same number. However, the heavy capacitive loading may cause slow falltimes on the jam input line. Pin D inputs on K220 and K230 may be regarded as 1 milliampere loads in this application.

The jam input rise time must be from an unslowed K Series output. Slow signals from the K580, K581, or K578 modules must be speeded up by a K501 Schmitt Trigger.
K184 RATE MULTIPLIER

The K184 Rate Multiplier accepts an input pulse frequency $f_i$, via a Binary Counter, multiplies this by a Binary Fraction $F$, and emits a pulse train, with average frequency $f_o = f_i \times F$. Note that $f_o$ is always less than $f_i$, also that the Counter and Fraction are Binary; the Fraction being presented in reverse order to the K184. FIG 1a shows how a K184 with the Binary Fraction preset on switches, generates the product frequency $f_o$.

Since this frequency is average, and not periodic, some digital smoothing may be added; $f_i$ can then be preselected, to control Hydraulic or Pneumatic Valve opening and closing rates, Stepping Motor velocities etc.

The resolution of the system is increased by cascading K184 modules and Counters. The K184 outputs, $f_o$, are simply commoned in this case.
PRINCIPLE OF K184 OPERATION

As shown above, the input clock frequency \( f_1 \) generates a binary sequence in the Clock Counter. The 1, 2, 4, and 8 Counter outputs, when connected to the K184 Clock inputs, generate pulses in the K184 on 0 \( \rightarrow \) 1 transitions. Note that no two 0 \( \rightarrow \) 1 transitions are ever in coincidence. Also notice that of all possible pulses, all but one are obtainable if each 0 \( \rightarrow \) 1 transition is allowed through; but when all bits simultaneously return to the zero state, no pulse is available. Thus the maximum output rates for 4, 8, and 12 bit rate multipliers are 15/16, 255/256, and 4095/4096 of the input rates.
RATE SQUARER

This circuit shows one of the many fascinating and useful tricks possible with rate multipliers. Here the output rate varies as the square of the input rate, so that, for example, a flywheel rotation rate could be read out in units of stored energy, etc.

SEQUENCE OF OPERATION

0. K230 holds previous rate number; K210s cleared
1. Gate $f_0$ to K210 counter for fixed period
2. Stop counter at end of internal; clear K206s and read in
3. Clear K210 and return to step 1.

<table>
<thead>
<tr>
<th>MODULE</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 K210</td>
<td>$27.00</td>
</tr>
<tr>
<td>2 K206</td>
<td>$20.00</td>
</tr>
<tr>
<td>2 K184</td>
<td>$18.00</td>
</tr>
<tr>
<td>TOTAL excluding control</td>
<td>$130.00</td>
</tr>
</tbody>
</table>

NOTE: $f_0$ is regarded as a fraction, where 1.0 is that frequency which just fills the counter during the count interval. Average output rate is the product of current count rate times the average rate in the previous interval. The sampling period must be short relative to the variations in input counting rate.
K184 AS A DIGITAL INTEGRATOR

If the fraction $F$, to a K184 is derived from a Counter also incremented by the input frequency $f_1$, $f_0$ increases, on average, in a linear fashion.

As shown below, if the FRACTION K210 overflows from 1111 to 0000, $f_0$ will fall to zero and begin again to increment as before. The result is a Digital Sawtooth generator. $f_0$ against time $t$ is shown here.

Resolution can be increased by module cascading. If the Fraction Counter is a K220 UP/DOWN Counter connected for Binary operation,* then the slope of $f_0$ can be reversed and controlled symmetrically.

*(Pins BD, BE grounded)
The output of the K184 shown above is, on the average, a linearly increasing frequency when the K220 counts UP, and a linearly decreasing frequency on K220 count DOWN. This facility is of use in controlling Stepping Motor Acceleration on K220 UP counts, and Deceleration on DOWN counts. The Fraction Counter must not be allowed to overflow.

The response of $f_0$ shown above is average and must be smoothed digitally to remove unacceptably large variations in pulse spacing; which would cause for example a Stepping Motor to change velocity instantaneously during the Acceleration period.

For more on rate multipliers, see references on K184 data page.
SERIAL ADDER

When speed is not paramount, one can sum the contents of two K230 shift registers bit-by-bit at low cost. The result can go back into one of the source registers.

Clock output CLK, 1 to 0 transitions, shift serially the addend and augend contained in K230 Shift Registers, A and B. The contents of the Registers are serially summed with the Carry In bits from the Carry flip-flop.

Carry Out signals, and CLK signal 1 to 0 transitions, cause the Carry Out flip-flop to be Set or Reset, i.e., Carry or No-Carry.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>carry in</th>
<th>sum</th>
<th>carry out</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<td>1</td>
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<td>1</td>
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<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
Checking the appearance of board contacts being gold-plated. Our 100 micro-inch plating is verified by periodic checking on a radiation gauge.
APPLICATION

STEPPING MOTORS

INTRODUCTION

There are two fundamental parts to the design of any stepping motor drive system: Designing the logic for correct sequencing, and electromechanical design. Several logic designs are shown on the next few pages; here first is a brief discussion of electromechanical aspects.

Much of the emphasis in stepping motor system design is on maximizing stepping rates. There are two components in maximizing stepper speed: Maximizing the rate of motor current rise and delay, and operating within the motor's limitations of torque, friction and stiffness during the critical acceleration — deceleration phase. Successful design results in accurate stepping with no missed or gratuitous steps.

To optimize the response speed of any magnetically operated device, a minimum requirement is that the ratio of circuit inductance to circuit resistance be less than the desired response time. Thus if response of 1 millisecond is required in a one henry winding, the total of winding, the total of winding resistance and series padding resistance should be greater than 1000 ohms. If this ratio (L/R or henries-divided-by-ohms) equals or exceeds the desired response time in seconds, electrical effects tend to be the dominant limitation on speed and override mechanical factors.

The design problem is complicated by the increase in winding inductance as motion is accomplished. The inductance at turnoff may be many times the inductance at turnon in efficient devices such as solenoids. However, many types of stepping motors are designed to achieve maximum performance at the expense of efficiency, and the inductance of these motors may vary only a negligible amount (less than 10%) as rotor position changes. Since inductance ratios are generally unpublished, the best approach may be to start with equal resistance and then measure the actual current rise and fall times, increasing the turnoff resistance if necessary later. (In all of this, the driving transistors are assumed to switch in zero time, as they respond in microseconds whereas L/R ratios are generally in the millisecond range.) The equivalent circuits below show both equal and unequal cases.
Notice that during turnoff the switching transistor experiences a voltage equal to the supply voltage for the equal case, but larger than the supply voltage if additional turnoff resistance $R_{pp}$ is added. Since the voltage rating of the driver is the limiting factor on the minimum $L/R$ that can be achieved with a given inductance, the ratio of drive transistor voltage rating to supply voltage should be adjusted as indicated below for optimum electrical response:

\[
V_T = L_{off} = R_L + R_p + R_{pp}
\]

\[
V_S = L_{on} = R_L + R_p
\]

Operating within the stepper's limitations of torque, friction, and stiffness during acceleration and deceleration is trickier than it looks, especially since some crucial constant may be omitted from published specifications for the device. There is often the wish to avoid abrupt (full frequency) starts and stops to achieve maximum stepping rates. Often only one or two steps need to be slowed to achieve maximum acceleration error-free. Too gradual change in stepping rate can actually encourage errors if inertia is moderate and friction low, caused by an actual resonant reversal of rotation at some particular step.

All of the logic circuits shown on the next pages can be used with any clock rate profile. It is best, however, to use an abrupt start-stop system unless the need for ultimate performance warrants a full study of system dynamics, including the use of a tachometer on the stepper shaft to observe the effect of proposed frequency profiling.
SLO-SYN® STEPPER SEQUENCER

A K202 flip-flop module, connected as shown, forms a reversible switch-tail ring counter. With the “direction” input logic 1, 1 to 0 transitions on the “step input” index a bifilar stepping motor forward. With logic 0 on the direction input, the direction is reversed.

A d.c. driver controlled by the switch-tail counter provides power for the stepping motor.

*SLO-SYN is a trademark of Superior Electric Co.
RESPONSYN® STEPPER SEQUENCER

This sequencer uses the same two bit shift register with inverted feedback as the SLO-SYN sequencer, but the outputs are gated to obtain the different drive pattern required by these motors.

*RESPONSYN is a trademark of United Shoe Machinery Corp.
FUJITSU STEPPER SEQUENCER

FUJITSU Stepper motors can be driven forward and reverse, with the module arrangement shown. The table describes the stepping sequence required by a FUJITSU 5 torquer motor (with or without hydraulic servo amplifier).

<table>
<thead>
<tr>
<th>STEP</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
ANALOG-TO-FREQUENCY CONVERTERS

When a relatively slow-varying or constant analog signal must be transmitted some distance through noise, some form of current-to-frequency or voltage-to-frequency conversion is appropriate. There are really two distinct sets of benefits to be gained:

1. Analog noise will be averaged, and may be almost entirely nullified even if it is comparable to the signal in amplitude. Normally the frequency is sampled for an exact internal number of line-frequency cycles to average power frequency coupling to zero. High noise frequencies are mostly averaged out by the conversion device itself.

2. Digital noise will be averaged also, since one or two extra pulses or missed pulses represent a small fraction of the total number. In addition, the digital form of the measured quantity is inherently noise resistant since noise less than the switching threshold at the receiver has truly no influence whatever.

The improved transmissibility of analog data both before and after the conversion to an equivalent frequency has to be paid for in reduced speed of response to changes. (From the viewpoint of an information theorist, such a transmission mode would be said to deliver high redundancy and low information rate.) But many sensors on slowly varying processes which are distant from an associated digital system are ideally suited for this treatment.

The diagram below shows how an operational amplifier may be utilized to provide direct conversion from an analog voltage to an equivalent frequency with errors in the tens of millivolts. This scheme measures how long current in the input resistor $R$ takes to charge the capacitor $C$ ten millivolts. Each time this occurs, the output switches to the other state and discharges the capacitor rapidly.

VOLTAGE-TO-FREQUENCY CONVERTER

Resistance $R$ should be about 1000 to 10,000 ohms to achieve a balance between error due to wide pulsewidth at high frequency and error due to the biasing effect of amplifier input current. To minimize the effect of amplifier switching time, capacitor $C$ should be large enough (100 mfd with $R=1000\Omega$, for example) to limit maximum full-scale frequency to around one kiloHertz. Nearly any quality silicon diode and PNP transistor with at least 30 volt ratings could be used, and the small capacitor with its associated current limiting resistor is not critical either. Other components should be selected carefully to minimize drift and temperature coefficient.

K303 clock circuits can be modified by the additional parts shown below to achieve lower performance conversion at a saving. Basically, a current source controlled by the input signal being converted replaces the action of the timing resistor $R$ shown in the Handbook diagrams. Transistors can be any high gain Silicon NPN type such as 2N2219.
FOR POSITIVE INPUTS

If output frequencies are counted for an integral number of power-frequency cycles, clock filler will be compensated along with line frequency pickup on the analog leads.

FOR NEGATIVE INPUTS

NOTE:
THE SMALL VOLTAGE DROP (1.5V MAX)
AVAILABLE LIMITS LINEARITY TO ±5%
OR SO FOR THIS CIRCUIT.
USING K604, K614 WITH 240 VOLTS

These isolated AC switches have semiconductors and other components rated for 240 volt service. However, the Triac switches used were rated primarily for phase control applications. The difference is that some switching applications require an "off" switch to remain substantially off in the presence of transients and noise, without conducting for even one half of one cycle. Since a transient voltage, larger than the breakdown voltage of these devices (400 volts) can cause them to start and remain conducting until several milliseconds later when the load current returns to zero, the K604 and K614 contain transient-clipping devices across each circuit which go into conduction between the peak voltage of a 120 volt line (200 volts) and the Triac break-over voltage (400 volts).

Triac switches are not readily available at present with breakdown ratings above 400 volts. However, K604 and K614 switches can successfully be used in 240 volt service if two types of application are distinguished:

1. Critical loads: For example, a hydraulic solenoid valve controlling the liquid metal on a die-casting machine, an ignition transformer on a process boiler, a trip solenoid on a punch press; any use involving both fast response and a potential safety hazard. For such applications, two circuits should be connected in series, so that any undesired conduction will be limited to the actual duration (usually microseconds) of a transient or noise spike. Wiring K614 outputs in series is simple because two terminals are provided on each circuit. To put K604 outputs in series, use K782 terminals or see K716 data page for connector cable information. Note indicator lamp connections in diagram below.

![Diagram of SERIES CONNECTED AC SWITCHES](image-url)
2. Uncritical loads, where spurious conduction for several milliseconds could not be damaging or hazardous. Since the other components are rated for 240 volt service already, simply remove the transient-clipping varistors. These are axial-lead-devices with a black body and metal end-caps, about 2 cm long and 8 mm diameter. Lamp return voltage may be supplied from the load common (240 volts) if a rectifier diode is provided to obtain half-wave operation. In a system containing both modified and unmodified circuits segregate and mark them. Use of unmodified units with 240 volts directly will destroy them by grossly overheating the varistors.
K-SERIES LOGIC LAB

INTRODUCTION

The K Series Logic Laboratory is designed for use with K Series Modules. It is a device for building prototype systems for experimentation and proof of logic design as well as an effective tool for learning solid state control logic.

It is excellent for training users in digital logic techniques by enabling an individual to construct logical networks, with a "hands on approach" to learning control systems for Industrial Applications.

The K Series Logic Lab is a completely self contained system consisting of a power supply, photo cell, pulse generator, switch controls, indicators, mounting hardware and a recommended basic complement of logic modules necessary to construct a working system. The system is expandable and can accommodate additional K901 patchboard panels for mounting additional logic modules.

EDUCATION AND TRAINING

As a training device the K Series Logic Lab offers the engineer, technician, and user a step by step approach to building an understanding of various digital logic functions, such as, AND, OR and the operations of NAND and NOR etc. The user has the option of using NEMA or MIL spec symbology when making logic connections. Symbology cards on basic logic modules for use with the K901 patchboard panel are printed with NEMA on one side and MIL SPEC 806 on the reverse side.

BREADBOARDING AND TESTING

The logic laboratory power supply is capable of supplying 5V-DC for about 100 modules. There is no restriction on the size of a system which can be implemented, since additional patchboard panels can be ordered and "K" Logic Laboratories interconnected directly.

There is no substitute for actually building the system and verifying the logic.

Some common uses of the Logic Laboratory are listed below. Many of these are described in detail in this Control Handbook and part III in the 1969 Positive Edition Logic Handbook.

- Timer Sequencers
- Shifter Sequencers
- Parallel Counters
- Pulse Rate Multiplier
- Serial Adder
- Stepping Motors Control
- Pulse Generator
- Annunciator
The K900 is a combination power supply and input control panel. The input devices include a photocell, three push button pulsers and timing components for a K303 clock mounted in a K901 panel. Clock timing components are provided for frequency steps in ranges of 2Hz to 60Hz and 200Hz to 6K Hz. Wiring diagrams for properly connecting the clock are shown in the logic and control handbooks (reference K303). The power supply can drive approximately ten type K901 panels of K series flip chip™ logic. Pulsers consist of a K501 schmitt trigger with a K581 switch filter. Power is supplied by K731, K743 and K732 power supply modules.

**Electrical Characteristics**

- Input voltage: Power supply: 115V 50-60 cps
- Output voltage: +5 VDC ±10%
- Output current: 3 amp

**Mechanical Characteristics**

- Panel width: 19”
- Panel height: 5½”
- Depth: 12”
- Finish: black
- Power Unit connection: 18/3 AC power cord

Power Output connection: Hayman Tab terminals which fit AMP “Faston” receptacle series 250, part 41774 or Type 914 Power Jumpers.

---

K900 — $185
K901 PATCHCORD MOUNTING PANEL

This panel provides up to ten FLIP CHIP modules with power and patch connections. Space between patching sockets allows insertion of logic diagrams. Logic diagrams are printed on all FLIP CHIP module data sheets. More permanent plastic diagrams are available for those modules listed.

PANEL WIDTH: 19 in.
PANEL HEIGHT: 5¾ in.
DEPTH: 6½ in. with FLIP CHIP modules inserted

FINISH: Black
POWER INPUT CONNECTIONS: Tabs which fit AMP “Faston” receptacle series 250, part 41774.

911 PATCHCORDS

DEC Type 911 Banana-Jack Patchcords are supplied in color-coded lengths of 2 in. (brown), 4 in. (red), 8 in. (orange), 16 in. (yellow), 32 in. (green), and 64 in. (blue). Patchcords may be stacked to permit multiple connections at any circuit point on the graphic panels of the DEC K901 Mounting Panel. The cords are supplied in snap-lid plastic boxes of ten for handy storage.

K901 — $125
911 — $9/pkg. of 10
The H902 Panel provides facilities for control and observation of the Logic Laboratory. It contains eight indicator lights and a lamp driver module, eight toggle switches and four potentiometers. Connections to these devices are made with Type 911 Stacking Banana-Jack Patchcords.

INDICATORS: Indicators inputs accepts signals of +5V and ground. An open circuit input will light the indicator. If the input is returned to ground, the indicator will not light. The load is 1 ma.

TOGGLE SWITCHES: The toggle switches are single pole, single throw with a logic diagram to show the open and closed positions.

POTENTIOMETERS: The potentiometers are 250,000 ohms. They may be used to control the frequency of delay one-shots or clock circuits in the K901 Mounting Panel.

MECHANICAL CHARACTERISTICS

| PANEL WIDTH: 19 in. | FINISH: Black |
| PANEL HEIGHT: 5¾ in. | POWER INPUT CONNECTIONS: Tabs which fit |
| DEPTH: 6½ in. | AMP “Faston” receptacle series 250, part 41774. |

K902 — $115
4913 MOUNTING RACK
The 4913 Mounting Rack provides support for a and up to four K901 Patchcord Mounting Panels, for a total of up to 40 FLIP CHIP modules ready to be patched together for experiments. It may also be used to mount general purpose mounting panels such as the K943. The power supply must be mounted at the bottom for stability.

Height: 26⅛ in.

Threads for mounting panels: 10-32

914 POWER JUMPERS
For interconnections between power supplies, mounting panels, and logic lab panels, these jumpers use AMP “Faston” receptacles series 250. Specify 914-7 for interconnecting adjacent mounting panels, or 914-19 for other runs of up to 19 inches. 914-7 contains 10 jumpers; 914-19 contains 5.

<table>
<thead>
<tr>
<th>4913K</th>
<th>$25</th>
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<tbody>
<tr>
<td>914-7</td>
<td>$ 4</td>
</tr>
<tr>
<td>914-19</td>
<td>$ 4</td>
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**BASIC EQUIPMENT LISTS**

**BASIC LOGIC LABORATORY**

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-K901</td>
<td>Patchboard panel</td>
<td>125.00</td>
</tr>
<tr>
<td>1-K902</td>
<td>Indicator Switch Panel (complete with K683 module)</td>
<td>145.00</td>
</tr>
<tr>
<td>1-K900</td>
<td>Power Supply and Control Panel (complete with Power modules)</td>
<td>185.00</td>
</tr>
<tr>
<td></td>
<td>1 pair — 4913 Mounting Rack</td>
<td>25.00</td>
</tr>
</tbody>
</table>

**RECOMMENDED LOGIC MODULES AND PATCHCORDS FOR USE WITH THE LOGIC LABORATORY**

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Unit Price</th>
<th>Total Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-K003</td>
<td>Expander</td>
<td>4.00</td>
<td>12.00</td>
</tr>
<tr>
<td>2-K012</td>
<td>Expander</td>
<td>7.00</td>
<td>14.00</td>
</tr>
<tr>
<td>3-K113</td>
<td>Gate</td>
<td>11.00</td>
<td>33.00</td>
</tr>
<tr>
<td>3-K123</td>
<td>Gate</td>
<td>12.00</td>
<td>36.00</td>
</tr>
<tr>
<td>2-K134</td>
<td>Inverter</td>
<td>13.00</td>
<td>26.00</td>
</tr>
<tr>
<td>1-K161</td>
<td>Decoder</td>
<td>25.00</td>
<td>25.00</td>
</tr>
<tr>
<td>1-K174</td>
<td>Comparator</td>
<td>18.00</td>
<td>18.00</td>
</tr>
<tr>
<td>1-K184</td>
<td>Rate Multiplier</td>
<td>18.00</td>
<td>18.00</td>
</tr>
<tr>
<td>2-K202</td>
<td>Flip flop</td>
<td>27.00</td>
<td>54.00</td>
</tr>
<tr>
<td>1-K206</td>
<td>Flip flop</td>
<td>20.00</td>
<td>20.00</td>
</tr>
<tr>
<td>1-K210</td>
<td>Counter</td>
<td>27.00</td>
<td>27.00</td>
</tr>
<tr>
<td>1-K220</td>
<td>Up-down Counter</td>
<td>52.00</td>
<td>52.00</td>
</tr>
<tr>
<td>1-K230</td>
<td>Shift Register</td>
<td>36.00</td>
<td>36.00</td>
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<tr>
<td>1-K281</td>
<td>Fixed Memory</td>
<td>8.00</td>
<td>8.00</td>
</tr>
<tr>
<td>2-K303</td>
<td>Timer</td>
<td>27.00</td>
<td>54.00</td>
</tr>
<tr>
<td>1-K323</td>
<td>One shot delay</td>
<td>35.00</td>
<td>35.00</td>
</tr>
<tr>
<td>1-K376</td>
<td>Timer Control (0.1-3.0 sec)</td>
<td>7.00</td>
<td>7.00</td>
</tr>
<tr>
<td>1-K378</td>
<td>Timer Control (1.0-30 sec)</td>
<td>9.00</td>
<td>9.00</td>
</tr>
<tr>
<td>1-K375</td>
<td>Timer Control (60 Hz-2 Hz clock)</td>
<td>8.00</td>
<td>8.00</td>
</tr>
</tbody>
</table>

4 pkgs. of 10 patchcords (911-2") 9.00 36.00
5 pkgs. of 10 patchcords (911-4") 9.00 45.00
2 pkgs. of 10 patchcords (911-8") 9.00 18.00
1 pkg. of 10 patchcords (911-16") 9.00 9.00
24 symbology cards .25 ea. 6.00

Complete K-series logic lab with workbook and modules listed — H510 $995.00

Asterisk* denote symbology cards unavailable. Symbology cards for use with K901 patchboard panel, .25 ea., minimum purchase of $2.00 applies.

IF ADDITIONAL K901 PATCHBOARDS ARE ORDERED:

1-911-4” pkg. of 10 patchcords 9.00
1-911-8” pkg. of 10 patchcords 9.00
1-911-16” pkg. of 10 patchcords 9.00
1-911-32” pkg. of 10 patchcords 9.00
K-SERIES INTERFACE MODULES

Recommended logic modules for input/output functions.

**AC Input/Output**

1-K578  120 VAC Input converter  80.00
1-K614  120 VAC Isolated AC switch  88.00

**DC Input/Output**

1-K580  Dry Contact Filter  20.00

Listed below are a number of DC output drivers that may be used:

1-K644  DC output Driver  66.00
or
1-K656  DC output Driver  80.00
or

1-K658  DC Output Driver  128.00

Each additional K series workbook  5.00

Note: only 3 out of 4 circuits are available when using above 3 modules with the K901 mounting panel.

Reference logic or control handbook for additional module information and selection.
CONTROL SYSTEMS

The Control Systems Group of Digital Equipment Corporation offers to its customers a complete design and manufacturing service in the area of module systems and PDP-14 special systems. The Control Systems Group maintains a qualified staff of experienced design engineers together with their manufacturing counterparts to provide these services with a high level of technical competence and at a reasonable cost saving to the customer.

In order to clarify and establish the policies and services offered by each of the two divisions of Control Systems: Modules Systems and PDP-14 Special Systems will be defined separately.

A. Module Systems

Digital Equipment Corporation offers to its customers the capability of designing and building special purpose digital logic systems. The ultimate aim of this group is to establish a limited production quick turn around capability.

To make this feasible, a minimum initial order of ten identical units must be ordered. After the initial commitments, orders for single units will be accepted. It should be understood that this group can take an existing system and produce it without going through the prototype stage. However, if there is any question concerning the operation of the system, a prototype will be required.

With respect to the prototype, prior to acceptance of the purchase order, all specifications must be defined and agreed upon between the Control Systems Group and the customer. All testing of the unit will be performed to this set of specifications. Acceptance will be based upon a successful demonstration to the customer that the specifications have been met. Digital Equipment Corporation will not warrant the system beyond the date of acceptance but will honor all existing module warranties.

The engineering and technician labor which a customer pays for at this time should be considered as his investment in product development and as such must be written off over the expected life of the product. The customer's decision at this point must be to decide how many systems are necessary to economically cover his investment.

Digital Equipment Corporation will, in effect, act as consultant engineers to these customers and the charges which are assessed must be viewed in this light. Unlike consultants, however, a maximum charge for engineering is specified which limits the amount which will be charged for these services.

The Control Systems Group also provides full documentation (engineering prints, module layouts, and, if deemed necessary, an operational write-up of the system). Should the need arise for training of the customer's personnel in the operation of the equipment, the Control Systems Group will also provide this service.
B. PDP-14 Special Systems

The primary function of the PDP-14 Special Systems group is to offer to the customer Digital Equipment Corporation’s experience and talent in designing tailor made control systems based upon a PDP-14 central processor. In order to accomplish this, each system will be developed by working as closely with the customer as possible. An emphasis will be placed on utilizing as many PDP-14 standard options as possible and specialized designs will be kept to a minimum. In addition, the PDP-14 Special Systems Group can provide computer based PDP-14 systems as well as stand alone PDP-14 systems. This approach offers the lowest possible cost and speediest delivery.

When it is determined that all of the customer’s requirements have been decided, a system will be designed implementing these functions. At that time, a firm quote will be developed to cover the cost of the equipment. In addition to the hardware, the quote will cover labor, documentation, diagnostic programming and testing costs. Each system will be warranteed to meet all of the electric specifications as agreed upon between the customer and Digital Equipment Corporation.

Acceptance testing will be performed at Digital Equipment Corporation and the customer will be notified sufficiently in advance should he care to be present at the time of the test. The warrantee of the system will be identical to that of the PDP-14 upon which it is installed.
COMPUTERS AND NUMERICAL CONTROL

The largest number of dedicated general-purpose computers connected directly to metalworking, component assembly, and measuring machines have come from DEC. An even greater number of PDP-8 family computers are in daily use preparing part programs to run conventional NC systems. With this background, DIGITAL can offer the machinery builder a broad range of CNC capabilities, complementing his use of K series logic modules to obtain superior reliability when interfacing conventional NC.

There are two ways that small, inexpensive, dedicated computers are being direct-connected for numerical control: replacing the conventional NC director or supplementing it. The supplementary approach uses the computer basically as a communication device responding to signals from the NC control panel by transmitting blocks of data from part programs stored in memory. Given adequate memory devices and capacity the computer can exclude paper tape from the production process except as a means of insurance against equipment failure. Since all data passes through the computer on command from the NC controllers, time-study information of interest to management can be derived without much additional cost. Economic justification is enhanced by the possibility of sharing one small computer among a number of machines.

Replacement of the conventional NC controller itself involves more engineering, but the payoff can be greater when design concepts are appropriate to the job. Having the computer directly connected to machine axes can offer opportunities for important productivity gains where the computer, with its complex program, can interact more intimately with both the man and the machine than is practical with special purpose electronics. Moreover, the high speed of the computer allows it to carry out several complex activities in successive fragments so brief that they appear simultaneous and continuous. For example a small computer can directly control two multi-axis machines performing entirely separate jobs and accumulate time study data on each, while simultaneously assisting a part programmer at a distant teleprinter.

Until a broad range of standard CNC products becomes commercially available, each machine tool builder who wants to exploit the potential of computer NC must continue to spend considerable effort in developing specifications appropriate to his particular customers' needs and wants. DIGITAL's Computer NC staff will be happy to assist, not only in defining system requirements and supplying basic computer hardware but also in developing special hardware or software, directly or through the help of systems and software companies with which we are in touch.

A number of machine tool importers and builders offer the Quick-point system to their customers as a means of applying the power of a small general purpose computer to conventional NC part programming. Below are a few examples of commands the system can execute, calculating coordinates directly from print data for point-to-point and even for some two-axis profiling without the need for separate calculation on the part of the part programmer.
GEOMETRIC COMMANDS

INC  **INCREMENT:** Allows incrementing along X or Y axis by specifying in order direction (R, L, U, or D for Right, Left, Up, or Down), increment (distance between holes), and number of holes.

```
\[ \begin{array}{c}
\text{INCREMENT} \\
\rightarrow \\
\text{+ + + + + + +} \\
\text{R} \\
\end{array} \]
```

LAA  **LINE AT ANGLE:** Allows incrementing along a line at an angle to the X axis by specifying, in order, the increment value, angle, and number of holes.

```
\[ \begin{array}{c}
\text{INCREMENT} \\
\rightarrow \\
\text{+} \\
\text{60°} \\
\end{array} \]
```

BHC  **BOLT HOLE CIRCLE:** Allows for computation of bolt holes by specifying, in order, the radius of circle, angle from X axis of first hole, and number of holes.

```
\[ \begin{array}{c}
\text{Radius} \\
\end{array} \]
```

ARC  **ARC:** Allows for computation of holes along an arc by specifying, in order, the radius of arc, angle from X axis of first hole, incremental angle between holes, number of holes.

```
\[ \begin{array}{c}
\text{INCREMENTAL ANGLE} \\
\text{STARTING ANGLE} \\
\end{array} \]
```

GRD  **GRID:** Allows for computation of holes in a grid pattern by specifying in order, direction, increment, and number of lines of each axis.

```
\[ \begin{array}{c}
\text{INCREMENT} \\
\rightarrow \\
\text{+ + + + +} \\
\text{Y} \\
\text{+ + + + +} \\
\text{U} \\
\text{+ + + + +} \\
\text{X} \\
\text{+ + + + +} \\
\text{R} \\
\end{array} \]
```
INDAC-8

The mini-computer is now available in a mini-priced data acquisition system with full-scale capabilities. Digital's INDAC-8 system offers today the sophisticated real-time data acquisition capabilities at 1/6 of the price you would have paid yesterday. Before INDAC-8 you had no real choice when looking for a small real-time data acquisition system: a mini-computer and your own extensive in-house software preparation or a large expensive computer with free software. Either way led to the same outcome: about a $150,000 minimum investment to get your system on-line. But INDAC-8 has changed all that. Now the basic system, including both hardware and user-oriented software, is available as low as $25,000.

INDAC-8 has done more than just lower the cost of real-time data acquisition. It has created a new threshold for economic justification of industrial computer systems. No longer must many unrelated tasks be combined into a large, unwieldy system to justify the high cost of yesterday's real-time data acquisition. INDAC-8 lets you tackle small, well-defined tasks to get your system up and producing results fast.

INDAC-8 HARDWARE

INDAC-8 systems are designed around the field-proven and highly-successful PDP-8/I general-purpose computer and standard DEC peripheral equipment. The standard pre-packaged system can be easily modified to meet special requirements. INDAC systems are truly modular and can be customized to meet many application requirements.

The basic INDAC system consists of:
- PDP-8/I with 4K of memory
- ASR-33 teletype
- DF-32 disk and controller with 32K words of storage (expandable to 128K words)
- KW8I/D clock — line frequency
- PR8/I high speed paper tape reader

A typical system would include all of the above plus an additional logging teletype, several options of multiplexed inputs, digital inputs and outputs and 4K core memory expansion.

Central Processor Options

- PDP8/ID Computer
- MC8/I Memory Extension
- DF-32/DS-32 Disc
- KW8/ID Clock
- PR8/I High Speed Paper Tape Reader
- PP8/I High Speed Paper Tape Punch
- PC8/I Combination of PR8/I and PP8/I
- PTO8B Assynchronous Serial Line Interface
- KSR-33/35 Teletype

Data Acquisition Interface Option

The Data Acquisition Interface consists of an Analog Input Subsystem and a Digital Input/Output Subsystem.
Analog Input Subsystem

Many of the signals that must be monitored by the INDAC-8 system are in analog form. Thermocouples, pressure transducers, strain gauges, etc. give an output in analog form that has to be converted into digital form through one of the standard analog input subsystems offered with the INDAC system.

These signals are permanently wired into a multiplexer unit. Under program control of the central processor, the signals connected to the multiplexer unit are selected and the values digitized by an analog-to-digital converter.

The following analog measurement subsystems are available with the INDAC system:

- AF01A
- AF02A
- AF03A
- AF04A
- Signal Conditioning Units:

These units are used for low level and for high level analog signals.

General Purpose Multiplexed A/D Converter Subsystem — AF01A

The General Purpose Multiplexed A/D Converter Subsystem, Type AF01A is used with PDP-8, PDP-8/I, or PDP-8/L computers to multiplex up to 64 high level, single ended, analog signals. It consists of the following units: (Fig. 1)

A/D Converter

The A/D converter is a general-purpose successive-approximation type with the following characteristics:

Accuracy \( \pm 0.025\% \) (11 bits \( \pm \) sign)

Conversion Time \( 35 \ \mu s \)

Aperture \( 35 \ \mu s \) unless
AH02 Sample and Hold option is used

Converter Recovery Time None

Analog Input Voltage Range
\( \pm 10V \) (AH03-A)
\( \pm 5V \) (AH03-D)

Loading \( \pm 1 \mu A \) and 125 pf for standard input

The AH03 is a necessary prerequisite for the AF01A subsystem whenever used with the INDAC-8 system.

Provision is made for using the AH02 Sample and Hold Amplifier between the multiplexer output and A/D converter input to reduce the effective aperture to less than 150 nsec. A second AH03 amplifier can be used if further scaling is required.

The control indicator panel contains twelve indicators to display and contents of the ADC buffer and six indicators to display the current multiplexer address.
Multiplexer Switches

The multiplexer can include from 1 to 16 Type A121 Switch Modules. Each module contains four single-pole, high speed, insulated gate FET switches with appropriate gating. The switched signal input wire and the continuous ground for each channel are run as twisted pairs to the input connectors mounted on the rear panel. The continuous grounds for all channels are terminated at the high quality ground of the AF01A System. (Refer to the Type AF03 and AF04 options for differential multiplexed systems).

Scanning Rates

The Type AF01A Subsystem is operated in the random address mode. Scanning rates of the AF01A is 20 kcs. Use AH03 amplifier or the AH02 (sample and hold option) decreases the scanning rate by 10%.

AH02 Sample and Hold Option

The AH02 is an accurate sample and hold amplifier capable of tracking a full scale excursion in 12 micro-seconds to 0.025% accuracy. In the hold mode, the droop (decay) is less than 1 millivolt per millisecond. Two analog inputs are provided; one input provides for unity gain, the second input provides for gain change using appropriate value of resistors.

Software

An I/O handler is provided with the INDAC Operating System to service and AF01A analog subsystem. To scan any number of analog points the user will program a GET (AF01) d, where d is a data list specifying where the digitized values will be stored.

The digitized value will be stored in integer or floating point format depending of the variable or array type specified in the EQUIPMENT list.

General Purpose Multiplexed A/D Converter Subsystem — AF02A

The General Purpose Multiplexed A/D Converter Subsystems Type AF02A, is used with PDP-8, PDP-8/L, or PDP-8/L computers to multiplex up to 1024 high level, single ended, analog signals and to convert the signals to binary numbers. Fig. 2

A/D Converter

The A/D Converter used is the ADC81. The ADC81 has the same characteristics as the A/D used in the AF01A system.

Multiplexer

The multiplexer control is designed for full expansion to 1024 channels, in groups of 128 or 256 channels. Facilities are included for sub-multiplexing in 64 (or 128) channel groups where multiple scale factors are required for different analog signals. DEC Type AH03 Amplifiers are used with each group using preset gains consistent with system requirements. Sub-multiplexing of each 64 or 128 channel group is included at the amplifier output.
Multiplexer Switches

The multiplexer can include from 16 to 256 Type A122 Switch modules. Each module contains four single-pole, high speed, insulated gate FET switches with appropriate gating.

The specification of the A122 switches are the same as the A121 described in the previous section.

Scanning Rates

Scanning rates are the same as in the AF01A Subsystem.

AH03 Amplifier Option

The DEC Type AH03 Amplifiers may be used with appropriate gains for each group of 64 or 128 channels.

AH02 Sample and Hold Option

The DEC Type AH02 Sample and Hold Amplifier may be specified to reduce the effective A/D converter aperture time.

Software

An I/O handler is provided with the INDAC-8 Operating System to service the AF02A analog subsystem. To scan any number of analog points the user will program a GET (AF02) d, where d is a data list specifying where the digitized value will be stored.

The digitized value will be stored in integer or floating-point format depending on the variable or array type specified in the EQUIPMENT list.

Differential Multiplexed A/D Converter Subsystem — AF03A

The Differential Multiplexed A/D Converter Subsystem, Type AF03A, is used with a PDP-8, PDP-8/I, or PDP-8L computer to multiplex up to 1024 differential analog signals and to convert the signals to binary numbers. Fig. 3

A/D Converter

The A/D Converter used is the ADC81.

Multiplexer

The multiplexer control is designed for full expansion to 1024 channels. The selection is grouped in 1 to 16, 64 channel groups. Facilities are included for sub-multiplexing in 64 channel groups where multiple scale factors are required for different analog signals. DEC Type AG01 Amplifiers are used with each group using preset gains consistent with system requirements. Only one AG01 amplifier is required if only one single gain setting is required.
Multiplexer Switch Specifications

At low levels, multiplexing of analog signals must usually include guarding and shielding provisions to control noise pickup. Fortunately, transducers having low level outputs are often slow speed devices like thermocouples, so that the speed of a relay multiplexer is adequate, and the superiority of relay contacts for ultralow-offset switching can be fully utilized. The two James Microscan 3-pole relays in the A111 are specially designed for this purpose, and are mounted on a double-clad circuit board which shields the analog from the digital circuitry and provides guarded contact wiring.

Software

An I/O handler is provided with the INDAC-8 Operating System to service the AF03A analog subsystem. To scan any number of analog points the user will program a GET (AF03, #n) d, where d is a data list specifying where the digitized value will be stored. #n is a control tag in the .EQUIPMENT list that will be used to specify the amplifier gain (whenever the AG02 programmable gain amplifier is used) and, optionally, a conversion routine that will, in between successive readings, do the conversion of a previously digitized value to engineering units.

Scanning Rates

Multiplexer addressing of the AF03A Subsystem is in the random access mode. The scanning speed with the AF03A subsystem is dependent on the amplifier gain and filter selected. Typically for a gain of 200 and 10 kHz filter the nominal scanning rate will be 200 points/sec.

Integrating Digital Voltmeter (IDVM) Analog Input Subsystem — AF04A

The AF04 is a guarded scanning integrating digital voltmeter subsystem, with wide dynamic range and high common-mode rejection, and capable of expansion to 1000 channels. The AF04A is used to multiplex up to 1000 3-wire analog channels into a 6-decimal-digit (BCD) integrating digital voltmeter. Full scale ranges are from \( \pm 10 \) mV to \( \pm 300 \) V, with automatic ranging, 300 percent over ranging, and a usable 5 \( \mu \)V resolution. Guarded input construction and active integration assist in attaining an effective common-mode rejection of greater than 140 dB at all frequencies. (Normal-mode rejection is infinite at multiples of power line frequency). Fig. 4

This system is ideally suited for data acquisition or process monitoring where a wide range of signals requires large dynamic range. The excellent noise rejection, allows accurate direct measurement of thermocouples, strain gauges, load cells, and other low-level transducers without additional amplification.

The AF04A Voltmeter is operated under program control, using random channel selection. The computer selects either program controlled ranging (for fastest speed) or autoranging, as well as the integration time of the integrating digital voltmeter.

A decimal display of the digitized value, including sign and decimal location, is continuously displayed on the front panel.

The current channel number is also displayed. Front-panel controls on the digital voltmeter allow manual setting of all the programmed functions. A front-panel control allows continuous display of the internal secondary stan-
standard, which can be prewired to a particular channel for reference checking during normal operation.

The AF04A subsystem may be manually controlled, completely independent of the computer. The IDVM is completely self-contained, and may be used separately as a bench instrument for voltage, period, and frequency measurements.

**Characteristics**

- **Full scale range (±)**: 10 mV, 100 mV, 1V, 10V, 100V, 300V, and automatic ranging
- **Over ranging**: 300% on all but highest range
- **Resolution**: 5 μV (usable), 0.1 μV (LSB)
- **Accuracy (overall)**: ± 0.004% of reading
- **Accuracy (worst case with daily calibration at calibration temperature)**: ± 0.01% of full scale
- **Accuracy (ambient)**: ± 0.05% of full scale
- **Normal-mode rejection**: Infinite at multiples of line frequency
- **Common-mode rejection**: 140 dB at all frequencies
- **(166.6 ms integration period and 1000 ohm-source unbalance)**

**Software**

An I/O handler is provided with the INDAC-8 Operating System to service the AF04 analog subsystem. To scan any number of analog points the user will program a GET (AFO4, #n) d, where d is a data list specifying where the digitized value will be stored. #n is control tag in the .EQUIPMENT list that will be used to specify the type of signal (DC, AC, etc), the range, resolution and optionally a conversion routine that will, in between successive readings, do the conversion of a previously digitized value to engineering units.

The raw or converted value will be stored in integer or floating-point format depending on the variable or array type specified in the .EQUIPMENT list.

**Signal Conditioning Units**

Several signal conditioning units are provided in the INDAC-8 system for:

- Thermocouple reference junction compensation.
- Current-to-voltage (I/V units, to convert input signal currents into a measurable voltage).
- Voltage-to-voltage (V/V units, to divide down input signals).

**Uniform Temperature Reference Junction Box — ATR80**

The Uniform Temperature Reference Junction Box provides thermocouple reference junction compensation for up to 32 thermocouples, (of any type — J, K, T, etc.). More than 1 ATR80 can be used in the INDAC system.
Software

The linearization routines provided for the J, K, and T thermocouples automatically correct for the reference junction temperature.

Digital Input System Type DS80

The digital input system type DS80 is used by the PDP-8, 8/1 or 8/L to interrogate digital inputs. The inputs must be contacts connected to a 6, 24, or 48 volt supply. The system can accommodate up to 696 inputs and can scan these inputs in either a synchronous or asynchronous mode. In the synchronous mode the computer periodically interrogates the digital inputs under program control. The inputs are organized into groups of 12 and are read into the computer as 12 bit words. Therefore, a full complement of 696 inputs would comprise 58, 12 bit words. In the asynchronous mode the computer will be interrupted whenever an input changes state in the desired manner. An interrupt can be generated when a contact closes, when it opens, or when it changes state. The type of contact change that generates an interrupt can be specified by the customer on a word basis. When the computer recognizes an interrupt from the digital input system, it can read all the words to determine which input has changed. The system can store an interrupt so that an input which changes state while the computer is scanning will not be missed.

The basic unit consists of the input controllers (DS80-CN for neg. bus and DS80-CP for pos. bus) and space for implementing up to 8 words (96 inputs). These 8 words can be either all synchronous (contact sense) or all asynchronous (contact interrupt) or any combination of them. The modules to implement these words are not included in the basic controller and can be purchased in 1 word increments. If more than 96 inputs are desired, expander units can be connected to the controller. The two types of expanders are:

- Contact Interrupt Expander (DS80-CI) — Up to 8 words of either contact sense, or contact interrupt or any combination.
- Contact Sense Expander (DS80-CS) — Up to 10 words of contact sense.

Up to 5 expanders can be connected to 1 controller. However, only 1 contact interrupt expander can be connected to any one controller. This means that a maximum of 192 contact interrupt points can be handled by a controller. As with the controller, the modules to implement these words are not included in the expanders and can be purchased in 1 word increments.

When scanning digital inputs a 6-bit control word programmed from the computer selects the desired word. The computer can then issue a Read I/O Transfer Instruction to read the contents of that word. A contact closure will be read into the computer as a “1” and an open contact will be read as a “0”. When a contact interrupt point changes state it interrupts the computer after a 3 ms delay. This insures that the contact has stopped bouncing and is settled by the time the computer interrogates it. When the computer finishes scanning the interrupt points, it must issue an End-of-Scan instruction. This enables the controller to interrupt the computer in any contact changed state while the words were being read or when any future changes of state occur.

Customer connections to the digital input system are typically made by means of soldered connections to connector modules which plug into the system. However, screw terminal connections are available as an option to facilitate customer connections.
Options

The options available for the digital input system are:

- **Contact Sense Units**
  - DS80-SA (6V) includes contact sense input modules to accommodate 12 digital inputs (1 word). Provides isolation from the external process and noise immunity.
  - DS80-SB (24V)
  - DS80-SC (48V)

- **Contact Interrupt Units**
  - DS80-IA (6V) includes contact interrupt input modules to accommodate 12 digital inputs (1 word). Provides isolation from the external process and noise immunity.
  - DS80-IB (24V)
  - DS80-IC (48V)

Power

Excitation power for the contacts may be specified by the customer as 6, 24, or 48 volts. This power supply is customer supplied.

Current required to energize the input modules is:

- Contact Sense — 6 ma/input
- Contact Interrupt — 20 ma/input

Software

**Contact Sense.** To scan field contacts, connected to the Contact Sense Units, the user will write GET (CONS) d, where d specified a data list. The channels (words) that were associated in the .EQUIPMENT list with d will be read by the GET statement and the contact status stored as a “1” if closed and as “0” if open.

**Contact Interrupt.** The scanning of the 16 words of Contact Interrupt Units will be done by the Contact Interrupt I/O handler of the INDAC-8 operating system. Two tables will be kept by the handler — a change of state table and the present contact status table. The handler will also request the running of the priority phase. When the priority phase starts execution, the user can obtain both tables by executing a GET (CONI) d. The d data list will determine how many words of each table (“Change of State” and “Present” status) will be transferred to the user.

**Digital Output System Type DR80**

The digital output system type DR80 is used with the PDP-8, 8/I or 8/L to provide discrete outputs to an external process. The system is capable of driving up to 732 digital output points (61, 12 bit words). This system can generate level outputs, pulse outputs, sustained, momentary and latching. The output module for the pulse and level outputs is a driver with the following ratings:

- **Resistive Load** 55v, 250 ma.
- **Inductive Load** 55v, 250 ma.
- **Lamp Driver**
  - Up to 48v for lamps rated at 40 ma.
  - Up to 28v for lamps rated at 60 ma.
  - Up to 18v for lamps rated at 80 ma.
  - Up to 12v for lamps rated at 100 ma.

The contact outputs are rated at:

- 2 amps. max.
- 500 volts max.
- 100 volt-amps max.
Customer connections to the output modules are typically made by solder connections to connector boards. Screw terminals are available as an option to facilitate customer connections.

The basic unit of this system is the Digital Output Controller (DR80-CN for negative bus interface and DR80-CP for positive bus interface). The controller contains all the addressing and control logic for up to 61 output words. The controller also contains space for up to 60 output bits (5 words). The actual output modules for these words are not supplied with the controller but must be purchased separately. These are available in 12 bit increments and any combination of the 4 output types can be accommodated in the controller.

A digital output expander is also available to enable the system to accommodate more than 60 output points. The expander can contain up to 84 additional output points (7 words). As in the controller, the actual output modules must be purchased separately in 12 bit increments and any combination of the 4 output types can be used. As many as 8 expanders can be connected to anyone controller. This accounts for the 61 word capability of the system.

The expanders are connected to each other and to the controller by means of daisy-chained cables. The maximum length for the entire daisy-chained cable from any controller is 40 cable feet.

The computer can change the state of any word (any group of 12 outputs) by issuing 2 I/O instructions. The first instruction loads a 6 bit address register from the least significant half of the accumulator. The address register is used to specify the desired word. The next I/O instruction uses the accumulator to determine the state of the 12 outputs in the addressed word. The state of each of the 4 types of outputs is determined as follows:

Level Outputs: When a level output is addressed, a "1" in the data word will set the corresponding flip-flop and turn on its output driver. In this state the output driver will draw current through its load. It will stay in this state (flip-flop set) until the same point is addressed with a "0" in the data word.

Pulse Outputs: When a pulse output point is addressed, a "1" in the data word will turn on the appropriate output driver for a pre-determined period of time. This means that the output driver will draw current through its load for that period of time. The duration of this pulse is adjustable between 10 ms. and 2 sec. There is a separate adjustment for every group of 6 pulse output points. Therefore, every point in the group will be set for the same pulse duration.

Sustained Contact Closures: When electrically latched contact closure point is addressed, a "1" in the data word will set the corresponding flip-flop and energize its output relay. The output relay will remain energized (contacts closed) until the same point is addressed with a "0" in the data word or until a power failure occurs.

Momentary Contact Closures: When a momentary contact closure point is addressed, a "1" in the data word will energize its corresponding output relay for a pre-determined period of time. This time is adjustable in the same manner as the duration of the pulse outputs.
Options

The options available for the digital output system are:

DR80-FF (Level Output Unit) — Includes flip-flops and drivers for 12 output points.
DR80-SS (Pulse Output Unit) — Includes single-shots and drivers for 12 output points.
DR80-SR (Sustained Contact Closure Unit) — Includes flip-flops and relays for 12 output points.
DR80-MR (Momentary Contact Closure Unit) — Includes single-shots and relays for 12 output points.
DR80-LR (Latching Relay Unit) — Includes flip-flops and mechanically latching relay for 12 output points.

Software

The output of digital information as level, pulses or contacts is executed by a simple INDAC-8 statement such as SEND (DIGOT) d. The channels (words) that were associated in the EQUIPMENT list with d will be energized. Each bit of the data list d, that contains a “1” will give a “1” logic level output, will trigger an output one-shot or will close a relay contact. The bits containing a “0” will give a “0” logic level output, no pulse output or will open the relay contact.
INDAC-8 SOFTWARE

INDAC-8 Language

The industrial data acquisition and control language developed by Digital Equipment Corporation is the INDAC-8 language.

The INDAC-8 language borrowed, from BASIC and FORTRAN, due to their inherent simplicity, the statements for arithmetic and logic computations and program control; and, added to it, statements for program segmentation, for program control, process I/O, file manipulation, etc. The I/O statements and the real-time extensions are supported by a real-time operating system. Programs written in the INDAC-8 language therefore must be executed under control of such system.

The INDAC-8 operating system provides for:

- Task or program scheduling based on time, events, or program decisions.
- Tasks, made of several program overlay, have distinct priority levels, depending if they are executed in response to process interrupts, events or timers, or whenever the system is idle.
- The automatic overlays of the program units.
- All device I/O handling. File maintenance in secondary storage. Tasks, program units and data are transferred from disk to core and vice versa by the system.
- Buffered output transfers to slow peripheral, such as the teletype; this allows for output operation to occur independent of program processing.

INDAC-8 real-time language allow industrial control problems to be stated entirely in compiler language. This means that an engineer already familiar with BASIC or FORTRAN can, in short time, with minimum training, produce programs for a process control environment. He does not have to worry about machine language real-time programming; he can concentrate instead on his control problem.

![Diagram](image-url)
PROGRAM ORGANIZATION

A total user programming job in INDAC is made up of segments that time share core memory. All segments are disc resident except the system unit header. Fig. 5 shows this segment-tree structure of user's program and Fig. 6 shows a snapshot of core memory.

PROGRAMMING USING INDAC-8

A simple programming example will be presented in this section to illustrate the concepts discussed previously.

In a sample test application, Fig. 7, the product test engineer wants to obtain data regarding the operational temperature characteristics of three specific areas of a certain product unit.

The basic INDAC-8 program to accomplish this test is shown in Fig. 8. This program follows the basic organization of information and program structure, i.e., SYSTEM, PHASE and SNAP units, as presented in Fig. 5.

The SYSTEM Unit Header contains the equipment specification information. It establishes the identity of the attached device (AF04), each input of the device which is used (CHAN 1, 2, 3), and the identity of each input signal (TEMP A, B, C). It also specifies that a conversion routine (TCONV) is to be performed for each input.

The PHASE Segment unit establishes the basic parameters which control the performance of the functional SNAPS which make up the PHASE. In this case, the cycle time of the single SNAP contained in the PHASE is specified.

The program SNAP segment specifies the exact operations to be performed — in this case, sampling the input signals (GET statement) and printing out the sampled (and converted) temperature values (SEND statement).

A more detailed analysis of the program is given in Table 1.
.EQUIPMENT
*AF04
CHAN (1) TEMPA
CHAN (2) TEMPB
CHAN (3) TEMPC
#101 DO TCONV

#1 .PHASE
.ACTION
#10 DO SNAP #2 EVERY 10 SEC
TIMER (START, #10)

#2 .SNAP
.PROCESS
GET (AF04, #101) TEMPA, TEMPB, TEMPC
SEND (TTY) TEMPA, TEMPB, TEMPC
EXIT

.END

FIG. 8

TABLE 1. ANALYSIS OF PROGRAM EXAMPLE

PROGRAM LISTING

STATEMENT FUNCTION

Equipment Specification Statements

.EQUIPMENT

Indicates that the following statements (up to next (. statement) comprise a description of the total equipment complement needed to execute the program.

*AF04
CHAN (1) TEMPA
CHAN (2) TEMPB
CHAN (3) TEMPC
#101 DO TCONV

Device identification

Identifies the first channel input of the AF04 as TEMPA,
second channel input as TEMPB, and
third channel input as TEMPC.

This statement specifies that an operation identified as TCONV is to be performed for each channel input. The identified operation is normally a plug-in subprogram used to perform a standard conversion, scaling or other signal conditioning operation.

Phase Statements

#1 .PHASE
.ACTION

Introduce a program phase segment.

Indicates that all of the following statements up to the next (. statement are concerned with the scheduling operations performed within this PHASE.
#10 DO SNAP #2 EVERY 10 SEC Specifies that the SNAP tagged #2 is to be performed every 10 seconds.

TIMER (START, #10) Initialized the performance of the timing operation specified in the statement tagged #10.

SNAP Statements

#2 .SNAP Introduces a SNAP program segment which is tagged #2.

.PROCESS Indicates that all of the following statements up to the next (.) statement are to be executed to carry out the process assigned to this SNAP.

GET (AF04, #101) TEMPA, TEMPB, TEMPC This statement directs the system to get from device AF04 inputs TEMPA, TEMPB, TEMPC and to perform on each input the operation described in program statement #101 (i.e. TCONV).

SEND (TTY) TEMPA, TEMPB, TEMPC This statement directs the system to send the data processed in the preceding statement (TEMPA, TEMPC) to the Teletype I/O device for printout.

EXIT Indicates the end of the current SNAP program segment; command returns control to the operating system.

.END Indicates the end of the program.
SUMMARY OF INDAC STATEMENTS

EXECUTABLE STATEMENTS

1. Assignment Statements:
   LET \( v = e \)

2. Control Statements:
   GOTO Statements
   GOTO \( k \)
   GOTO \( (k_1, k_2, \ldots, k_n), i \)
   IF Statement
   IF \( (e_1) = (e_2) \) THEN \( S \)
   \( S = \) GOTO \( k \)
   or
   \( S = \) GOTO \( (k_1, k_2, \ldots, k_n), i \)

   \( O = EQ, NE, LS, LE, GR, GE \)

DO Statements
   DO \( k \)
   DO \( (u_1, u_2, \ldots, v_n) \)
   DO SNAP \( t \)
   DO PHASE \( t \)

RETURN Statement
   RETURN

Program Control Statements
   STOP or STOP \( a \)
   PAUSE or PAUSE \( a \)
   EXIT or EXIT THEN DO SNAP \( t \) or
   EXIT THEN DO PHASE \( t \)
   ABORT or ABORT THEN DO PHASE \( t \)

Loop Statement
   FOR \( i = m_1 \) TO \( m_2 \) or FOR \( i = m_1 \) TO \( m_2 \) STEP \( m_3 \)
   NEXT \( i \)

TIMER Statement
   TIMER (STOP, \( t \)) or TIMER (START, \( t \)) or TIMER (RES)

4. Input/Output Statements
   GET \( (u, t) \) list or GET \( (u) \) list
   SEND \( (u, t) \) list or SEND \( (u) \) list

3. Activity Statements
   \( t_1 \) DO SNAP \( t_2 \) EVERY \( c \)
   \( t_1 \) DO SNAP \( t_2 \) AT \( c \) \( t_1 \) DO PHASE \( t_2 \) AT \( c \)
NON-EXECUTABLE STATEMENTS

1. Specification Statement
   .EQUIPMENT
   *u
   CHAN (i) ........
   t v_1, v_2, ..., v_n DO s

2. Allocation Statements
   .STORAGE
   v_1, v_2, ..., v_n
   .ACTION
   t .FORMAT
   t .HEADER

3. Program Unit Segmentation Statements
   t .PHASE or t .PHASE (BACKGROUND)
   t .PHASE (u_1, u_2, ..., u_n)
   t .SNAP
   .SUBROUTINE s

4. Compiler Directives
   .PROCESS
   .END
PDP-14 Solid State Industrial Control System (in NEMA enclosure)
Digital Equipment Corporation's PDP-14 is a programmable solid state controller which is well suited to a variety of applications. The PDP-14 combines the advantages of solid state with the relay characteristics of simplicity and ease of use. It offers solid state logic in an easily programmed system which will operate in an industrial environment.

The basic PDP-14 Controller resembles a computer in that it contains input-output interfaces, a control unit and a memory. However, there are several important differences. First, the control unit is simplified and may be programmed using a few simple instructions. This allows a control engineer who has had no prior computer training to program the PDP-14. Second, the input-output interfaces are designed to accept 120 VAC line inputs, such as are field wired from limit switches, and the outputs are similarly 120 VAC with sufficient capacity (500 VA) to drive solenoids or motor contactors. Third, the PDP-14 memory is nonvolatile; it is a hard-wired, read-only-memory which contains the programmed instruction to control a specific application. Although the memory cannot be destroyed electrically, it can be altered by the insertion of a new set of wires.

The software and hardware of the PDP-14 offer a ready means of computer monitoring a control system. The PDP-14 serves as the AC interface to the controlled equipment. A computer interface between a PDP-14 and a PDP-8/L or 8/L general purpose computer is available. This computer interface permits the monitoring computer to interrogate inputs and outputs through the PDP-14 on a "cycle-stealing" basis. Using this technique, the monitoring computer may isolate component failure bringing downtime for repairs to a minimum. When necessary, the PDP-14 and the monitoring computer may communicate through 12 bit registers contained within the PDP-14. The monitoring computer may supply information to the PDP-14 which will affect its operation or it may supply actual instructions to be executed by the PDP-14.

The PDP-14 is designed to be more reliable, more flexible and, in most cases, less expensive than any other electrical system now available for control of machines and systems utilizing two state devices such as limit switches, pushbuttons, motor contactors and solenoids.
PDP-14 Mainframe
The PDP-14 system is all solid-state, and inherently reliable because of two key factors.

a. The K-series industrial control modules. For several years, the K-series has been widely accepted by industry as the most reliable solid-state module series available at reasonable cost. The rugged and flexible K-series has been designed into many types of custom control systems where speed and reliability are demanded. It is now available to serve the control needs of the mass-production industry as part of the PDP-14 system.

b. DEC experience as leader of the small-computer field. Switching circuits in a computer must function reliably hundreds of thousands of times a second. We have applied our knowledge of solid-state design and programming techniques to the PDP-14.

The PDP-14 system was designed specifically for industrial control. It is an integrated group of plug-in modular components. This allows the user to buy only the equipment actually needed for his control function. The modular approach also allows components to be easily replaced if necessary.

The "memory" used is a matrix of wires, inserted in the PDP-14 Control unit. This matrix is directly analogous to the wiring used in relay panels — but much smaller. It directs the entire operation of the PDP-14, and is designed by each user for his specific control needs, using a flexible computer program. This memory is so inexpensive that if changes in your manufacturing dictate new control operations, you can simply discard the memory and design a new one.

Large industrial relay control panels have a normal service life of two to five years, and then must be replaced entirely. During this period, individual relays and contacts must constantly be replaced. In contrast, the PDP-14 has no moving parts, and its components have a normal life expectancy of over ten years.

The PDP-14 system initial cost is about the same as relay systems, and for large control applications, is even less. In ten years of manufacturing, you could wear out three relay systems, and the PDP-14 should still be functioning reliably. Maintenance costs are reduced. And if the machinery is ever refitted for a new task, you don't have to start from scratch; just replace the PDP-14 memory.

As added bonuses, the PDP-14 system requires far less power and as little as one-tenth the space of conventional systems.
PDP-14 System Diagram
PDP-14 System Components

The PDP-14 Control System is a unified assembly of three basic units:

a. Input Interface Boxes ("I" Boxes)
b. The PDP-14 Programmed Control unit
c. Output Interface Boxes ("O" Boxes)

All system inputs and outputs are designed for 120 volts AC, 60 Hz, single-phase, compatible with the present industry standard.

INPUT BOXES

The "I" boxes are signal-conditioning devices; they accept 120 VAC inputs from two-state sensing devices such as limit switches, push buttons, proximity switches, pressure switches, and photo-cells. These inputs are converted into signals which are proper for our solid-state equipment. They then pass along control cables to the PDP-14 Control unit. Each I-box contains 32 inputs. A maximum of eight I-boxes, providing a total of 256 inputs is permitted in one PDP-14 system.

PDP-14 CONTROL UNIT

The control contains a wire matrix or "braid", which is the memory of the entire unit. It is called a "read-only memory," or "ROM" because it cannot be altered electrically (that is, "written on"). The ROM is actually a list of permanently wired electrical instructions which are "read" by the control to determine its operation.

The control operates in a way analogous to scanning a relay ladder diagram rung by rung. Each rung of the ladder represents a specific group of sensed input conditions which must be satisfied to cause a change in the condition of an output. The ROM contains instructions in small groups, each corresponding to a single rung in the ladder. The ROM directs the control to select each input specified in a group and test whether it is on or off. (This is the action performed by the "Test" unit shown.) Finally, the specified output is selected and set on or off, based on the test results. (This is the function of the "Set" blocks.) The control now continues to the next group of inputs and outputs, and repeats the process. This action proceeds one instruction at a time, but so fast that all inputs are checked and outputs properly changed in thousandths of a second; in fact, usually faster than one or two control relays could respond.
PDP-14 Input and Output Boxes
OUTPUT BOXES

Control signals sent from the control are accepted by the "O" boxes to activate selected 120 VAC outputs. Each output is a triac, the solid-state equivalent of a remotely controlled switch. Once set on, each output remains on and supplying power until it is set off by a new control signal.

Output boxes have an additional system function; they can be interrogated by the control unit to determine whether their outputs are on or off. In this mode, they can be considered as control inputs.

Each output of an output box can be connected to its own source voltage and to loads, such as solenoids, motor contactors, small motors, lamps and signalling devices.

Each output box contains 16 outputs. A total of 16 O-boxes providing 256 outputs may be incorporated in one PDP-14 system.

READ-ONLY MEMORY

The heart of the control operation is the read-only memory (ROM). The ROM contains all the instructions which allow the Control to sample specific groups of inputs and then select a specified output and turn it on or off. The ROM is provided in one to four separate plug-in sections, each of which has over 1,000 "locations" in which control instructions are stored. The number of sections required is determined by the size of the control "problem" — the number of inputs and outputs, and the number of control decisions which must be made.

The ROM is an actual physical matrix or "braid" of solid wires permanently embedded in a potting compound and surrounded by electronic sampling circuits (96 transformer cores) in a "sandwich" packaging. The arrangement of the braid wires is determined in a series of computer-aided steps, which result in a punched paper tape. This tape is used to operate an automatic wire placing machine, or "loom," which forms a wire braid. This braid, returned to be installed in the Control unit, represents the specific solution to the individual control problem. Whenever this element is changed, the PDP-14 System behaves as though it were rewired, allowing you complete flexibility in changing machine operations and retrofit.

In operation, the ROM acts like a series of wires strung through and around small current transformers. Each wire represents eight individual control instructions, which are read by sending a current pulse through it. The read out is in groups of eight instructions. The single desired instruction is selected from these eight. Only the transformers with wires running through their cores will be energized. The pattern of energized transformers is then read as an electronic instruction code. The code is the 12-bit binary instructions which are understood by the PDP-14 control unit.

As many as 5% of the instructions can be changed by cutting out wires and manually replacing them with new ones placed through different transformer cores. This makes it possible to make small revisions in control system operation. Complete ROM packages can be made in advance and stored for periodic changes in manufacturing operations.
ACCESSORIES

In addition to normal outputs, the PDP-14 system may be equipped with solid state timers, retentive memories, and storage outputs. The timers and retentive memories are provided in an accessories box (A-box). The storage outputs are provided in storage boxes (S-box) of 32 storage outputs or 16 storage outputs (half S-box).

The solid state timers may be adjusted to provide timing functions from fractions of a second to thirty seconds. The retentive memories are mercury-wetted relays which provide 1-bit of storage information after a power failure. The storage outputs provide temporary storage of intermediate processing results, status information, and are sometimes used for communication between the PDP-14 and the monitoring computer.

Also supplied as an accessory is an auxiliary power supply which is required for large PDP-14 systems.
PROGRAMMING THE PDP-14

Programming in the PDP-14 system is simply the procedure used to generate the read-only memory (ROM) to control a process or machine. PDP-14 programming does not require previous computer experience; it does require experience in machine control.

PDP-14 programs provide relationships between inputs (limit switches, push buttons, selector switches, etc.) and outputs (solenoids, motor contactors, indicator lights, etc.). These relationships, or control functions, may be expressed as Boolean equations which, when solved for particular input values, specify the state (ON or OFF) of an output.

Machine inputs and outputs must be assigned to the PDP-14 input (I) and output (O) boxes before a PDP-14 control program can be written. These assignments permit the PDP-14 instructions to test the state of specific inputs and outputs. Once these assignments are made, the inputs and outputs are referred to by unique numbers preceded by an "X" for an input, or a "Y" for an output. For programming purposes, these X and Y numbers represent specific input and output devices.

BOOLEAN REPRESENTATIONS OF MACHINE CONTROL

Programming a PDP-14 requires familiarity with simple Boolean representations of control functions. These representations are comprised of "operators" and "variables". The variables of PDP-14 control equations are inputs (X's) and outputs (Y's). The variables have two "states", namely, ON and OFF. The operators in these equations are * (AND), + (OR) and / (NOT). Parentheses may be used within equations to group variables.

For example, the equation:

$$Y_{10} = X_{23} + X_{21} * Y_{7}$$

is read "output 10 is set ON when input 23 is ON, or when both output 7 and input 21 are ON." This equation instructs the PDP-14 to test input 23; if it is ON, set output 10 ON. In input 23 is OFF, test output 7 and input 21; if they are both ON, set output 10 ON. If neither set of conditions is satisfied, set output 10 OFF.

The above equation could be represented by the following familiar ladder diagram:

![Diagram](image)

where SOL F corresponds to Y10; 2LS corresponds to X23; 7CR corresponds to Y7; and 3LS corresponds to X21.
A set of control functions similar to the preceding example comprise a PDP-14 program. A series of equations corresponding to these functions and written in terms of X's and Y's are then translated into the PDP-14 machine code program using BOOL-14.

**BOOL-14**

BOOL-14 is a translator program for control equations. It operates on a PDP-8 family computer and translates the equations into the PDP-14 machine code instructions needed to solve these equations. The machine code instructions will later be woven to form the ROM for the PDP-14. Before this happens however, the program should be rigorously tested and debugged. This is done with SIM-14. The translation for two equations is:

\[ Y_{10} = X_{23} + X_{21} \times Y_{7} \]

\[
\begin{array}{cccc}
0000 & 2423 & TXN & 023 \\
0001 & 5407 & JFN & 007 \\
0002 & 2021 & TXF & 021 \\
0003 & 1007 & TYF & 007 \\
0004 & 5007 & JFF & 007 \\
0005 & 3010 & SYF & 010 \\
0006 & 0344 & SKP \\
0007 & 3410 & SYN & 010 \\
\end{array}
\]

\[ Y_{17} = X_{2} \times X_{51} + X_{3} \times Y_{7} + X_{4} \times Y_{21} \]

\[
\begin{array}{cccc}
0010 & 2402 & TXN & 002 \\
0011 & 2451 & TXN & 051 \\
0012 & 5423 & JFN & 023 \\
0013 & 2003 & TXF & 003 \\
0014 & 1007 & TYF & 007 \\
0015 & 5023 & JFF & 023 \\
0016 & 2004 & TXF & 004 \\
0017 & 1021 & TYF & 021 \\
0020 & 5023 & JFF & 023 \\
0021 & 3017 & SYF & 017 \\
0022 & 0344 & SKP \\
0023 & 3417 & SYN & 017 \\
\end{array}
\]
The resultant PDP-14 program is a "closed loop" of disjoint instructions groups. Each group of instructions solves an equation for one output, setting it on or off. For example, if a machine control requires twenty outputs, there are twenty equations and instruction groups in the control program. The last instruction group is terminated with a "jump" to the first instruction group. The following diagram illustrates the construction of the program.
SIM-14 is a PDP-8 based program which simulates PDP-14 operation in two modes. The user may operate in an offline or “local” mode to debug or modify his program completely within the PDP-8. When relatively certain that the program is correct, the user may switch to on-line mode where the program is executed to control the machine’s operation.

Local mode debugging offers three features for testing programs.

1. The user supplies input states for a given equation and SIM-14 reports the resultant state of the output. This proceeds equation by equation.

2. The user generates a complete truth table, or binary array, which completely defines the state of an output for all possible input states. This is also done for each equation.

3. The user tests the complete program using simulated execution. He tests the complete program in sequence by specifying input states. Changing output states are reported by SIM-14. The user continues to vary input values to test all segments of the program.

The following are sample truth tables as generated by SIM-14 for the two equations which were translated by BOOL-14.

\[ Y10 = X23 + X21 \cdot Y7 \]

\[
\begin{array}{c}
\text{TA0} \\
\text{X23} \\
\text{X21} \\
\text{Y7} \\
\text{S0}
\end{array}
\]

A: \(X023\)
B: \(X021\)
C: \(Y007\)

\[
\begin{array}{c}
\text{ABC} \\
000 = 0 \\
001 = 0 \\
010 = 0 \\
011 = 1 \\
100 = 1 \\
101 = 1 \\
110 = 1 \\
111 = 1
\end{array}
\]

258
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<td>100000 = 1</td>
</tr>
<tr>
<td>B</td>
<td>X051</td>
<td>100001 = 1</td>
</tr>
<tr>
<td>C</td>
<td>X003</td>
<td>100010 = 1</td>
</tr>
<tr>
<td>D</td>
<td>Y007</td>
<td>100110 = 1</td>
</tr>
<tr>
<td>E</td>
<td>X004</td>
<td>100100 = 1</td>
</tr>
<tr>
<td>F</td>
<td>Y021</td>
<td>100101 = 1</td>
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<td>011110</td>
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<td></td>
</tr>
<tr>
<td>011111</td>
<td>111110 = 1</td>
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PDP-14 System Layout Example
PDP-14 SYSTEM EXAMPLE

What are the procedures involved in designing and maintaining a PDP-14 system?

- Configuring the system and selecting hardware
- Developing the control program
- Installing the hardware
- Debugging the system
- Installing the ROM
- Maintaining the system

All except the first of the above steps are assisted by software provided by DEC.

Configuring the System

How do you decide what PDP-14 hardware you will need to solve your control program? You must answer the following questions.

1. How many real outputs (motor contactors, solenoids, lights, etc.) are required?

2. How many timers are needed?

3. Must the PDP-14 record information with storage outputs or retentive memories?

4. How many inputs (limit switches, push buttons, selector switches, pressure switches, etc.) are in the system?

5. Will the PDP-14 be monitored by an external computer?

6. How many variables are in an equation to control a typical output?

Question 1 determines the number of output boxes required. Let’s assume there are 72 outputs. (If a relay system is being changed over to PDP-14, control relays should be excluded from this count.) These 72 Outputs require 5 output boxes and leaves 8 spare outputs.

Question 2 concerns the selection of accessory boxes. An “A-box” can contain 16 timers. Let’s assume there are 12 operations which must be timed. You need one A-box and 6 timer cards (each provides 2 timers).

Question 3 also concerns the A-box, if retentive memories are needed. Retentive memories are available as one mercury-wetted relay per card. Only 4 retentive memories may be used in one A-box, and each uses two output slots. Let’s assume no retentive memories are needed. However, there are 7 status conditions which must be recorded (similar to the old control relay), and 5 push buttons, the activation of which the PDP-14 must remember after the input is no longer present. These require 12 storage outputs or one half S-box with 4 spares.
Question 4 is a straight forward count of two state inputs. Each position of a selector switch is considered as a single input. Let's assume there are 91 inputs. Thus 3 input boxes are required, providing 96 input slots, five of which are spares.

Question 5 has several implications. The obvious need is a computer interface. However if the PDP-14 is to be monitored, several other considerations are also needed. Storage outputs may be required for communication between the PDP-14 and the monitor. More memory may be needed to handle monitoring information. Let's assume that the monitor will simply check inputs and outputs on a cycle-stealing basis and that there will be 5 status words sent from the PDP-14 to the monitor. The requirement is for approximately 25 extra PDP-14 locations.

Question 6 is probably the toughest to answer. It is aimed at an estimate of the amount of PDP-14 memory required for the system. If equations on the average contain 5 variables (e.g. \( Y_1 = (X_2 + X_3 + X_4) \times X_5 \)), or more, a good estimate is that it will require \( 2N \) PDP-14 memory locations to solve the equation, where \( N \) is the number of variables. For less than 5 variables, \( 2N + 2 \) is the suggested estimating rule.

Let us assume there are on the average 7 variables in an equation (\( N = 7 \)). We have 72 output equations, 12 timer equations, 12 storage output equations, a total of 96 equations each requiring approximately 14 PDP-14 (\( 2N \)) locations. Thus, the memory requirement is 1344 locations (96 x 14). We also needed 25 locations to handle the monitoring needs. Thus a 2K (2000 location) memory is needed.

There are several trade-offs which may be made when configuring a system. Unused outputs may be used as storage outputs; programming (subroutines) may replace other storage outputs; monitoring systems may adjust the amount of processing done in the PDP-14 with the amount done in the monitor to vary the amount of memory required; excess memory may be used to diagnose equipment failures by turning on signal lights when inputs are found to be in the wrong state.

Developing the Control Program

The PDP-8 computer is used to run BOOL-14 and SIM-14 to write the PDP-14 control program. If the PDP-14 program will require greater than 1K of memory (1000 locations), an 8K PDP-8 is needed to develop the program. For programs of 1K or less, a 4K PDP-8 is sufficient.

The steps involved are:

1. Assign each input and output to a specific PDP-14 I or O-box and obtain the X and Y number.
2. Write the Boolean equations for each output using the X and Y numbers for inputs and outputs.
3. Type the equations on the Teletype.
4. Use BOOL-14 to generate the machine code program.
5. Read the machine code program into SIM-14.
6. Use local mode of SIM-14 to verify the instructions for each equation, by varying the input and recording the resultant output value; generate
truth tables for each equation; use simulated execution to test the whole program without attaching the PDP-14. SIM-14 will later be used to debug the complete hardware/software system.

Installing the PDP-14 Hardware

The PDP-14 hardware is installed within a standard NEMA 12 enclosure. The PDP-14 control unit is mounted near the bottom of the enclosure with the cables connecting it to the input, output, accessory and storage boxes. These boxes are usually mounted above the PDP-14 but still within the NEMA enclosure.

The required 110 VAC power is supplied to the processor directly. The I and O-boxes must be supplied independently with 110 VAC at each terminal either from an input, (e.g. limit switch) or to be switched to an output (e.g. a solenoid). The field wiring to the input and output strips may be direct or via terminal strips within the NEMA 12.

The PDP-14 system when installed may be thoroughly checked to ascertain that no damage to the circuitry was received during shipment using TEST-14, a PDP-8 based diagnostic program. This program operates on a 4K PDP-8 and exercises all of the internal PDP-14 logic and contains options for testing the I and O-boxes. Failures cause message typeouts on the teletype console indicating which test the PDP-14 failed. The documentation provided indicates which module or modules may be defective, and the priority in which they should be checked. A defective module may be replaced in seconds.

If the I and O-box circuitry is to be tested, the field wires to the O-boxes should not be connected. Field wiring to inputs which directly turn on other devices should also be disconnected.

Once the PDP-14 has been thoroughly tested (one pass through the test takes approximately 3 minutes), the field wiring, if not already in place, is completed to the I and O-boxes and the complete system is debugged.

Debugging the System

When the program has been written and debugged and the hardware is installed, the system is debugged using online mode of SIM-14. In online mode, the PDP-14 program, which has been thoroughly debugged in local mode of SIM-14, is supplied to the PDP-14 and executed. The machinery will operate under SIM-14 as it will when the ROM is installed except that the PDP-14 will check inputs and set outputs at a significantly faster rate when its program is stored in the ROM. (This difference in processing speed between online mode and the ROM will not be a factor in most applications and can be counteracted, if necessary, through use of software subroutines.)

Bringing up a system that is to be controlled by a PDP-14 is considerably easier than a relay controlled system, because of the features of online mode and the terminal lights of the I and O-boxes. Wiring errors are easily detected by looking at indicator lights. If an operation does not occur, a glance at the lights indicates which input or inputs is not present. Using SIM-14, the state of storage outputs, timers, and retentive memories may be determined. Quick patches may be made to the program if problems are discovered. Check out progresses at a considerably improved pace because of the PDP-14 hardware and software.
The PDP-14 program may be executed in online mode in sections, using strategically placed "program stops" at which point execution of the PDP-14 program halts and control returns to SIM-14. Shut-down sequences or "stop equations" that are executed before control returns to SIM-14 may also be used in online mode. Thus the PDP-14 program may be run in total, or if desired, in parts thereby testing each individual programmed operation.

Installing the ROM

Once the system has been checked-out and the program is correct, a paper tape is punched from which DEC will weave a ROM. The ROM will be returned to you in two to three weeks. During that time the PDP-14 may continue to operate in online mode of SIM-14 and thus the controlled equipment may still be operated.

Once the ROM (or ROM's, if a greater than 1K program is used) has returned, it is plugged into the PDP-14 mainframe. The PDP-8 interface cables for SIM-14 online mode are removed, and the PDP-14 system is complete.

Field rewiring can change any instruction in the program after it is woven in the ROM. The procedure is simply to clip the lead from the old wire, and solder a new wire in its place. The new wire is then placed through, or around, the series of transformer cores to represent the correct instructions. If more than 10% of the programmed instructions must be altered, the rewiring becomes cumbersome and a completely rewoven ROM should be considered.

A PDP-8 based program, VER-14 may be used to verify that the memory contains the same instructions as contained on a paper tape. Thus a program change should be made using SIM-14 and a new tape generated. (The change should, of course, be tested in local and online modes of SIM-14 first.) The wires may then be replaced in the ROM. When the ROM is re-installed in the PDP-14, VER-14 may be used to verify that the changes were properly made.

Maintaining the System

Once a system has been installed it may be maintained in several ways. When a failure occurs, it must be diagnosed to be in one of three areas:

(1) the controlled machine

(2) the input, output, accessory or storage boxes

(3) the PDP-14 control unit

Assume that the failure may be characterized as, "this should happen now, but it doesn't!" Examining the input and output lights, it can easily be determined if the output to start the operation is present and if the inputs required to activate this output are present. If the output is on, the problem is in the machine; if the output is off and an input required for that output is missing, the problem is in the machine. If all inputs are present and the output is missing, the fault can be either in the PDP-14 I and O-boxes or in the PDP-14 control unit.

Once it has been determined that the failure is in the PDP-14 part of the system, the isolation of the failure to either the I and O-boxes or the PDP-14 processor itself is achieved by assuming that the I or O-box is at fault. The I and O-boxes may be checked out by swapping the modules concerned with the faulty input or output. Spare part kits are available for this purpose. If
module swapping in the interface boxes does not resolve the problem, the PDP-14 processor must be considered at fault.

The processor may be checked out with TEST-14, the PDP-8 based diagnostic program to ascertain that the PDP-14 circuitry operates properly. If TEST-14 does not point out any electronic failure, the ROM memory may be tested with VER-14 against the paper tape record of the program. If no problem has been discovered in either the memory or the processor, it must be in the circuitry of the I and O-boxes. These may be tested using TEST-14 and a special box tester fixture. To perform this test, the field wires are first removed from the O-boxes.

If a PDP-8 is not available for testing the PDP-14, a portable tester may be purchased to determine the proper operation of the PDP-14. This unit plugs into the maintenance port on the front of the PDP-14 cover and shows proper operation of the PDP-14 through a set of display lights.

If neither a portable tester nor a PDP-8 is available, the central processor may be maintained by swapping modules using the spare part kit and the module utilization lists supplied with the PDP-14.

The maintenance procedure described above may be performed by the end user or by the wide network of well trained DEC Field Service Specialists. Service contracts beyond the 90 day warranty for the PDP-14 are available.
DEC PRODUCT SUMMARY

PDP-8/I and PDP-8/L

PDP-8/I and PDP-8/L are the latest members of the PDP-8 Family of general purpose computers. They are the faster, smaller and more economical successors to the over 4,000 PDP-8 Family computers installed all over the world.

Both PDP-8/I and PDP-8/L are built around the same 4,096-word, 12-bit core memory and fully parallel central processor. Both have TTL integrated circuits throughout. Both come with a big software package that is compatible throughout the PDP-8 Family. And PDP-8/I and PDP-8/L inherit a world-wide service organization renowned for its speed and dependability. PDP-8/L is the lowest cost full scale digital computer available. It comes in a very neat, small package with a very neat, small price. Just right for plugging into anybody's integrated system. PDP-8/I has the same basic capability plus an internal peripheral control and data break panel for plug-in expansion. The PDP-8/I is faster, slightly more expensive, and more flexible than the PDP-8/L. That's because the 8/I is designed for those who need plug-in expansion and the 8/L is designed for those who don't.

Both machines are built in the Digital tradition. They are tested and retested by skilled engineers and sophisticated computerized test equipment.

8/I Specifications:
Word Length: 12 bits
Memory: 4096 to 32,768 words; cycle time 1.5 microseconds
Add Time: 3.0 microseconds
In-Out Transfer Rates: 7,992,000 bits per second
Standard I/O Device: ASR-33 Teletypewriter with paper tape reader and punch

8/L Specifications:
Word Length: 12 bits
Memory: 4096 to 8192 words; cycle time 1.6 µsec
Add Time: 3.2 microseconds
In-Out Transfer Rates: 7,500,000 bits per second
Standard I/O Device: ASR-33 Teletypewriter with paper tape reader and punch
PDP-9 and 9/L

The PDP-9 is a general-purpose computer designed to handle a variety of on-line, real-time scientific applications calling for more power and flexibility than offered by the PDP-8. The basic PDP-9 features 8,192 words on 18 bit core memory; a real-time clock; a 300-character-per-second paper tape reader; a 50-character-per-second tape punch; and input-output teleprinter (KSR-33). Input/Output can be via programmed transfers, data channel transfers, or direct memory access.

Single address instructions are used, with auto-indexing and one level of indirect addressing permitted. A single memory reference instruction can directly address any location in a block of 8,192 words of memory. PDP-9 has a Direct Memory Access channel plus four built-in Data Channels.

A comprehensive software package including FORTRAN IV, MACRO Assembler, a monitor system, and diagnostic routines is provided with the basic machine. With the modular software package, PDP-9 users can program in a device-independent environment to take full advantage of configurations with mass storage devices and central processor options. And with the PDP-9 background/foreground monitor, new software can be tested con-currently with on-line system functions.

The $19,900 PDP-9/L, a smaller version of the PDP-9, is available at a 4096-word level that fits easily into a dedicated systems environment. Its basic software includes COMPACT, a complete programming system for the 4K PDP-9/L, with Assembler, Editor, Math Package, debugging programs (ODT, Trace), and utility programs, all with complete upward compatibility.

Expanded, the PDP-9/L can take full advantage of the Advanced Software System developed for the PDP-9.

Specifications:

- 4096 18-bit words of core memory, expandable to 32,768 words
- 1.0 microsecond cycle time (1.5 microseconds on 9/L systems)
- 4 data channels
- Up to 64 input/output devices
- COMPACT, a complete software system for the 4K PDP-9/L
- Advanced Software System for larger machines, including FORTRAN IV and background/foreground monitor

Options. DECtape, IBM-compatible magnetic tape, displays, A/D converters, line printers, card readers, plotters, etc.
PDP-10

PDP-10 is an expandable, 36-bit computer system designed to perform conversational time-sharing, real time applications, and batch processing simultaneously. It is currently serving in such wide spread applications as physics and bio-medical research, process control, university and industrial computation, time-sharing utilities, chemical research, and hybrid simulation.

The PDP-10 includes an extremely powerful processor with 16 general purpose registers for use as accumulators or index registers, from 16,384 to 262,144 words of 36-bit core memory, and a seven level priority interrupt subsystem. The PDP-10 features an I/O bus which provides 200K word/sec transfer rate and interfaces up to 128 devices or device controllers with the processor. It has 366 easy-to-learn and logically complete instructions.

All PDP-10 systems have in common two basic hardware elements: the central processor and core memory. The same central processor is used in every PDP-10 configuration, but core memory can be composed of any mix of several modules, which vary in size, speed, and cost.

The remainder of the system depends upon the functions it will perform. Software choices include three levels of monitors: single user, multiprogramming, and the multiprogramming/swapping monitor. Most software is re-entrant so that a single compiler can serve many users simultaneously, allowing more users to reside in core at the same time and providing better system response.

Other software includes FORTRAN IV, BASIC, AID, COBOL, a macro assembler, a context editor, a symbolic debugging program, a peripheral interchange program, a desk calculator and FORTRAN library programs. All software systems assure upward compatibility from the standard 16,384 words of memory through the multiprogramming and swapping systems at both the symbolic and relocatable binary level.

Hardware choices include three types of disk systems, magnetic tape units, DECTape systems, line printers, card readers and card punches, communications equipment, CRT displays, plotters, and real-time interface equipment.

PDP-10 features a 1-microsecond cycle time, a 2.6 microsecond add time and a modular, proven software package that expands to make full use of all hardware configurations. Memory can be expanded in 8,192, 16,384, or 32,768 word increments to the maximum directly addressable 262,144 words.
PDP-12

Digital's PDP-12 is a general-purpose computer system. It is designed as a simple to operate, yet uniquely flexible tool for a wide variety of research and real-time data handling applications.

Performance characteristics of the PDP-12 have been optimized around a complete hardware/software system, rather than an expandable minimum configuration. The PDP-12 systems concept works to the advantage of users at all levels of programming sophistication. By simplifying programming tasks, the PDP-12 frees users from the mere mechanics of program preparation to concentrate on the more creative aspects of their work.

The following is a brief list of some of the PDP-12's outstanding features:

- All-new, unified display-based programming system
- Automatic program loading from magnetic tape
- Built-in program debugging hardware
- 7” x 9” CRT display with graphic and alphanumeric capabilities
- Large existing library of applications programs
- TTL integrated-circuit modules throughout
- LINCTape-addressable, bi-directional program and data storage
- Free-standing cabinet and console table

Specifications:

- 4,096 12-bit words of core memory, expandable to 32,768 words
- 1.6 microsecond cycle time
- 43 basic instructions including 29 memory reference instructions
- 15 auto-index registers
- 6 programmable SPDT relays
- 6 sense switches
- 12 external sense lines
- Peripherals including 16-channel A/D converter, DECtape units, and new 7” x 9” display, all fully buffered
- Software: new unified display-based system; FORTRAN, FOCAL, BASIC, mathematical, maintenance, and utility routines
PDP-15

PDP-15 systems offer comprehensive solutions to real-time data problems. They combine new design concepts with a wide array of traditional features that spring from Digital's years of leadership in the medium-scale scientific computer field. Both elements share the common purpose of simplifying the user's tasks in a demanding real-time environment.

Since certain types of data-handling tasks require specific hardware and software configurations, Digital has developed four standard PDP-15 systems, ranging in power from the modestly priced basic PDP-15/10 to the real-time disk monitor environment of the PDP-15/40. At every level, the capabilities of the hardware are under the control of a monitor designed specifically for them, so that for every step of hardware growth there is a straightforward step of software control to match.

- PDP-15/10: 4,096 18-bit words of 800-nanosecond core memory, Teletype Model ASR-33 console teleprinter. COMPACT Software System including assembler, editor, debugging aids, and mathematical and utility routines.

- PDP-15/20 Advanced Monitor System: 8,192 words of core memory, KSR-35 Teletype for extra reliability, two DECTape transports and control unit, high-speed paper tape reader/punch, Extended Arithmetic Element for high-speed arithmetic operations and register manipulation. Advanced Monitor System with FORTRAN IV, FOCAL-15, MACRO-15 macro assembler, linking loader, batch processor, system generator, scientific library, and comprehensive debugging and utility routines.

- PDP-15/30 Background/Foreground System: 16,384 words of core memory, KSR-35 Teletype, Extended Arithmetic Element, Automatic Priority Interrupt system, Memory Protect system, high-speed paper tape reader/punch, three DECTape transports and control unit real-time clock, and a second on-line Teletype for background use. Background/Foreground Monitor System combining all Advanced Monitor functions with concurrent execution of real-time foreground tasks and program development or other low-priority background computation.

- PDP-15/40 Disk-Oriented Background/Foreground System: 24,576 words of core memory, KSR-35 Teletype, Automatic Priority Interrupt system, Relocation/Protect system, high-speed paper tape reader/punch, two DECTape transports and control unit, RF15 DECDisk control and two RS09 random-access disk files, real-time clock, and a second on-line Teletype for background use. Disk-oriented version of the Background/Foreground Monitor system, allowing concurrent execution of real-time tasks and background computation, in addition to all standard Advanced Monitor functions.
COMPUTER LAB

The COMPUTER LAB is a new high performance low-cost digital logic trainer. The COMPUTER LAB uses the same monolithic integrated transistor-transistor logic circuitry used in DIGITAL's latest PDP computers.

The digital logic fundamentals presented by the COMPUTER LAB constitute the basic knowledge required to pursue a career in computer technology as computer technician, engineer, programmer or operator. The COMPUTER LAB will also help the math-oriented student to understand "New Math" concepts because computer logic operates with binary numbers according to Boolean algebraic laws.

Wiring is easy because of the standard logic symbology used on the front panel and the color coded Patchcords which are easily inserted and removed. An improper circuit will not damage the COMPUTER LAB. The faulty circuit merely "waits" for correction.

Features:

- Transistor—Transistor logic circuitry as used in DIGITAL's PDP computers
- Teaches modern computer logic
- Easy to use: MIL-STD 806 logic symbology on front panel
- Portable: Dimensions of 12½" x 17" x 3¼", weighing only 11 lbs.
- Comprehensive Workbook provides:
  - Ten detailed chapters
  - More than 30 experiments
  - Over 200 hours of laboratory study
  - Dozens of tables and diagrams
  - An extensive appendix of supplementary information
- Teacher's Guide with answers, additional text, extra problems, course plans, at only $5.00
- Low cost: COMPUTER LAB, Workbook and Patchcord set, ready to use $445.00
WARRANTY

WARRANTY 1. B, R, W, M, K, AND A MODULES — All B, R, W, M, K, and A modules shown in Catalogs C-105, or C-110 as revised from time to time, are warranted against defects in workmanship and material under normal use and service for a period of ten years from date of shipment providing parts are available. DEC will repair or replace any B, R, W, M, K, or A modules found to be defective in workmanship or material within ten years of shipment for a handling charge of $5.00 or 10% of list price per unit, whichever is higher. Handling charges will be applicable from one year after delivery.

WARRANTY 2. SYSTEM MODULES, LABORATORY MODULES, HIGH CURRENT PULSE EQUIPMENT, G, S, H, NON-CATALOG FLIP-CHIP MODULES AND ACCESSORIES — All items referenced are warranted against defects in workmanship and material under normal use service for a period of one year from date of shipment. DEC will repair or replace any of the above items found to be defective in workmanship or material within one year of shipment. Handling charges will be applicable from one year after delivery with handling charges varying depending on the complexity of the circuit.

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Modules must be returned prepaid to DEC. Transportation charges covering the return of the repaired modules shall be paid by DEC. DEC will select the carrier, but by so doing will not thereby assume any liability in connection with the shipment nor shall the carrier be in any way construed to be the agent of DEC. Please ship all units to:

Digital Equipment Corporation
Module Marketing Services
Repair Division
146 Main Street
Maynard, Mass. 01754

No module will be accepted for credit or exchange without the prior written approval of DEC, plus proper Return Authorization Number (RA#).

All shipments are F.O.B. Maynard, Massachusetts, and prices do not include state or local taxes. Prices and specifications are subject to change without notice.

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INDEX

Adder, Serial .............................................................. 204
Amplifier, Differential .................................................. 72, 74, 126, 184
Amplifier, Operational .................................................. 126
Amplifier, Transducer ................................................... 72, 74, 126, 184
Analog-to-Digital Converters .......................................... 178
Annunciators .................................................................. 192
BCD ................................................................. 27, 38, 42, 60, 62, 64, 78, 94, 182, 190, 191
Brake Drivers ................................................................. 92, 93
Cabinets ..................................................................... 146, 147
Clutch Drivers ................................................................. 90, 92, 93
Comparator, Analog ........................................................... 74, 126
Comparator, Digital ........................................................... 23, 30
Computer Lab .................................................................. 276
Computers ..................................................................... 266
Connector Mounting Bars ............................................... 118, 137
Connectors .................................................................... 120, 121, 138, 139, 140, 148
Control Systems .............................................................. 224
Conversion, Analog-to-Digital .......................................... 178
Conversion, Digital-to-Analog .......................................... 128
Counters, Binary-coded Decimal ...................................... 38, 40, 42
Counters, Switch-tail Ring ................................................. 208
Counters, Up/Down ........................................................... 42, 182, 197, 203
Data Acquisition Systems ................................................. 228
Decimal Counters .............................................................. 38, 40, 42
Decimal Decoders ............................................................... 28
Decimal Indicator ............................................................... 60, 94
Decoding — Digital ........................................................... 19, 23, 24, 27, 30, 64
Delay ........................................................................... 11, 48, 50, 52, 54, 66, 124, 166, 174, 181, 190, 197
Differential Amplifier — Fixed Gain .................................... 126
Digital Divider ................................................................. 33, 34, 38, 40, 42, 44
Digital Inputs .................................................................... 7, 10
Discriminator, Frequency ................................................... 174
Discriminator, Voltage ..................................................... 72, 74, 126, 184
Drivers, Clutch/Brake ....................................................... 90, 92, 93
Drivers, Indicator ............................................................... 96
Drivers, Motor Starter ....................................................... 85, 88, 90, 92, 93
Drivers, Relay/Solenoid ..................................................... 85, 88, 90, 92, 93
Drivers, Stepper Motor ..................................................... 93
Drivers, Using ................................................................ 188
EIA Converters ................................................................ 84, 98
Encoding — Digital ........................................................... 61, 62
Equality — see Comparators
Flip-Flops ................................................................. 18, 25, 33, 34, 36
Hydraulic Valve Drivers ................................................... 92, 93
INDAC Systems ................................................................. 228
Indicators .................................................................... 59, 60, 96
Indicator Drivers ................................................................. 96
Input Converters ................................................................. 69, 70, 72, 74, 78, 80, 82, 84
Input Loading .................................................................. 10
Interfaces, transducer ....................................................... 72, 74, 126, 184
Isolated AC Switches ......................................................... 85, 88, 214
Limit Switch Inputs ........................................................... 70, 80, 82
Logic Lab — K Series ........................................................ 217

281
M Series Modules — inquire at nearest sales office

Manual Controls ................................................. 59
Memories ....................................................... 18, 25, 33, 34, 36, 42, 44, 45, 46, 47, 196
Monostable Multivibrator ...................................... 52
Motor Starters .................................................. 86, 88
Motor, Stepper .................................................. 206
Multiplexer Digital ............................................. 16, 17, 18, 21, 26, 27
Multiplier, Pulse Rate .......................................... 32, 198
Noise (electrical) ................................................ 4, 17
Numerical Control ............................................... 226
Numerical Control Tape Preparation ......................... 226
Off-Delay ......................................................... 48, 50
One-Shot ......................................................... 52, 181
Operational Amplifiers ........................................ 126
Output Converters .............................................. 85, 88, 90, 92, 93, 94, 96, 98
Output Loading .................................................. 10
Panel, Control ................................................... 122, 218, 219, 220
Patch Cords ..................................................... 219
PDP-8/I ............................................................ 266
PDP-8/L ............................................................ 266
PDP-9/I ............................................................ 268
PDP-9/L ............................................................ 268
PDP-10 .............................................................. 270
PDP-12 .............................................................. 272
PDP-14 .............................................................. 246
PDP-15 .............................................................. 274
Power Supplies ................................................. 108, 109, 110, 112, 114, 121, 130, 132
Photocell Inputs ................................................ 72, 74, 126, 184
Pneumatic Valve Drivers ...................................... 92, 93
Pulse Amplifiers ............................................... 52
Pulse Generators ............................................... 181
Quadrature Decoders .......................................... 78, 182
QUICKPOINT ................................................... 226
Real-time Clock .................................................. 38, 40, 108
Relay Drivers .................................................... 85, 88, 90, 92, 93
Scanners .......................................................... 17, 21, 27, 166
Sensor Converters .............................................. 72, 74, 126, 184
Sequencers ....................................................... 166
Setpoint Control .................................................. 174
Shift Registers ................................................... 33, 34, 44, 208, 209, 210
Shift Registers, Bi-directional ................................ 208
Starters, Motor .................................................. 86, 88
Stepper Motors .................................................. 206
Switches and Filters .......................................... 61, 69, 70, 80, 82, 194
Thermistor Inputs .............................................. 72, 74, 126, 184
Thumbwheel Switches ........................................... 62, 64, 194
Timer Controls ................................................... 54, 66, 124
Timers ............................................................... 48, 50, 168, 174, 175
Transducers Interfaces ....................................... 72, 74, 126, 184
Trimpots ............................................................ 72, 74, 184
Valve Drivers .................................................... 90, 92, 93
Wire ................................................................. 141, 144
Wire-wrap .......................................................... 142

282
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