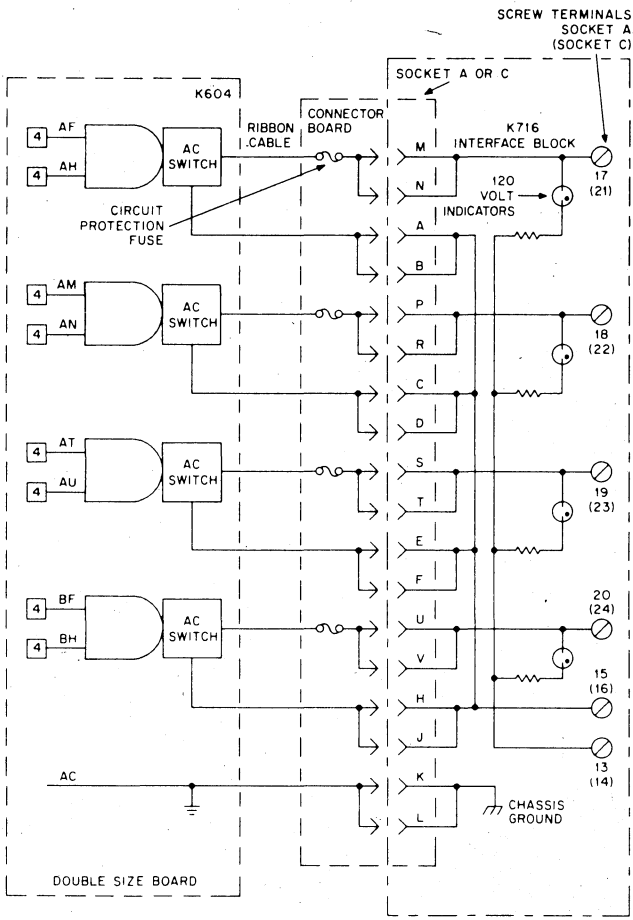
After the modules are flow-soldered, they undergo a visual inspection to insure that all solder points and runs are properly made. If needed, additional solder is added.

ISOLATED AC SWITCH
K604

K SERIES



Operating in conjunction with the 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_R motor starters. Less sensitive starters or relays may have significantly reduced capacity.

K604 — $82

Maximum Capacity, each K604 circuit (120 v AC lines)						
Condition	Continuous V.A.	Inrush V.A.	Motor Direct	Type K Starter	208/220 Max. H.P.	480/600 Max. H.P.
With Fuse	250	600	1/20 H.P.	Size 3	30	50
No Fuse	250	1800	1/10 H.P.	Size 4	50	100

Littelfuze® 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.

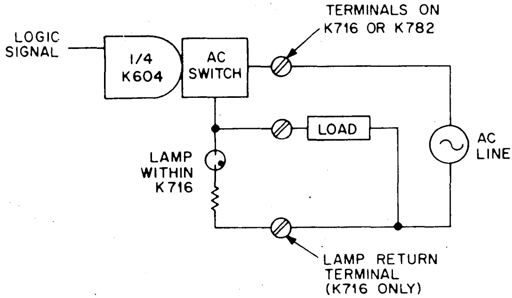
AC switch turnon takes place within 500 microseconds after input logic gate goes high. Turnoff takes place at zero crossings of the current. Maximum "off" leakage: 10 ma RMS at 140 VAC. Line voltage rating: 100 to 140 VAC, 50 to 60 Hz. Each triac output circuit has 400-volt breakdown rating. Shunt capacitor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

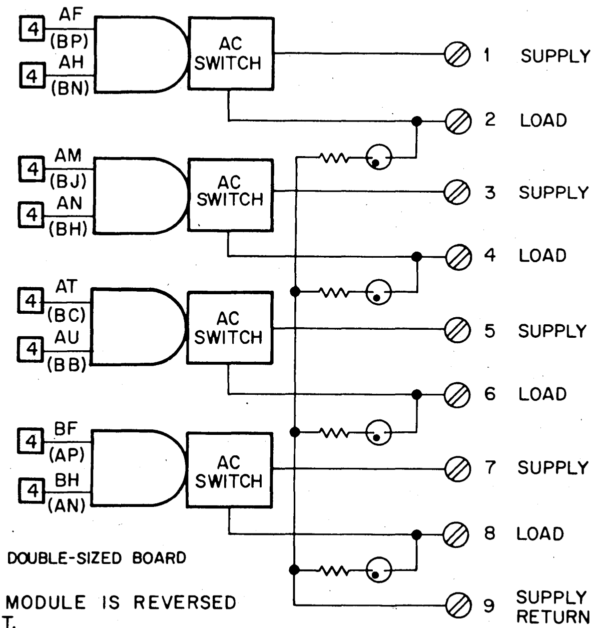
Two special precautions are made necessary by the presence of AC line voltages on the K604 module. First, always disconnect the ribbon cable connector before inserting or removing a K604 or an adjacent module, to avoid shocks or component damage. Second, W993 copper-clad boards ($4 each) should be installed 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 by the K782, however.

For 240 volt operation, refer to the application note on this topic.



K604 CIRCUIT IN USE



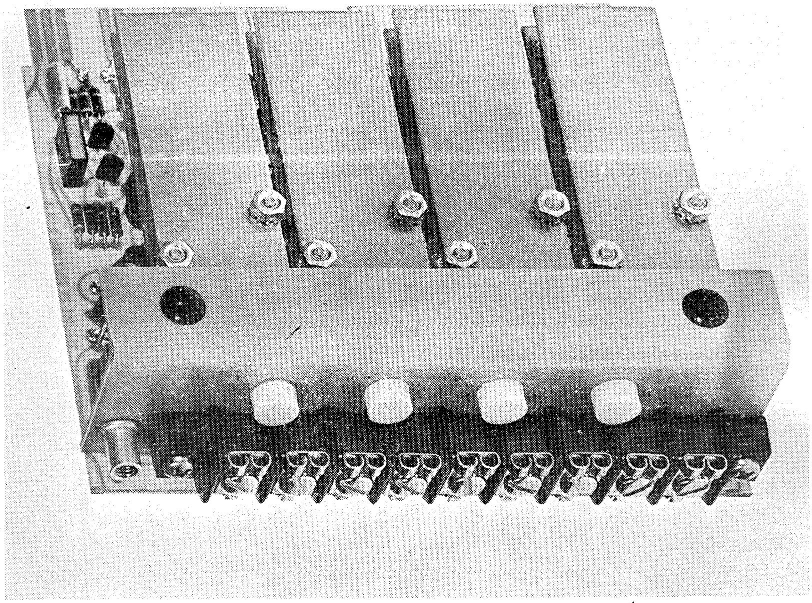
NOTES:
(GR=BT) DOUBLE-SIZED BOARD
(+5=AV)
( )PINS IF MODULE IS REVERSED IN SOCKET.

K614 AC SWITCH

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, Neon indicators, and output ratings boosted to 500 VA per circuit by the larger heat sink area available in this configuration. However, total for any module must not exceed 750 volt-amperes averaged over any one minute.

See Applications Notes for information on 240 volt operation.

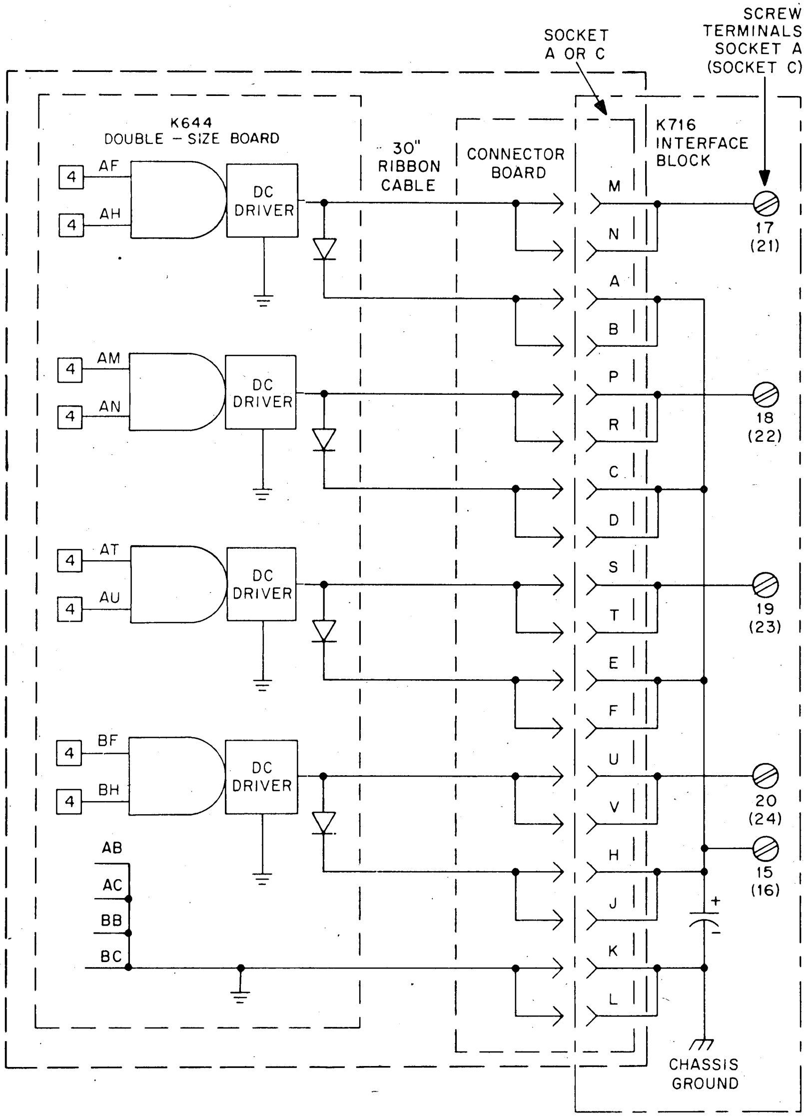
K614 — $88



K614 TERMINALS AS VIEWED LEFT TO RIGHT ARE NUMBERS 1 THROUGH 9

DC DRIVER
K644

K SERIES



K644 — $66

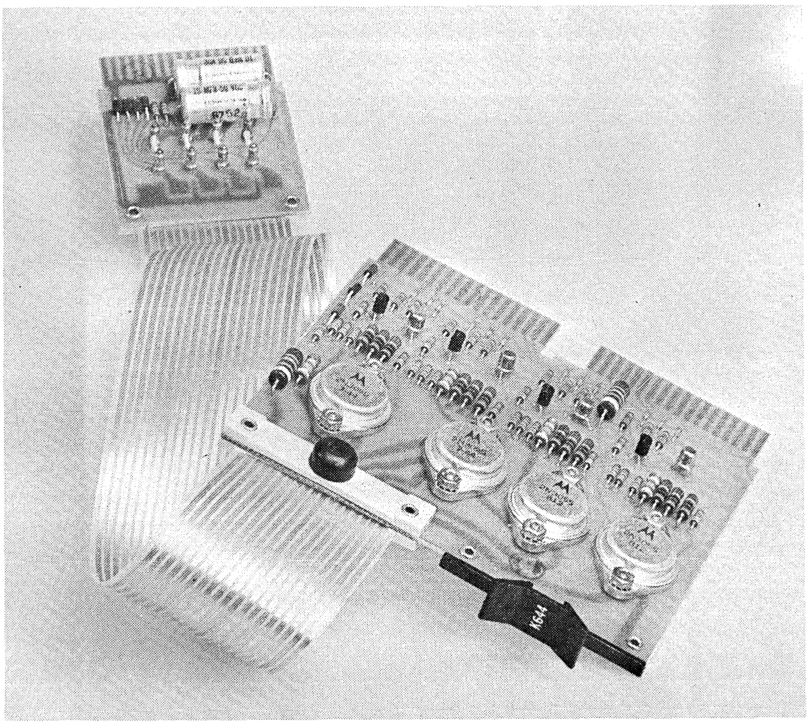
Operating through the K716 Interface Block, the K644 DC Driver permits stepping motors, dc solenoids, and similar devices rated up to 2.5 amperes at 48 volts to be driven directly from K series logic. Built-in clamping diodes protect switching transistors from transient over-voltage.

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 load supply to protect the module from overvoltage during turnoff.

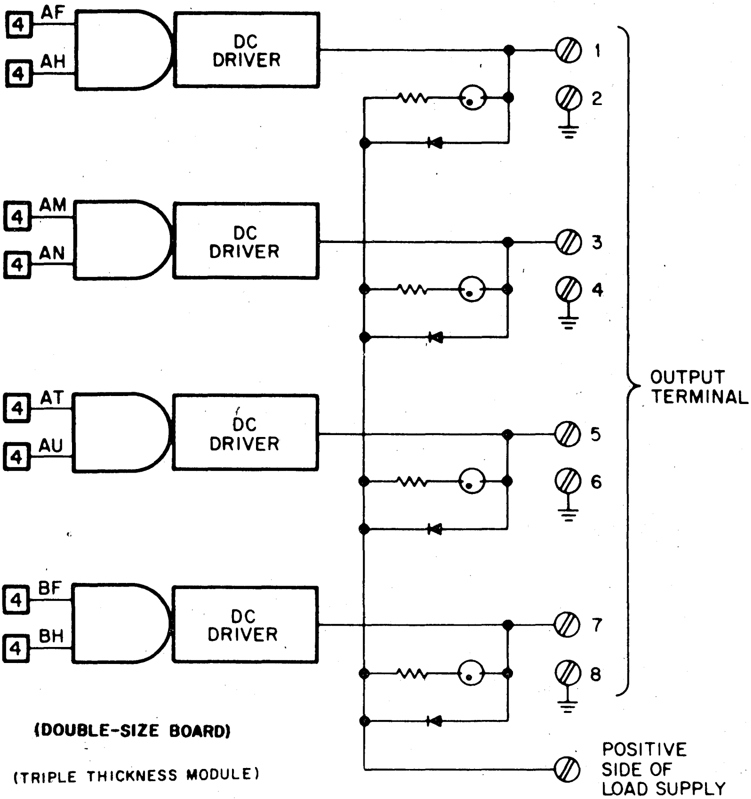
The K644 may be used with a K782 instead of a K716 to obtain the screw terminals needed for connecting heavy duty field wiring.

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



DC DRIVER
K656

K SERIES



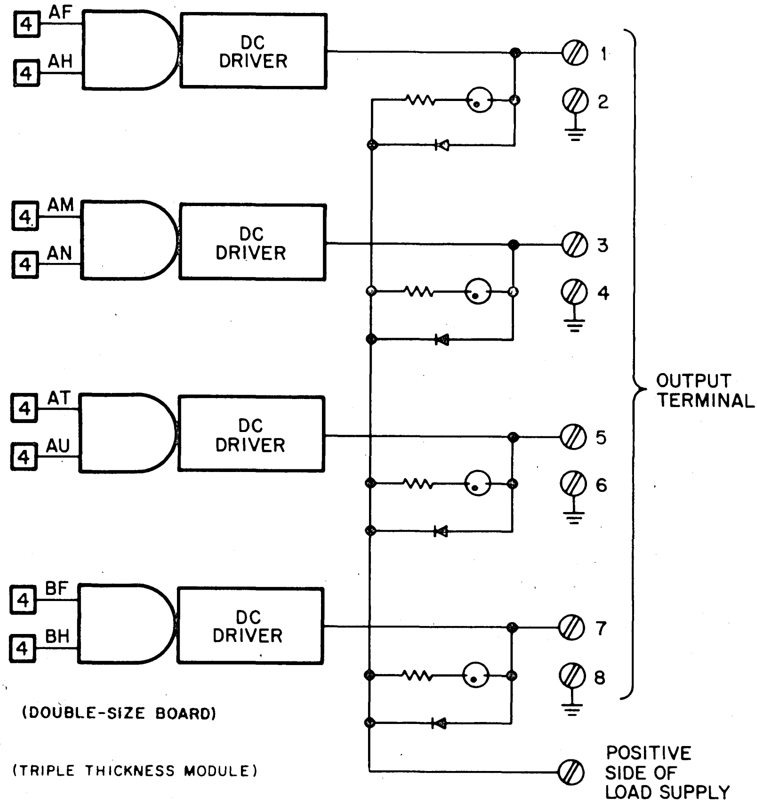
K656 250 VOLT DRIVER

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 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.

K656 — $80

DC DRIVER
K658

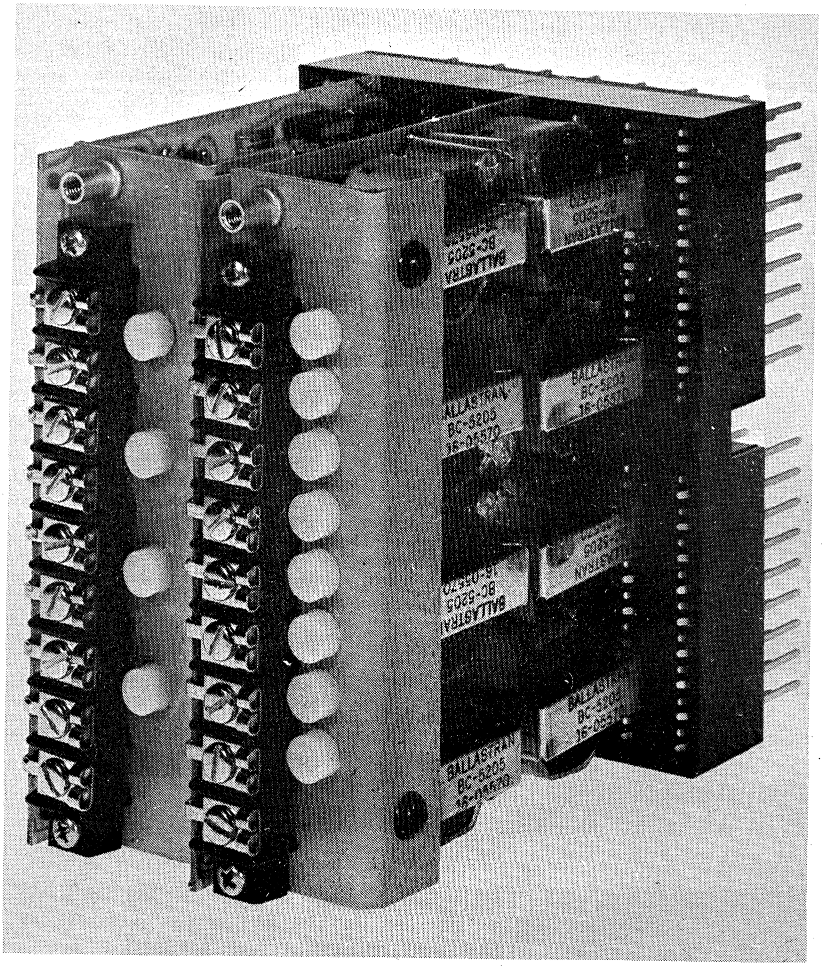
K SERIES



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.

K658 — $128

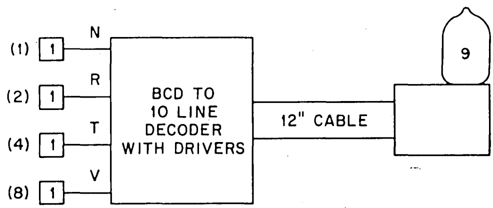


K656 AND K578

Modules with terminal strip output connections may be used in the K724 and K725 interface shells or they can be used in the K943 mounting panels. K578, K614, K656, and K658 are all triple thickness modules.

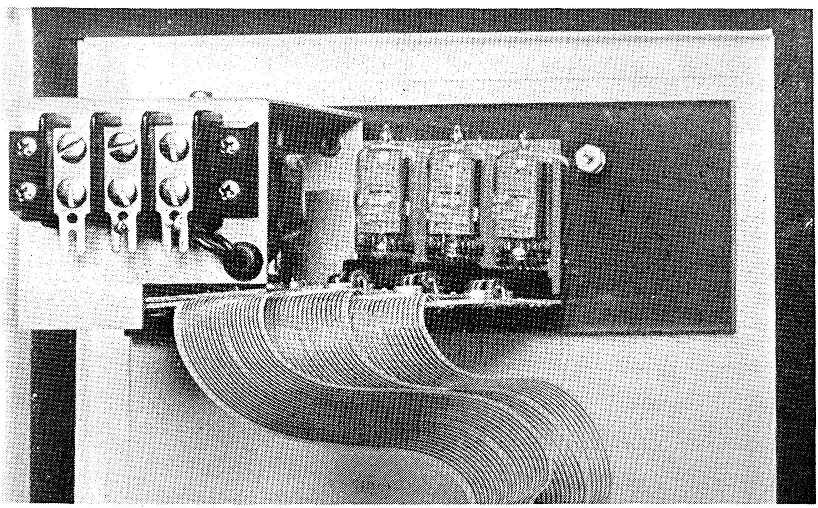
DECIMAL DECODER AND NIXIE DISPLAY
K671

K SERIES



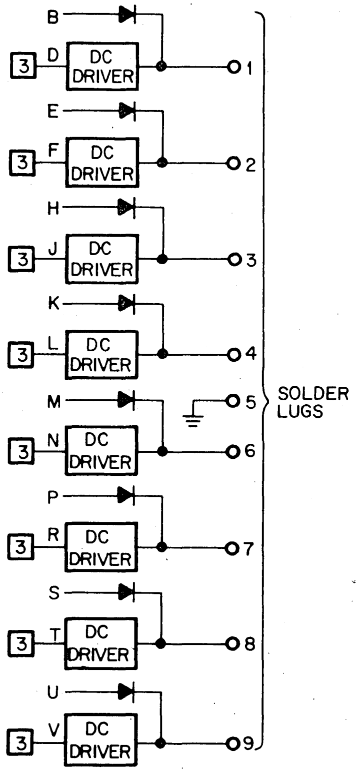
This module has two parts separated by a 1-foot ribbon cable. One part plugs into any module socket, the other contains a side-viewing Burroughs type B-5440 long life NIXIE glow tube on a mounting board. Four connections to corresponding module socket pins of a K210 or K220 binary-coded decimal counter 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.

K671 — $43

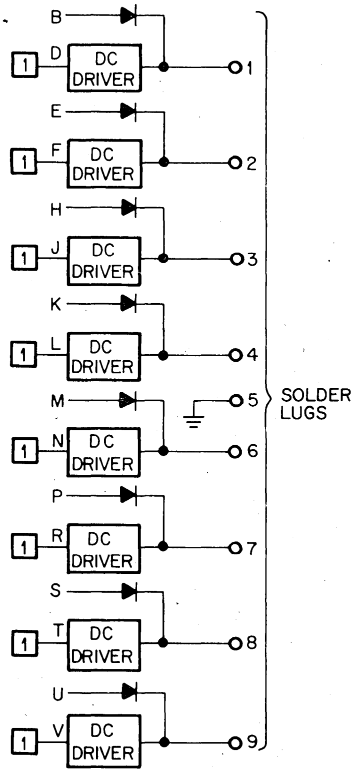


LAMP DRIVERS
K681, K683

K SERIES



K681 LAMP DRIVER



K683 LAMP DRIVER
(DOUBLE-SIZE BOARD)

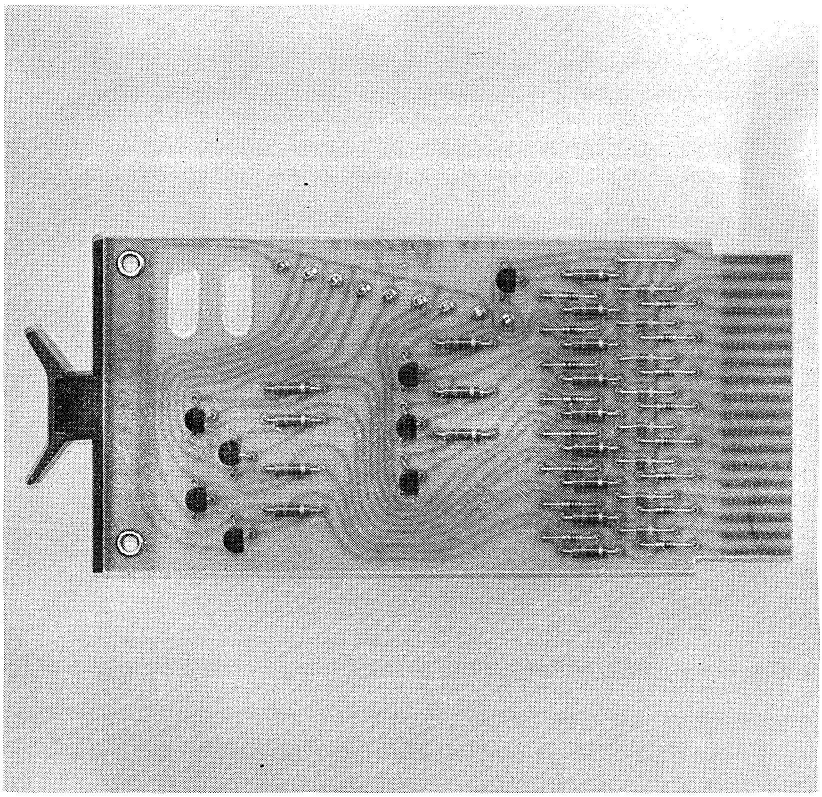
These eight-circuit modules drive external loads through 9-conductor cable soldered to split lugs at handle end by user. Strain relief holes, prepunched in board. Ground input to turn off, +5V to turn on.

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

MODULE TYPE	OUTPUT RATINGS		
	RESISTIVE	INDUCTIVE	INCANDESCENT LAMPS
K681	18V, 30ma	18V, 30ma with suppression diodes (K784)	Lamps rated 18V, 40ma operated at 12V to reduce current to 30 milliamperes.
K683	55V, 250ma	55V, 250ma with added suppression diodes (K784)	Lamps rated 40ma, to 48V; Lamps rated 60ma, to 28V; Lamps rated 80ma, to 18V; Lamps rated 100ma, to 12V

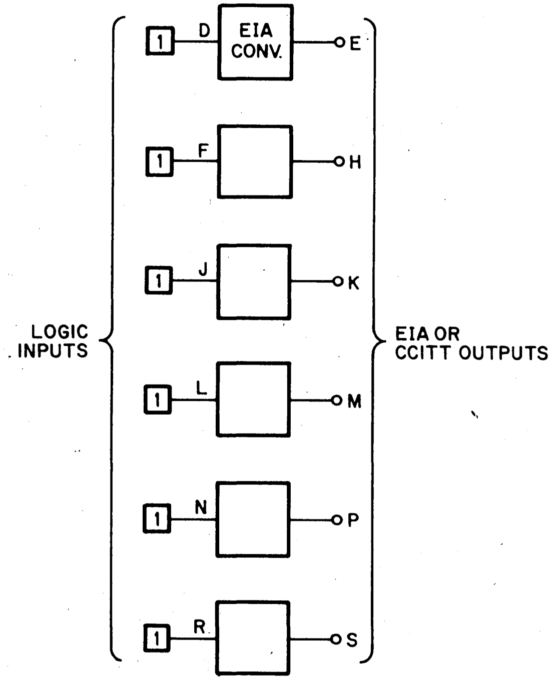
Note greatly reduced ratings on tungsten loads. Lamp filaments draw typically ten times more current at turnon than when hot, resulting in very high transistor dissipation if supply voltage is high. Series current limiting resistors or shunt preheát resistors could be used to limit surge in certain cases, but ratings above assume this would be awkward or impractical.



K681 MODULE

EIA OUTPUT CONVERTER
K696

K SERIES



EIA OUTPUT CONVERTER K696

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.

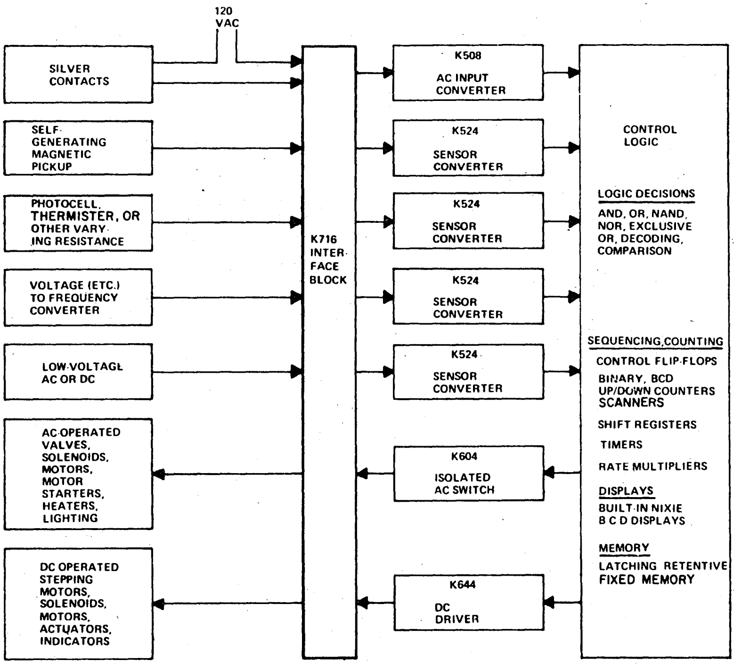
Please observe that noise and interference can enter a digital system through any wires that pass through a noise field. K696 modules should be located at the edge of the system, and communications wiring should not be allowed to lie close to logic wiring for more than a few inches. A high impedance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

K696 — $44

In addition to being a set of noise-immune logic, the DIGITAL K Series offers a versatile system of modular instrumentation and control hardware. On the following pages you will find a variety of equipment for mounting, wiring, powering, etc. The table below may help you get acquainted.

FUNCTION	PRODUCT	
Accessories for Interface Modules (K5XX, K6XX)	K716	Interface Block
	K724	Interface Shell, Power wiring only
	K725	Interface Shell, Prewired for scanning
	K782	8 Terminals
	K784	8 Terminals with Diodes
Power	K731	1 Amp Regulator
	K732	2 Amp Slave Regulator
	K741	2 Amp Transformer
	K743	3 Amp Transformer with Auxiliary Winding
	K771	NIXIE Supply
Mounting Hardware and Connectors	K940	Mounting Foot for K941
	K941	Mounting Bar
	K943	64 Module 19" X 5¼" Mounting Panel
	K980	End Brackets
	1907	Hold-Down and Cover
	H001	Cover Supports
	H800	8-Connector Block
	H802	Single Connector

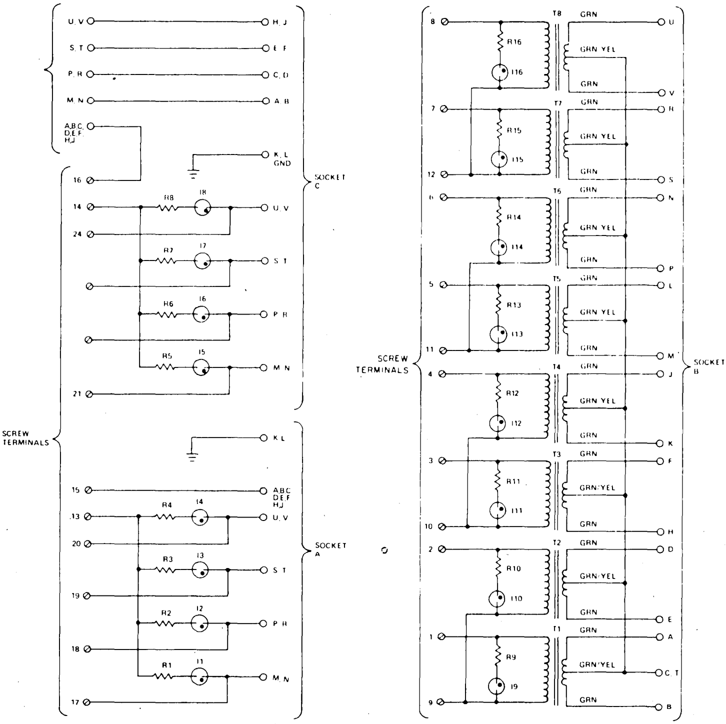
An important hardware feature of the K Series system is the K716 Interface Block, which permits field wiring to be installed at ordinary screw terminals by electricians. The logic modules interconnect to the K716 by plug-in ribbon cables.



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

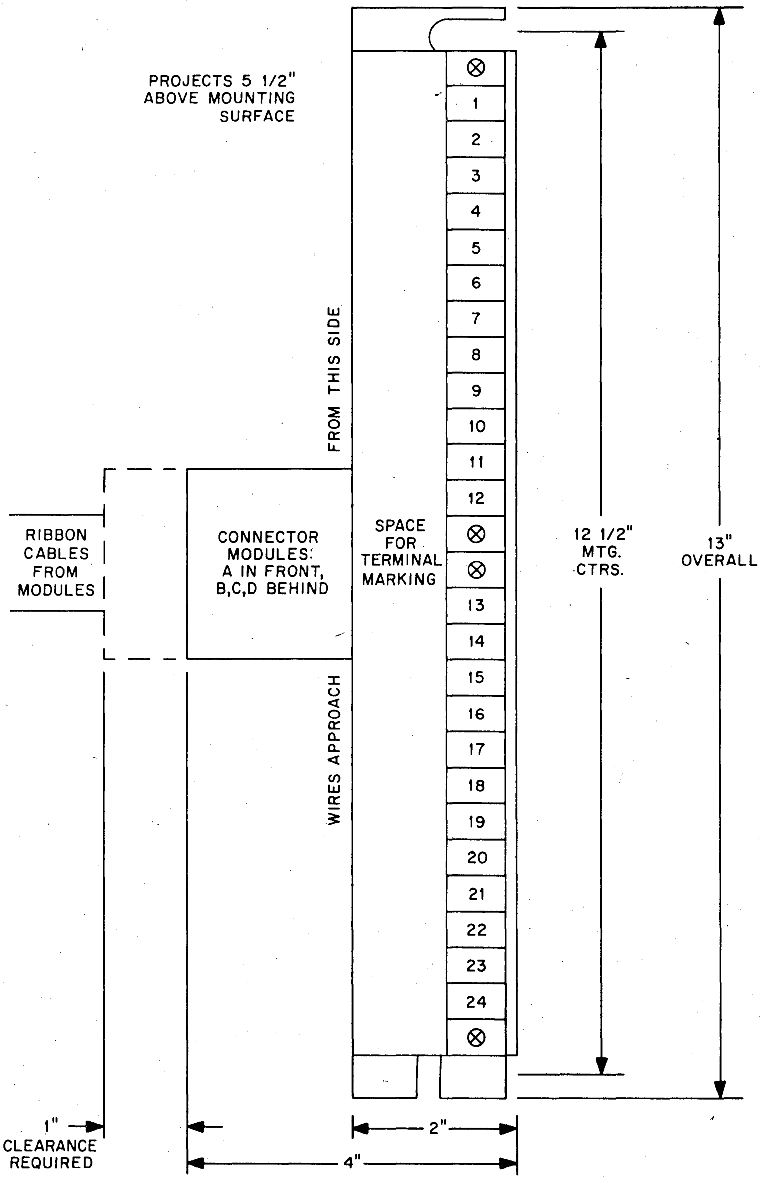
Ribbon cables from the K Series interface modules connect to printed circuit board sockets on the K716. This allows the K716 terminal block to mount on the rear panel of a NEMA enclosure for the convenience of electricians, while the digital system itself mounts on the door for easy access to both modules 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 mounting hardware, allows initial check-out 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.

K716 — $90



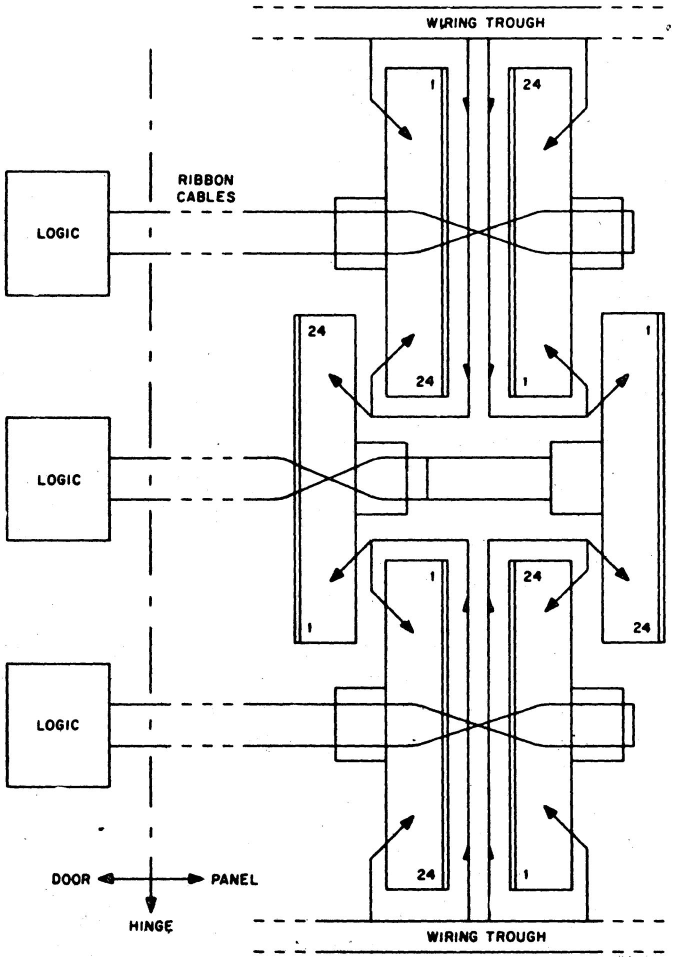
K716 INTERFACE BLOCK
FRONT VIEW

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

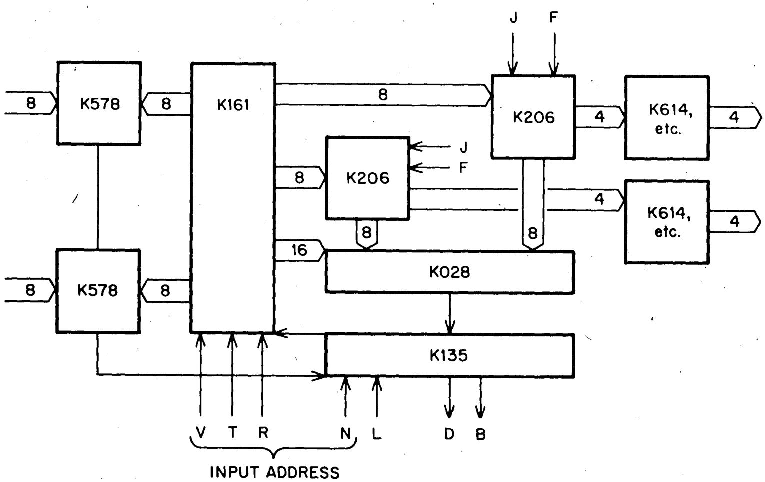
INTERFACE SHELLS
K724, K725

K SERIES

Unlike the K716 interface block pictured on the next page, 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 connections between 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

K724 — $55
K725 — $82

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.

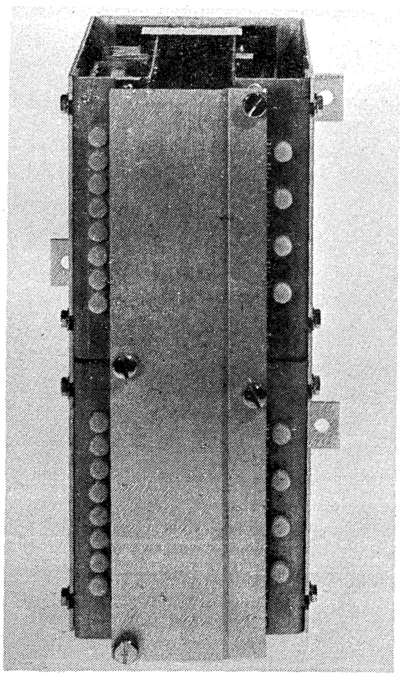
K206 Enable: If high, clears addressed output flip-flop or, if pin N is high, sets the flip-flop.

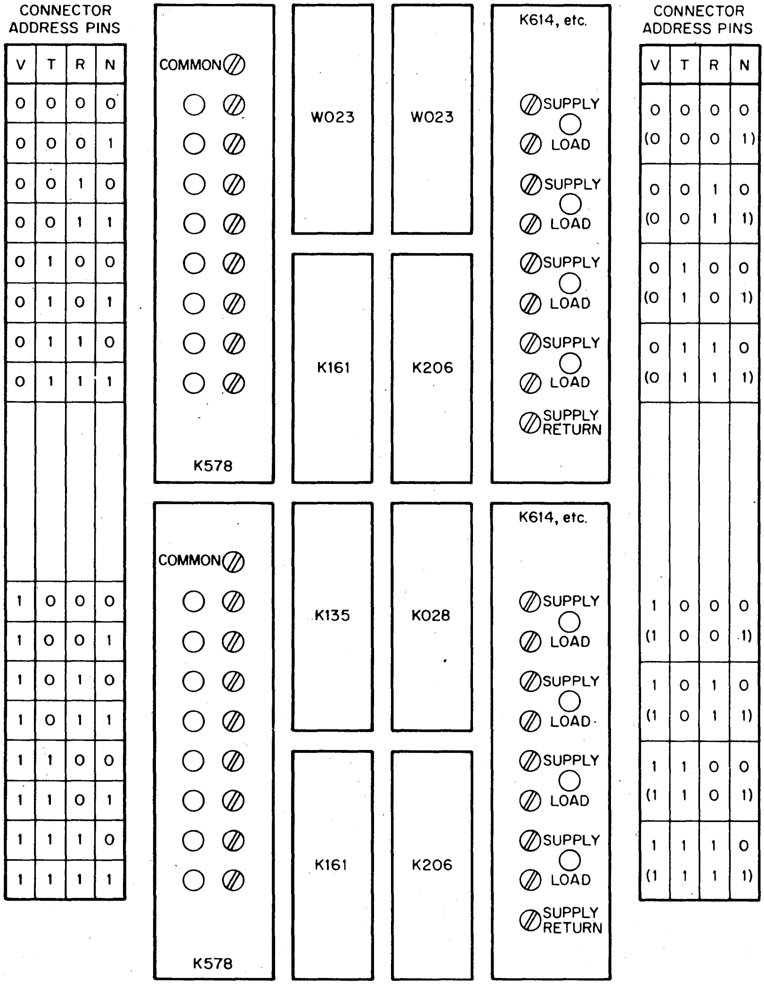
K206 Clear: If low, clears all output FFs.

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.

A	+5V power
B	K206 returns
C	Ground
D	K578 returns
E	spare
F	K206 enable
H	spare
J	K206 clear
K	spare
L	K135 enable
M	spare
N	Address, LSB
P	spare
R	Address
S	spare
T	Address
U	spare
V	Address, MSB



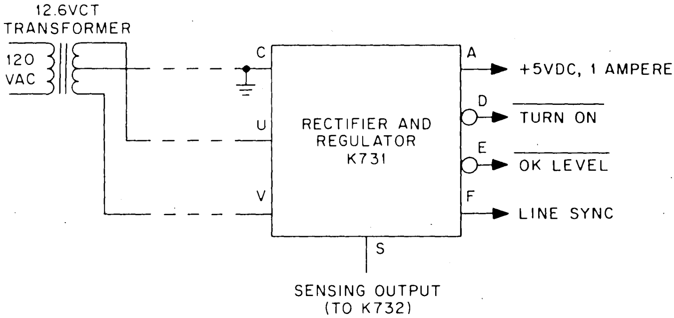


K725

INTERFACE SHELL

SOURCE MODULE
K731

K SERIES



(TRIPLE THICKNESS MODULE)

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 v (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 fan-out 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.

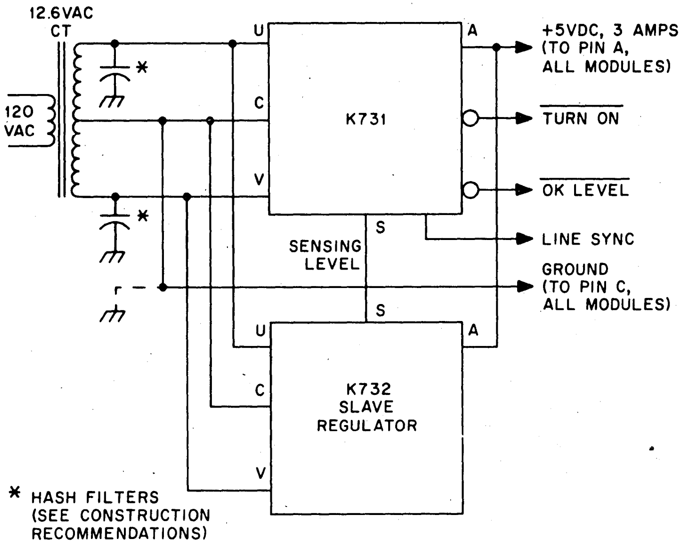
K731 delivers up to 1 ampere when used with a 12.6 volt transformer rated for 105-130 volt line. For 5% input voltage reduction (12.0 V transformer or 100 volt line) the output current capability decreases 10%. Output voltage temperature coefficient is typically minus 0.1%/°C. See summary of module current consumption following K732 data, and K741-K743 transformers on following pages.

See power supply section for photos.

K731 — $24

SLAVE REGULATOR
K732

K SERIES



(FOUR MODULES THICK)

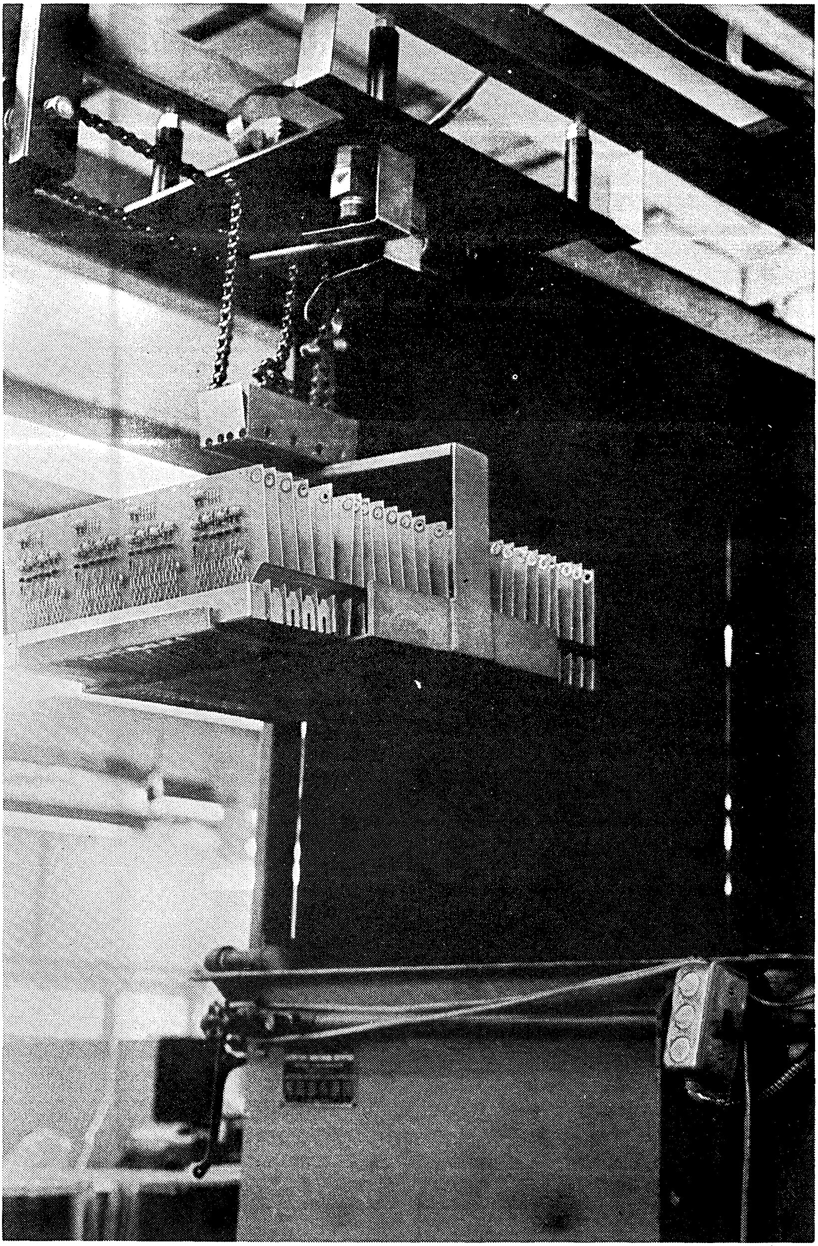
This module is normally tied to corresponding pins A,C,S,U, and V of a K731 Source. For each unit of current emitted by the K731, the K732 emits two. Up to three K732 slaves can be controlled by a single K731 for a total system current of 7 amperes.

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 K732 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.

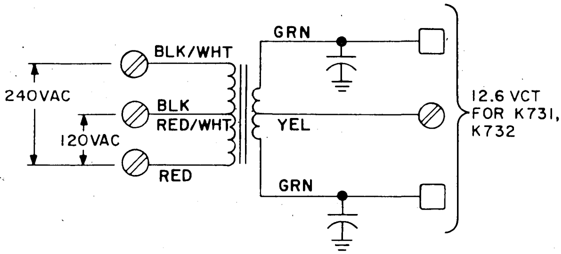
K732 — $27



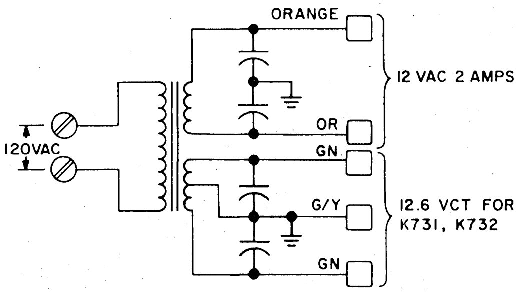
After all the components have been attached to the board, the module is degreased to remove contaminants in preparation for flow soldering.

POWER TRANSFORMERS
K741, K743

K SERIES



K741 TRANSFORMER WITH FILTER



K743 TRANSFORMER WITH FILTER

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 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:

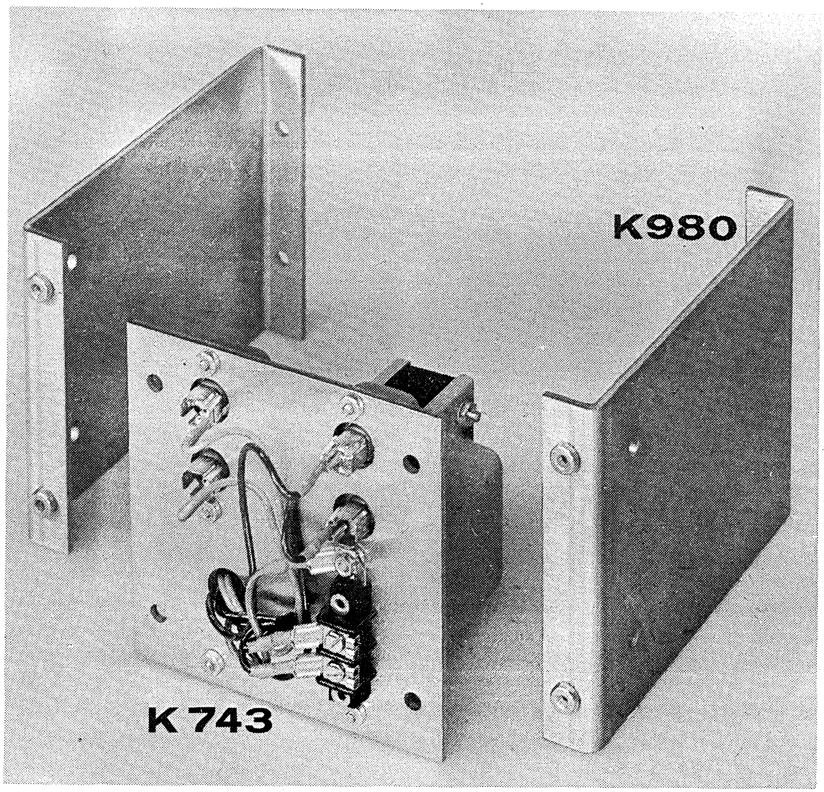
	PLATE DIMENSIONS	HOLE CENTERS	MATCHING K980 Ctrs.
K741	3½″ x 5″	2½″ x 3⅜″	2½″
K743	5″ x 5″	4″ x 3⅜″	4″

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.

60 Hz	50 Hz	K732	TRANSFORMER
0.1-1A	0.1-0.8A	0	K741 or K743
0.5-2A	0.4-1.6A	1	K741 or K743
1-3A	0.8-2.4A	1	2 K741s or K743
2-4A	1.6-3.2A	2	2 K741s or 2 K743s
3-5A	2.4- 4A	2	3 K741s or 2 K743s
4-6A	3.2-4.8A	3	3 K741s or 2 K743s
5-7A	4-5.6A	3	4 K741s or 3 K743s

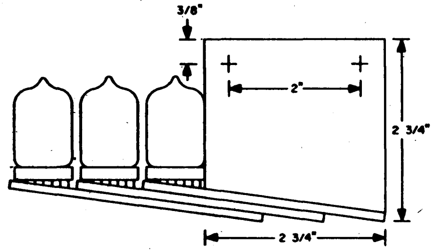
K741 — $22
K743 — $38



K743 WITH K980

DISPLAY SUPPLY
K771

K SERIES



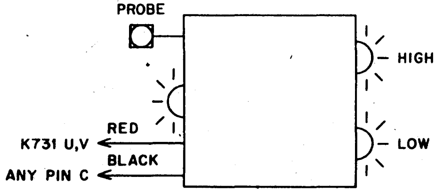
(SHOWN WITH 3 K671'S)

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" 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

K SERIES



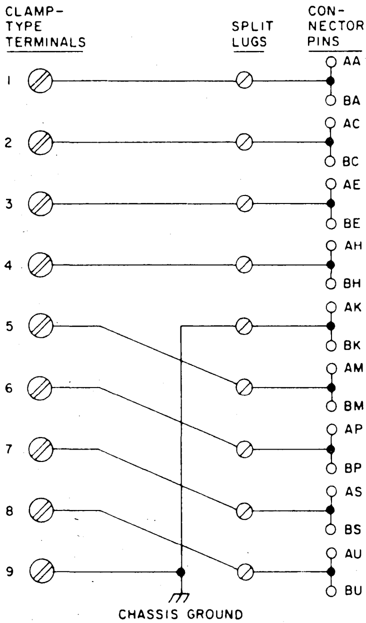
K791 TEST PROBE

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.

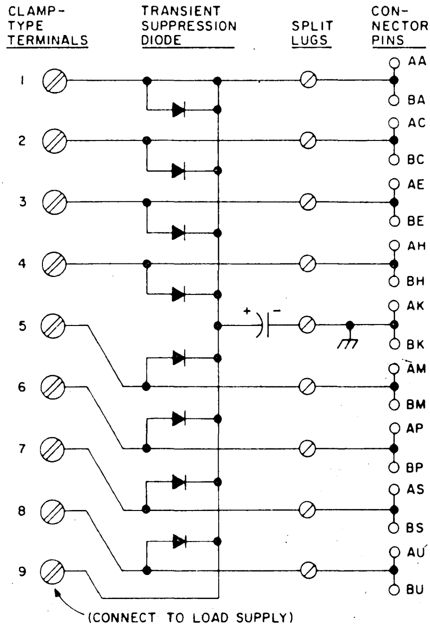
K791 — $27

TERMINALS
K782, K784

K SERIES



K782



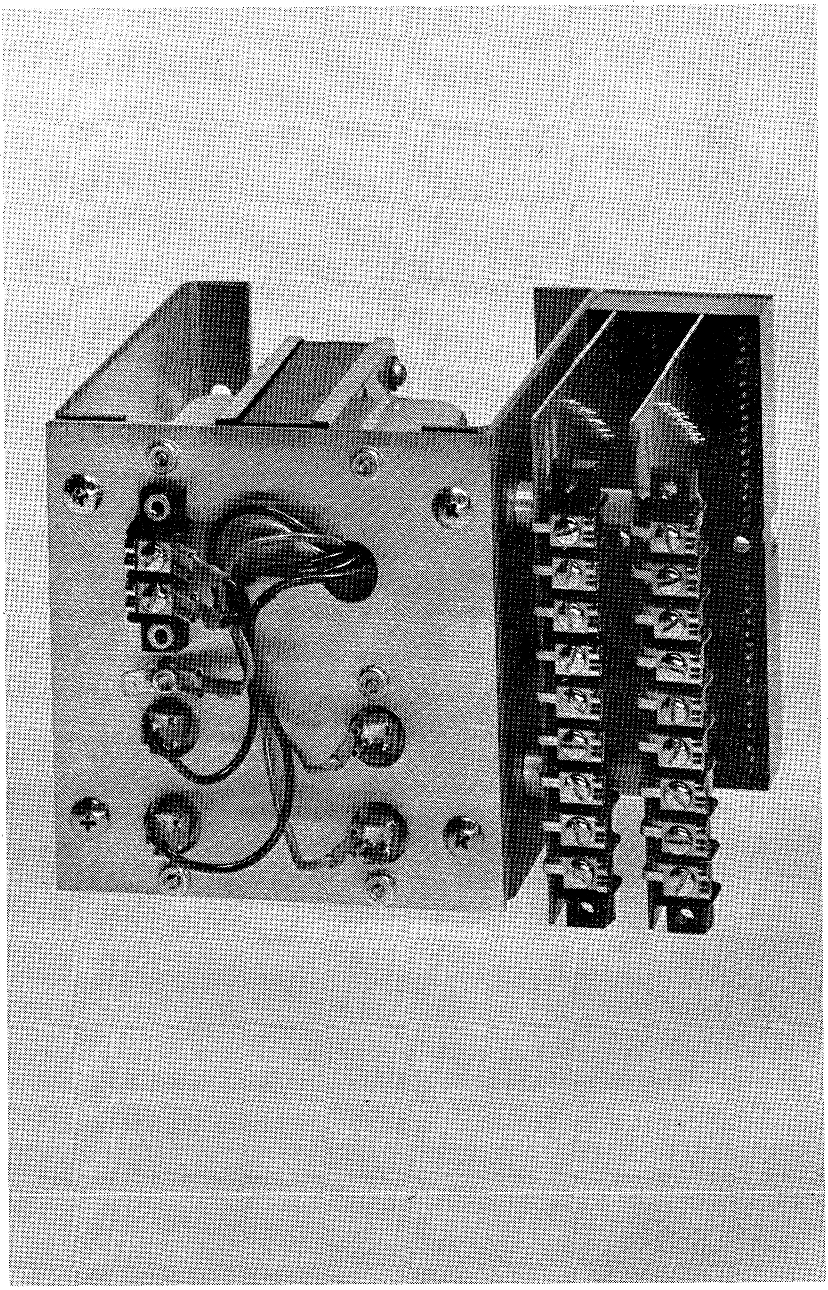
K784

These two double size modules offer an alternative to the K176 for obtaining field wiring connections in K series systems. The K782 has straight-through connections for use with K524, K580, 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

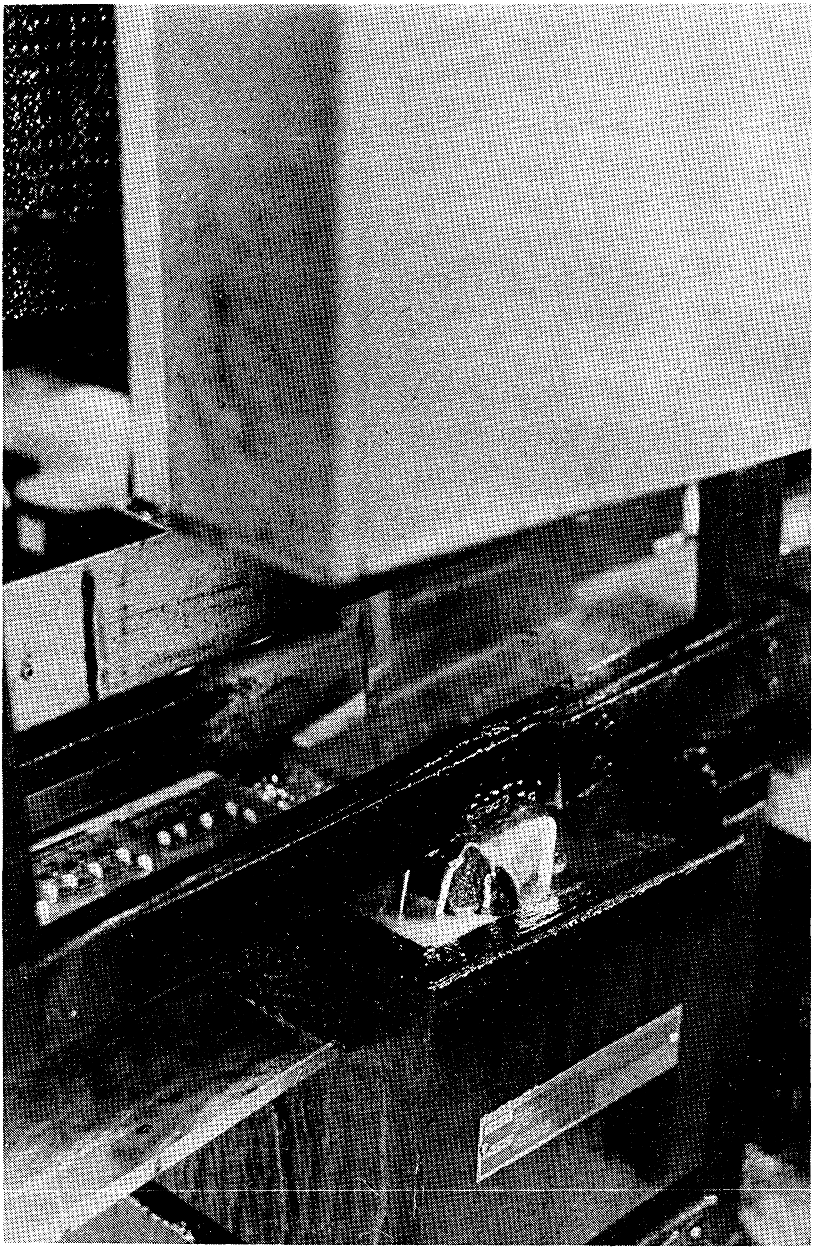


K782 TERMINALS WITH
K743 AND K980

SUMMARY OF MODULE CURRENT REQUIREMENTS

K SERIES

LOGIC MODULES		OTHER MODULES		
K003	3 ma	K508		65 ma
K012	12 ma	K522	Transducer bias plus	25 ma
K026	6 ma	K524	Transducer bias plus	35 ma
K028	8 ma	K578		0
K113	17 ma	K580	(Uses separate supply)	
K123	18 ma	K581	Per contact closed	22 ma
K124	21 ma	K596		30 ma
K134	23 ma	K604	All circuits off	40 ma
K135	22 ma		additional per circuit on	20 ma
K161	45 ma			
K174	12 ma	K614	All circuits off	40 ma
K184	56 ma		additional per circuit on	20 ma
K202	120 ma	K644	All circuits off	10 ma
K206	50 ma		additional per circuit on	160 ma
K210	150 ma	K656	All circuits off	10 ma
K220	220 ma		additional per circuit on	160 ma
K230	150 ma	K658	All circuits off	10 ma
K273	50 ma		additional per circuit on	350 ma
K281	0	K671		13 ma
K303	30 ma	K681		16 ma
K323	35 ma	K683		160 ma
K501	45 ma	K696	(Also requires 6.3vac 60 Hz or 9.0 vac 50 Hz)	7 ma



This flow-soldering machine solders all component leads to the board and makes all solder runs in one fast, exceedingly reliable, operation.

A SERIES

NOTES ON OPERATIONAL AMPLIFIERS

I. INTRODUCTION

This article describes some of the basic characteristics and uses of operational amplifiers. It is written especially for people with a digital background, but with a limited exposure to analog technology. The equations presented are not exact, but are good engineering approximations, which are accurate enough for most applications. It is hoped that this simplified discussion will provide more insight into the uses and limitations of operational amplifiers than a more rigorous approach.

The operational amplifier is a basic building block in analog work, much the same way as a NAND gate can be a basic building block in a digital computer. An operational amplifier (op amp) together with other components such as resistors and capacitors, can be used to perform addition, subtraction, integration, and many other functions. Op amps can be used to make oscillators, active filters, and even digital circuits such as Schmitt triggers, gates, and flip-flops. When used with A/D and D/A converters in data processing work, op amps perform such functions as scale changing, offsetting, and isolation between source and load.

II. GENERAL CHARACTERISTICS

An operational amplifier can be considered a 3 terminal device, plus a common or ground return, see Fig. 1. Chopper-stabilized op amps, which will not be considered here, have the Plus Input permanently tied to ground. The op amp is really a difference amplifier, in that it amplifies only the difference between the two inputs, and tries to reject any DC or AC signal that is common to both inputs.

Op amps are characterized by high DC gain, high input impedance, low output impedance, and a gain that decreases with increasing frequency. Op amps used without feedback would be operating open loop, a rare situation; but with feedback the operation would be closed loop. The use of properly applied negative feedback stabilizes the operation of the composite circuit against changes in the amplifier, and provides its versatility and usefullness.

When an op amp is working in the linear region, two approximations can be made to help in the analysis of the circuit configuration. First, the voltages of the two inputs are the same; and second, no current flows into or out of the input terminals. Fig. 2 shows a simple inverting amplifier. Assume the Minus Input is 0 volts, the same as the Plus Input, and that no current flows into the Minus Input, called the summing junction. Then $i_1 = i_F$, and some simple manipulations show that the gain is equal to $-R_F/R_1$. Similar reasoning applied to the non-inverting amplifier of Fig. 3 shows that the gain is equal to $+\frac{R_1 + R_2}{R_1}$. An easy way to remember this is to think of the two resistors as forming a tapped divider network.

III. SPECIFICATIONS

Specifications are usually given for open loop performance, so that the user has to interpret and calculate how this will affect his particular closed loop circuit. The following section will give some brief descriptions of what some of the specifications mean.

Settling time. This is the time it takes the output to get within and stay within a certain amount of is final value, after the input has received a step input, see Fig. 4. This parameter is important when an amplifier is used in front of an A/D converter, since the A/D should not begin its conversion until the amplifier has settled.

Overload recovery. It takes an overload recovery time for the output to first assume its proper value after an overdriving input signal has been removed. However, the output still has not settled, and this extra time must be waited before the output is valid.

Slew rate. This term is comparable to rise or fall time in a digital circuit. It is a measure of how fast the output can change. If an amplifier output could go from 0 volts to 10 volts in 2 μsec, it would have a slew rate of 5 volts/μsec.

Frequency for full output. This is the maximum frequency at which a full scale sine wave (such as +10 to —10 volts) can be assured at the output, without noticeable distortion. In many ways this is real frequency limitation of an op amp, since up to this frequency there are no other restrictions on the amplitude of the input signal.

Frequency for unity gain. The open loop gain of an amplifier is equal to one at this frequency. But the input signal must be restricted in amplitude such that the maximum rate of change of output (slew rate) is not exceeded. Usually only millivolt signals may be processed at this frequency, therefore the full amplifier bandwidth is not usable for normal data processing systems.

Impedance. The input impedance is simply the resistance between the two inputs. The common mode impedance is the highest resistance attainable with feedback.

Common mode rejection. This is a measure of how well an amplifier will not respond to a signal common to both inputs. If used as a voltage follower, an op amp with a common mode rejection ratio (CMRR) of 10,000 could have error of 1 mv if the input were 10 v. (10/10,000 volts).

Voltage offset. The inability to achieve perfect balance in the input circuit causes the output to respond to an apparent signal when the inputs are tied to ground. For an inverting amplifier, the output error due to the input voltage offset is equal to the offset times the closed loop gain plus one. With an input offset of 3 mv, and a gain of 1, the output error would be 6 mv. Fortunately, initial voltage offset can be trimmed with a potentiometer at the right place in the circuit.

Current offset. Current offset (or bias current) multiplied by the feedback resistor (Fig. 2) produces an output error. This effect can be minimized by using the differential offset (the difference in offset currents for the two inputs) when the resistance seen from both inputs to ground are equal. For Fig. 2, the Plus Input should than be returned to ground through a resistor equal to the parallel combination of R_I and R_F.

Output ratings. The output voltage and current ratings imply a minimum value for the load resistor. 10 volts and 5 ma would correspond to a load resistor of 2 K. In an inverting amplifier, the feedback resistor is a load for the output, and the current through this resistor must be subtracted from the amount of current still available at the output. All really useful operational amplifiers can be shorted to ground without damage, but shorting to a voltage will usually destroy some of the circuitry.

IV. APPLICATIONS

Some common configurations for operational amplifiers are shown in Figs. 5 through 10. The pin letter assignments correspond to the op amps sold by Digital Equipment Corp. If these op amps are used, the jumper between Pin S and the Minus inpunt should be removed.

The voltage follower, Fig. 5, features high input impedance, but will have an error depending on the CMRR. Large voltages cannot be handled, since common mode voltage ratings should not be exceeded. The inverter configuration, Fig. 7, is very versatile and does not have a common mode voltage problem, since both inputs are near ground. Large input voltages can be handled if the input resistor is made appropriately large. One disadvantage of the inverting configuration is that the input impedance is relatively low, essentially equal to the input resistor. When a gain trim potentiometer is used, the gain accuracy by itself becomes irrelevant. What is important is gain resolution (mostly determined by the potentiometer), and the gain stability (mostly determined by the temperature coefficients of the input and feedback resistors). The ratio of the closed loop gain to the open loop gain gives the suitability of an amplifier as far as static accuracy is concerned. With a closed loop gain of 5, and an open loop gain of 10,000, an amplifier could be used in a system with an allowable error of 1 part in 2,000.

The possibility of oscillation must always be considered when feedback amplifiers are used. Usually the more feedback used, the greater is the tendency to oscillate. Oscillations can always be attributed to phase shift. Therefore, stabilization of operational amplifiers involves phase shifting to oppose oscillation. In Fig. 7, the feedback capacitor allows high frequency signals to be fed back to the inverting input (degenerative feedback) with a phase lead. In the inverting configuration, the output will be 180° out of phase with the input at low frequencies, and the feedback signal will oppose the input signal. At high frequencies, these are additional phase lags in the amplifier and feedback circuitry. If the feedback signal has a total phase shift (lag) of 360° with a gain through the amplifier and feedback network of greater than 1, the amplifier will oscillate, since the input and output are in phase.

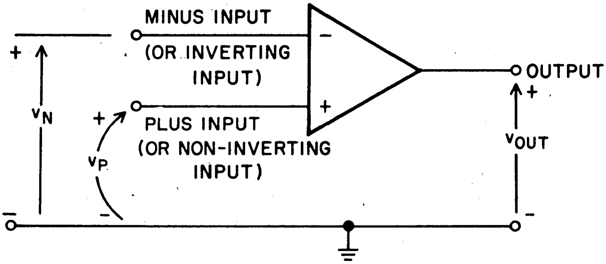
V. REFERENCES

1. "An Operational Amplifier Application Manual"
   Analog Devices, Inc., Cambridge, Mass.

2. "Handbook of Operational Amplifier Applications"
   Burr-Brown Research Corp., Tucson, Arizona

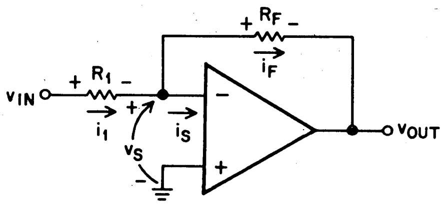
3. "Linear Integrated Circuits Applications Handbook"
   Fairchild Semiconductor, Mountain View, California

4. "Applications Manual for Operational Amplifiers"
   Philbrick/Nexus Research, Dedham, Mass.



$v_{OUT} = A(v_P - v_N)$, WHERE A IS THE AMPLIFIER GAIN

Fig. 1, Basic Operational Amplifier Symbol

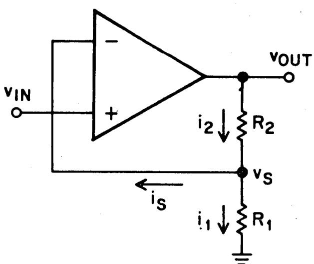


ASSUME: $v_S = 0$ THEN $i_1 = i_F$
$i_S = 0$

$$\frac{v_{IN}}{R_1} = -\frac{v_{OUT}}{R_F}$$

$$\frac{v_{OUT}}{v_{IN}} = -\frac{R_F}{R_1}$$

Fig. 2, Inverting Amplifier



ASSUME: $v_S = v_{IN}$
$i_S = 0$

THEN $i_1 = i_2$

$$\frac{v_S}{R_1} = \frac{v_{OUT} - v_S}{R_2}$$

$$\frac{v_{IN}}{R_1} = \frac{v_{OUT} - v_{IN}}{R_2}$$

$$v_{IN} R_2 = v_{OUT} R_1 - v_{IN} R_1$$

$$\frac{v_{OUT}}{v_{IN}} = +\frac{R_2 + R_1}{R_1}$$

Fig. 3, Non-Inverting Amplifier

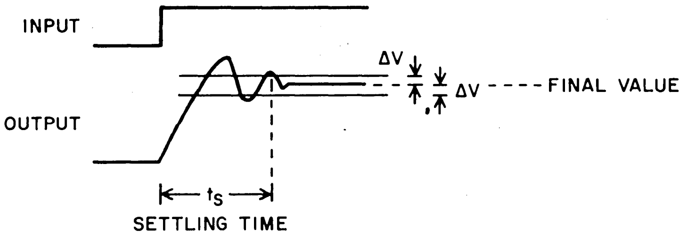
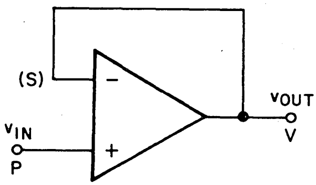


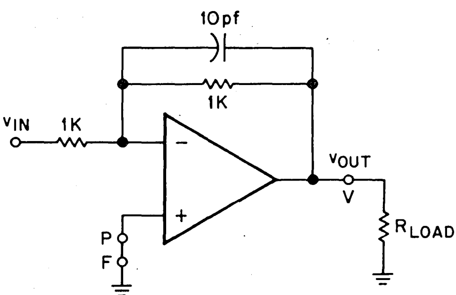
Fig. 4, Setting Time



$$\frac{v_{OUT}}{v_{IN}} = +1$$

$$R_{IN} = R_{COM\ MODE}$$

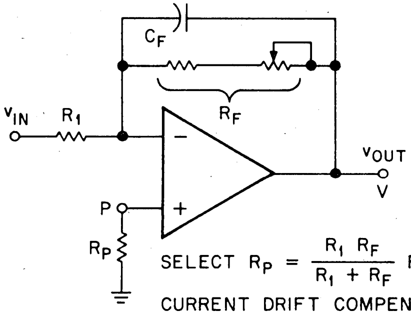
Fig. 5, Voltage Follower



$$\frac{v_{OUT}}{v_{IN}} = -1$$

$$R_{IN} = 1K$$

Fig. 6, Inverter



$$\frac{v_{OUT}}{v_{IN}} = -\frac{R_F}{R_1}$$

$$R_{IN} = R_1$$

GAIN STABILITY DEPENDS ON THE INPUT AND FEEDBACK RESISTOR, AND GAIN TRIM POTENTIOMETER.

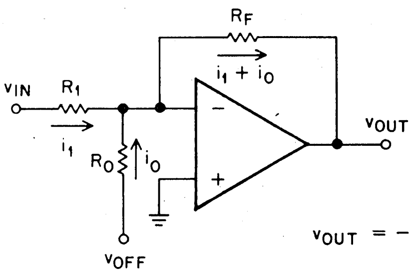
SELECT $R_P = \dfrac{R_1 R_F}{R_1 + R_F}$ FOR CURRENT DRIFT COMPENSATION.

TYP VALUES

R_1	1K TO 10K
R_F	1K TO 100K
R_P	500Ω TO 5K

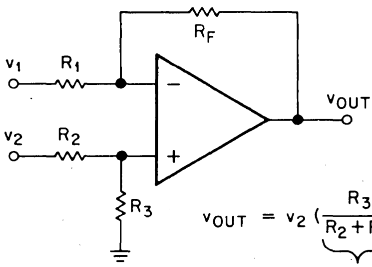
THE USE OF C_F REDUCES THE TENDENCY OF THE OP AMP TO OSCILLATE

Fig. 7, Adjustable Gain and Current Compensation



$$v_{OUT} = -v_{IN}\left(\frac{R_F}{R_1}\right) + \underbrace{\left[-v_{OFF}\left(\frac{R_F}{R_O}\right)\right]}_{\text{OFFSET}}$$

Fig. 8, Offsetting

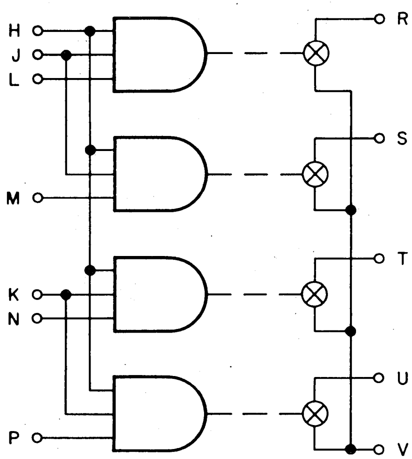


$$v_{OUT} = v_2 \underbrace{\left(\frac{R_3}{R_2+R_3}\right)}_{\text{ATTENUATION FACTOR}} \overbrace{\left(\frac{R_F+R_1}{R_1}\right)}^{\text{NON-INV GAIN}} - v_1 \underbrace{\left(\frac{R_F}{R_1}\right)}_{\text{INV GAIN}}$$

Fig. 9, Differential Gain

POSITIVE LOGIC MULTIPLEXER
TYPE A123

A SERIES



INPUT	OUTPUT TERMINALS
+3V	CONNECTED
OV	OPEN

The A123 Multiplexer provides 4 gated analog switches that are controlled by logic levels of 0v and +3v. The module is equivalent to a single-pole, 4-position switch, since one output terminal of each MOS FET switch is tied together. If all three digital inputs of a circuit are at +3v (or not connected) the two output terminals are connected together. If any digital input is at 0v, the switch terminals are disconnected. Two switches should not be on at the same time. The analog switch can handle signals between +10v and —10v, with currents up to 1 ma.

The positive power supply must be between +5v and +15v, and at least equal to or greater than the most positive excursion of the analog signal. The negative power supply must be between —5 and —20v, and at least 10 volts more negative than the most negative excursion of the analog signal. The voltage difference between the two supplies must not be more than 30v.

SPECIFICATIONS

Digital Inputs

Logic ONE:	+2.4v to +5.0v
Logic ZERO:	0.0v to +0.8v
Input loading:	0.5 ma at 0 volts

Analog Signal

Voltage range:	+10v to —10v
Current (max.):	1 ma

Output Switch

On resistance, max.:	1000 ohms
On offset:	0 volts
Off leakage, capacitance:	10 na, 10 pf
Turn on delay, max.:	0.2 μsec
Turn off delay, max.:	0.5 μsec

Power

+5v (pin A):	45 ma
+v (pin D):	18 ma (for +10v)
—v (pin E):	50 ma (for —20v)

A123—$58

OPERATIONAL AMPLIFIER
TYPE A200

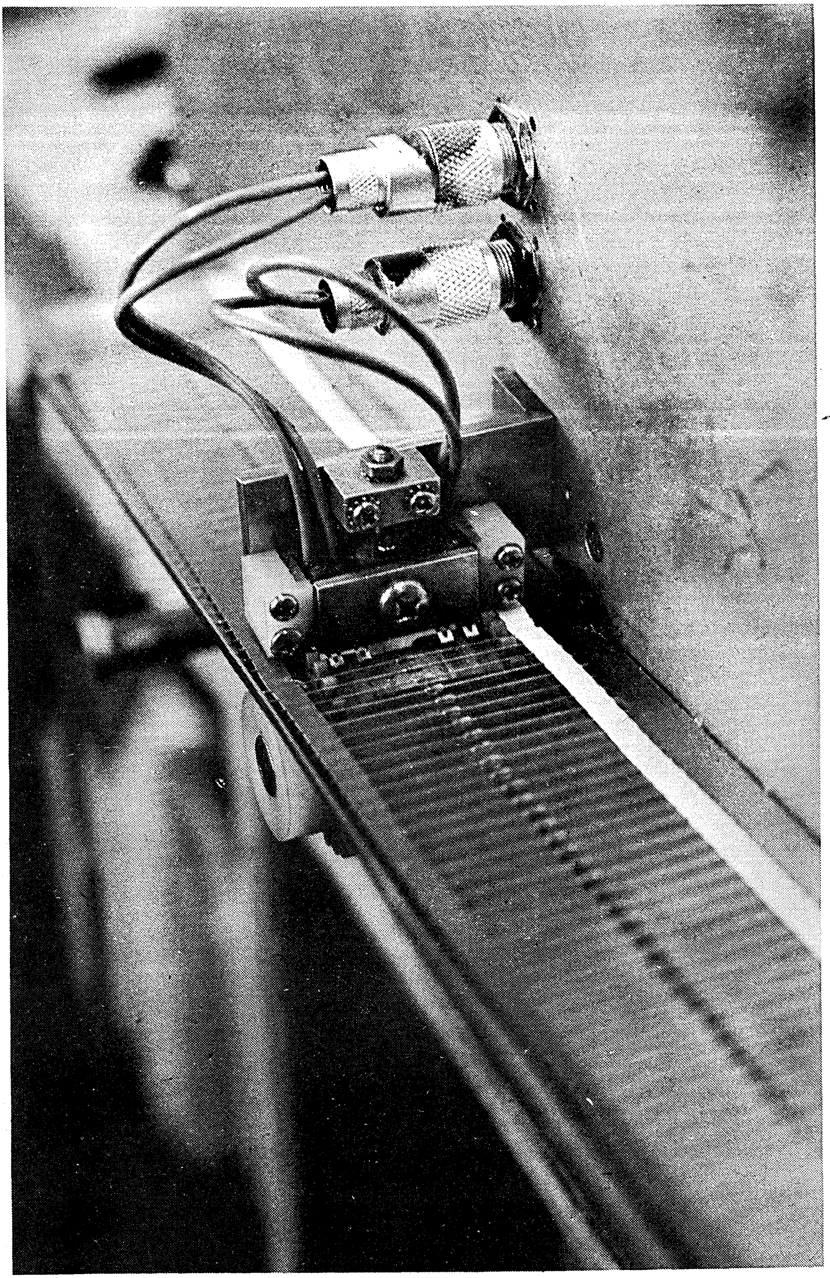
A SERIES

The A200 is an operational amplifier mounted on an A990 amplifier board. Provisions are made on the board for the mounting of potentiometers for gain trim and balance. Mounting holes are also provided for input and feedback networks, and rolloff capacitor. The module is a double width board.

OPEN LOOP GAIN:	$2x10^6$
RATED OUTPUT	
Voltage:	±11v
Current:	20 ma
FREQUENCY RESPONSE	
Unity gain, small signal:	10 MHz
Full output voltage:	300 kHz
Slewing rate:	30v/μsec
Overload recovery:	200 μsec
INPUT VOLTAGE OFFSET (Adjustable to Zero)	
Average vs. Temperature:	20 μv/°C
Average vs. Supply voltage:	15 μv/%
Average vs. Time:	10 μv/day
INPUT CURRENT OFFSET:	±2 na
Average vs. Temperature:	0.4 na/°C
Average vs. Supply voltage:	0.15 na/%
INPUT IMPEDANCE	
Between inputs:	6 megohm
Common mode:	500 megohm
INPUT VOLTAGE	
Maximum:	±15 volts
Maximum common mode:	±10 volts
Common mode rejection:	20,000
POWER	
Voltage:	±15 volts
Current at rated load:	35 ma

*REFER TO A990 FOR CONNECTIONS

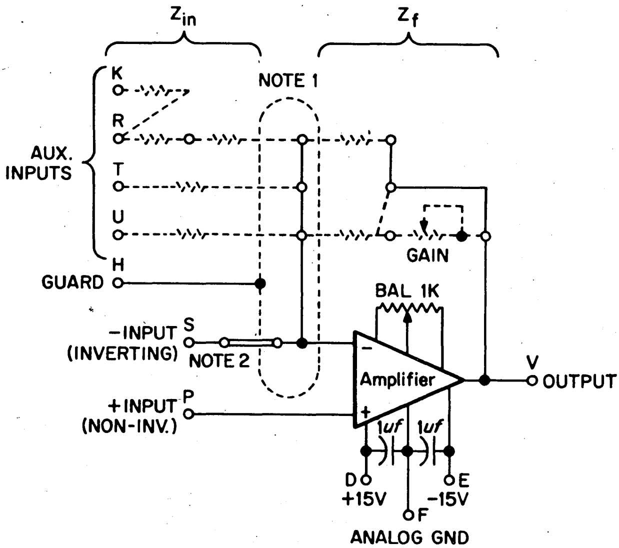
A200 — $130



All incoming components are 100% tested. Here, diodes are being tested automatically.

OPERATIONAL AMPLIFIER
A206

A SERIES



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.

The A206 Operational Amplifier features extremely fast settling time (2 μs to within 1 mv), making it especially suited for use with Analog-to-Digital Converters. FET's are used in the input stage to provide high input impedance. The A206 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 A206.

The A206 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 A206 is pin-compatible with the A200 Operational Amplifier.

SPECIFICATIONS—At 25°C, unless noted otherwise.

Settling Time*	
Within 1 mv, 10v step input, typ:	1.5 μsec
Within 1 mv, 10v step input, max:	2.0 μsec
Frequency Response	
DC open loop gain, 670 ohm load, min:	100,000
Unity gain, small signal, min:	10 MHz
Full output voltage, min:	1 MHz
Slewing rate, min:	100v/μsec
Overload recovery, max:	0.5 μsec
Output	
Voltage, max:	±10v
Current, max:	±15 ma
Input Voltage	
Input voltage range, max:	±10v
Differential voltage, max:	±15v
Common mode rejection, min:	7,000
Input Impedance	
Between inputs, min:	10^{10} ohms
Common mode, min:	10^{10} ohms
Input Offset	
Avg. voltage drift vs. temp., max:	±30 μv/°C
Avg. volt. drift vs. supply volt., max:	±20 μv/%
Initial differential current offset, max:	0.03 na
Avg. dif. cur. drift vs. temp., max:	±0.003 na/°C
Temperature Range	0°C to +60°C
Power	
+15v (pin D), quiescent:	15 ma
−15v (pin E), quiescent:	15 ma

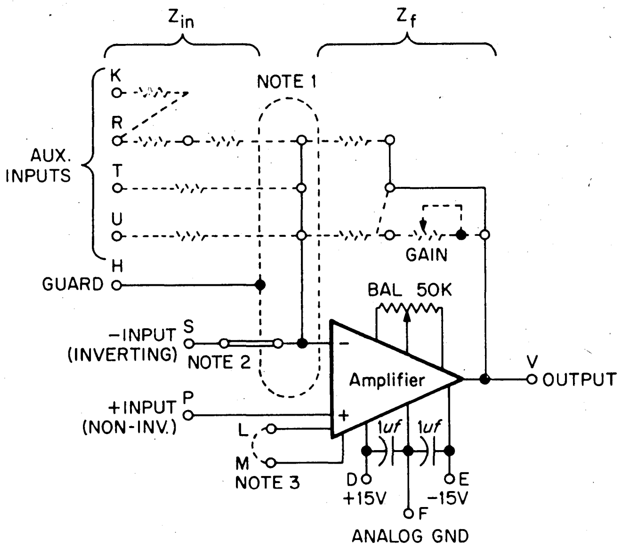
If the Output is accidentally shorted to ground, the amplifier will not be damaged.

*Gain of 1, inverting or non-inverting configuration.

A206 — $190

OPERATIONAL AMPLIFIER
A207

A SERIES



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.

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

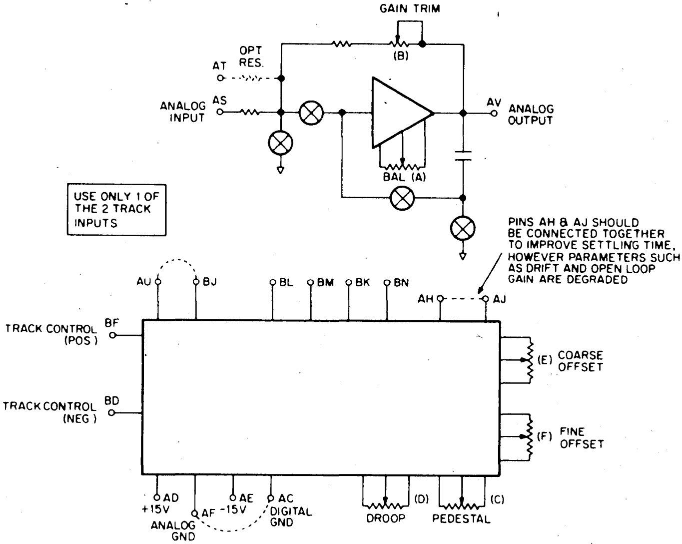
If the Output is accidentally shorted to ground, the amplifier will not be damaged.

*Gain of 1, inverting or non-inverting configuration.

A207 — $45

SAMPLE AND HOLD
A404

A SERIES



JUMPER CONNECTIONS TO OFFSET OUTPUT

	MODE	
PIN	TRACK (sample)	HOLD
BF (pos)	+3v or open	0v
BD (neg)	—3v or open	0v

Positive	Negative
AU to BJ	AU to BJ
	BL to AD
BM to AE	
BK to AF	BN to AF

Analog gnd (pin AF) and digital gnd (pin AC) must be connected together at one point in the system.

The A404 Sample & Hold has an acquisition time of 6 μsec for a 10 volt signal to within 10 mv (0.1%). The circuit inverts the input signal, and has an input impedance of 10 K. Features of the circuit include potentiometers to control the pedestal and the droop of the output signal.

Two digital Track Control (sample) inputs are provided: one for negative logic (0v & —3v), and the other for positive logic (0v & +3v). Either input by itself will perform the necessary control, and the inadvertent application of both digital signals will cause no damage to the circuit.

Potentiometers are also provided for zero balancing, gain trim, and offset adjustment (up to ±10v). If offsetting is desired, connections should be made according to the table shown with the diagram. The A404 is pin-compatible with the A400 Sample & Hold.

SPECIFICATIONS—At 25°C, unless noted otherwise. Pins AH & AJ are connected together.

Acquisition Time	
Within 10 mv, 10v step input, typ:	4 μsec
Within 10 mv, 10v step input, max:	6 μsec
Within 2.5 mv, 10v step input, max:	11 μsec
Aperture Time, max:	0.2 μsec
Gain	—1.000 (adjustable ±0.2%)
Input	
Voltage range, max:	±10v
Impedance:	10 K ohms
Output	
Voltage range, max:	±10v
Current, max:	10 ma
Pedestal*	
Initial pedestal:	Adjustable to less than 1 mv
Pedestal variation vs. temp, max:	0.2 mv/°C
Droop	
Initial droop:	Adjustable to less than 5 mv/ms
Droop variation vs. temp, max:	2 mv/ms/°C
Track Control	
Pos. (pin BF)	+3v, Track 0v at 2 ma, Hold
Neg. (pin BD)	—3v, Track 0v at 1 ma, Hold
Board Size	1 double height board, single module width
Temperature Range	0°C to +50°C
Power	
+15v (pin AD), quiescent:	22 ma
—15v (pin AE), quiescent:	35 ma

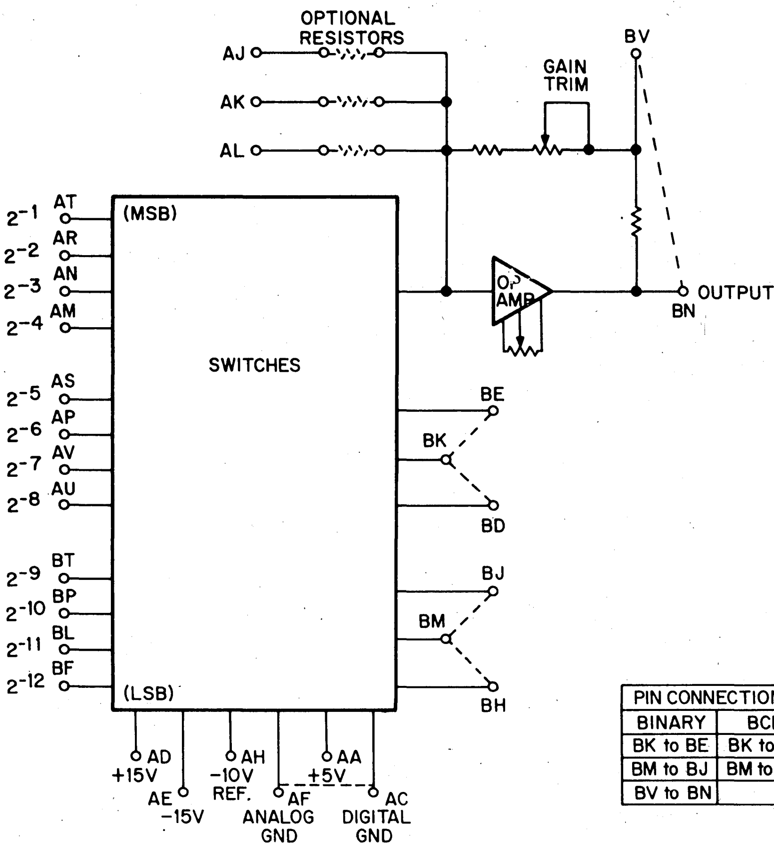
If the Output is accidentally shorted to Ground, the circuit will not be damaged.

*Difference in output voltage when changing from Track to Hold mode.

A404 — $130

12-BIT DAC
A613

A SERIES



PIN CONNECTIONS	
BINARY	BCD
BK to BE	BK to BD
BM to BJ	BM to BH
BV to BN	

BINARY INPUTS		OUTPUT
2^{-1}	ALL OTHERS	
0V	0V	+0.000V
+3	0	+5.000
+3	+3	+9.9975

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:	+2.0v to +5.0v
Logic ZERO:	0.0v to +0.8v
Input loading:	1 ma (max.) at 0 volts

Output

Standard:	0v to +10v
Optional, (requires Positive REF)	10v range between —10v and +10v
Settling time, (10v step):	50 μsec
Output current:	10 ma
Capacitive loading:	0.1 μf (without oscillation)

Binary Dig. In.	Analog Out	BCD (8421)	Analog Out
000 — 00	0.0000v	000	0.000v
000 — 01	+0.0025	001	+0.010
100 — 00	+5.0000	050	+0.500
111 — 11	+9.9975	500	+5.000
		999	+9.990

Accuracy

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

Board Size

1 double height board, single module width

Temperature Range

+10°C to +50°C

Power

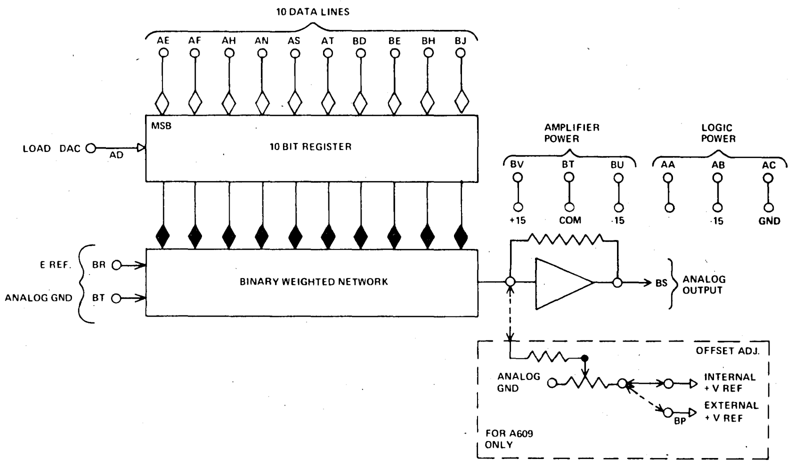
+15v at 35 ma
—15v at 60 ma } at max. load
+ 5v at 60 ma
—10.0v REF at —7 ma (reverse current)

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

A613 — $250

10-BIT D/A CONVERTER SINGLE BUFFERED
TYPES A618 and A619

A SERIES



The A618 and the A619 Digital to Analog Converters (DAC) are contained on one DEC double Flip-Chip™ Module. These modules are also double width in the lower (B section) half. The converters are complete with a 10-bit buffer registers, level converters, a precision divider network, and a current summing amplifier capable of driving external loads up to 10 ma. The reference voltage is externally supplied for greatest efficiency and optimum scale factor matching in multi-channel applications.

The A609 DAC output voltage is bi-polar while the A618 DAC output voltage is uni-polar.

Binary numbers are represented as shown (right justified) in Table 1:

TABLE 1

Binary Input	Analog Output (Standard)	
	A618	A619
0000_8	0v	−10v or −5v
0400_8	+2.5v	−5v or −2.5v
1000_8	+5.0v	0 volts
1400_8	+7.5v	+5v or +2.5v
1777_8	+10.0v	+10v or +5v

OUTPUT:

Voltage: (A618 — Standard)	0 to +10 volts
Voltage: (A619 — Standard)	±5 or ±10 volts
Current:	10 ma MAX.
Impedance:	<0.1 ohm
Settling Time:	
(Full scale step, resistive load)	<5.0 μsec
(Full scale step, 1000 pf)	<10.0 μsec
Resolution:	1 part in 1024
Linearity:	±0.05% of full scale
Zero Offset:	±5 mv MAX.
Temperature Coefficient:	<0.2 mv/°C
Temperature Range:	0 to 50°C

INPUT:

Level: 1 TTL Unit load.

Pulse: (positive)

Input loading: 20 TTL Unit load	
Rise and Fall Time:	20 to 100 nsec
Width:	> 50 nsec
Rate:	10^6 Hz max.

Timing:

Data lines must be settled 40 nsec before the "LOAD DAC" pulse (transition) occurs.

POWER REQUIREMENTS:

Reference Power:	—10.06 volts, 60 ma
Amplifier Power:	±15 volts, 25 ma (plus output loading)
Logic Power:	+5volts, 135 ma
	—15 volts, 60 ma

NOTES:

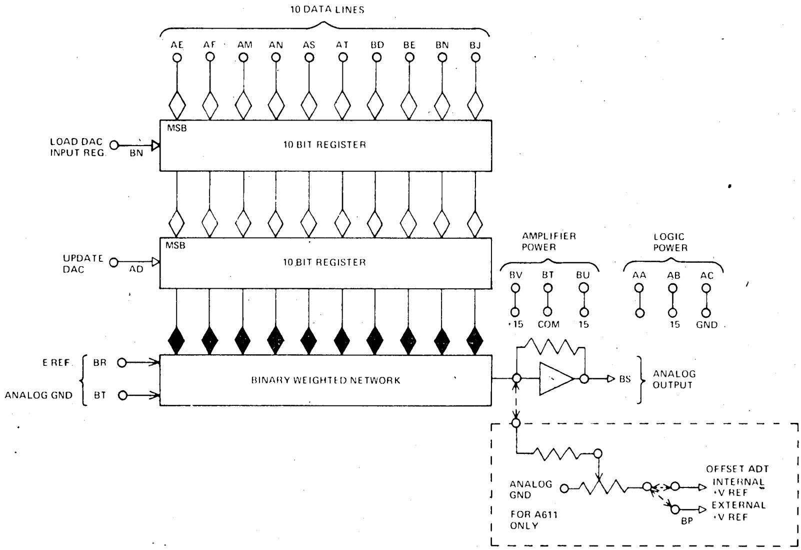
*Voltage — A619: Full scale voltage (±5 or ±10) must be specified at time of purchase.

Price: Price stated is for standard output voltage and current. Other output characteristics are available on request.

A618 — $350
A619 — $375

10-BIT D/A CONVERTER DOUBLE BUFFERED
TYPES A620 and A621

A SERIES



The A620 and the A621 Digital-to-Analog Converters (DAC) are contained on one DEC double Flip-Chip Module. These modules are also double-width in the lower (B section) half. The converters are complete with two 10-bit buffer registers, level converters, a precision divider network, and a current summing amplifier, capable of driving external loads up to 10 ma. The reference voltage is externally supplied for greatest efficiency and optimum scale-factor matching in multi-channel-application.

The A621 DAC output voltage is bi-polar while the A620 DAC output voltage is uni-polar.

The double-buffered DAC's are offered to satisfy those applications where it is imperative to update several analog output simultaneously. When DAC's deliver input to a multi-channel analog tape system or update the constants of an analog computer, the double-buffer feature may be necessary to prevent skew in the analog data.

Binary numbers are represented as shown (right justified) in Table 1:

TABLE 1

Binary Input	Analog Output (Standard)	
	A620	A621
0000_8	0v	—10v or —5v
0500_8	+2.5v	—5v or —2.5v
1000_8	+5.0v	—0 volts
1500_8	+7.5v	+5v or +2.5v
1777_8	+10.0v	+10v or +5v

OUTPUT:

Voltage: (A620 — Standard)	0 to 10 volts
Voltage: (A621 — Standard*)	±5 or ±10 volts
Current:	10 ma MAX.
Impedance:	<0.1 ohms
Settling Time:	
(Full scale step, resistive Load)	<5.0 μsec
(Full scale step, 1000 pf)	<10 μsec
Resolution:	1 part in 1024
Linearity:	±0.05% of full scale
Zero Offset:	±5 mv MAX.
Temperature Coefficient:	<0.2 mv/°C
Temperature Range:	0 to 50°C

INPUT:

Level: 1 TTL Unit load

Pulse: (positive)

Input loading:	20 TTL Unit load
Rise and Fall Time:	20 to 100 nsec
Width:	> 50 nsec
Rate:	10^6 Hz MAX.

Timing:

1. Data lines must be settled 40 nsec before the "LOAD DAC" pulse (transition) occurs.
2. The "Update DAC" pulse must occur more than 100 nsec after the "LOAD DAC" pulse.

POWER REQUIREMENTS:

Reference Power:	—10.6 volts, 60 ma
Amplifier Power:	±15 volts, 25 ma (plus output loading)
Logic Power:	+ 5 volts, 190 ma
	—15 volts, 60 ma

Notes:

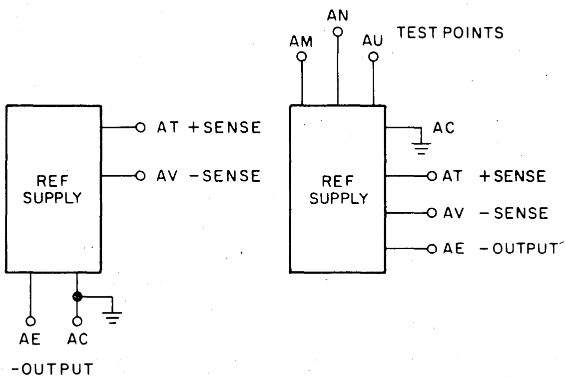
*Voltage — A621: Full scale voltage (±5 or ±10) must be specified at time of purchase.

Price: Price stated is for standard output voltage and current. Other output characteristics are available on request.

A620 — $400
A621 — $425

REFERENCE SUPPLIES
TYPES A702, A704
(DOUBLE HEIGHT)

A SERIES



Module Type	Output	Current	Temperature Coefficient	Regulation	Ripple Peak to Peak
A702	−10 v	±60 ma	1mv/°C	30 mv, no load to full load	10 mv
A704	−10 v	−90 to +40 ma	1 mv/8 hrs 1 mv/15° to 35°C 4 mv/0° to 50°C	0.1 mv, no load to full load	0.1 mv

Module Type	Adjustment Resolution	Input Power	Use	Output Impedance
A702	5 mv	−15 v/100 ma +10 v (B)/10 ma	Load with 500 μf at load. May also be preloaded if desired	0.5 ohms
A704	0.01 mv	−15 ±2 v/250 ma	See below for sensing and preloading	0.0025 ohms

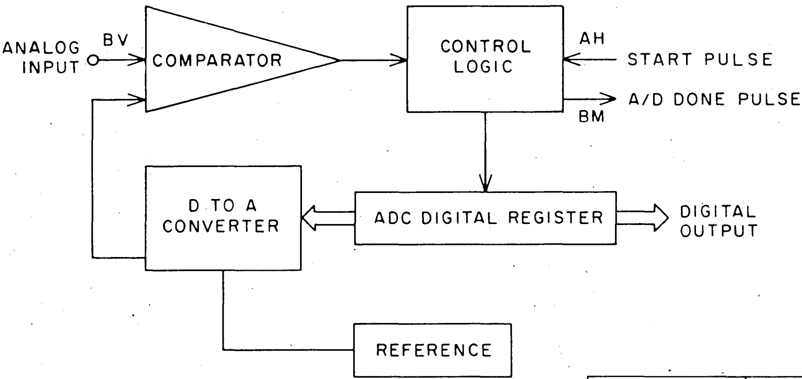
Remote Sensing: The input to the regulating circuits of the A704 is connected at sense terminals AT (+) and AV (—). Connection from these points to the load voltage at the most critical location provides maximum regulation at a selected point in a distributed or remote load. When the sense terminals 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 pin 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.

A702 — $ 58
A704 — $184



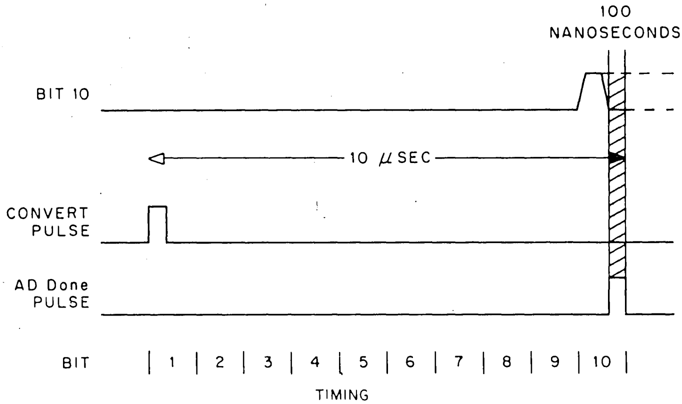
BIT 1 (MSB) 2	AE AD
3 4	AN AM
5 6	BL BR
7 8	BK BP
9 10 (LSB)	BS BT

A811 10-BIT ANALOG-TO-DIGITAL CONVERTER

A811 10-BIT ANALOG-TO-DIGITAL CONVERTER

The A-811 is a complete, 10-bit successive approximation, analog to digital converter with a built in reference supply. The complete converter is contained on one DEC double FLIP CHIP™ logic module. Conversion is initiated by raising the Convert input to logic 1 (+4 volts). The digital result is available at the output within 10 microseconds. An A/D Done Pulse is generated when the result is valid. The A-811 uses monolithic integrated circuits for control logic, output register, and comparator.

The A811 requires 2 vertical connectors and the top section (connector A) requires 2 connector widths.



SPECIFICATIONS:

	Max.	Min.
Convert Pulse Input:		
Input loading	10 TTL unit load	
Pulse Width	500 nsec	100 nsec
Pulse Rise Time	250 nsec	—
A/D Done Pulse Output:		
Pulse Width	300 nsec	100 nsec
Digital Output:		
Logical "0"	+0.4v	0v
Logical "1"	+3.6v	+2.4v
Output Current "0"	16 ma	
Output Current "1"	—0.4 ma	
Input:		
Input Voltage	0 to +10v	
Input Impedance	1000 ohms	
Resolution:	10 bits	
Accuracy:	0.1% of full scale	
Temperature Coefficient:	0.5 mv/°C	
Operating Temperature:	0°C to 50°C	
Conversion Rate:	100 KHz MAX.	
Output Format:	Parallel Binary Uni-polar	

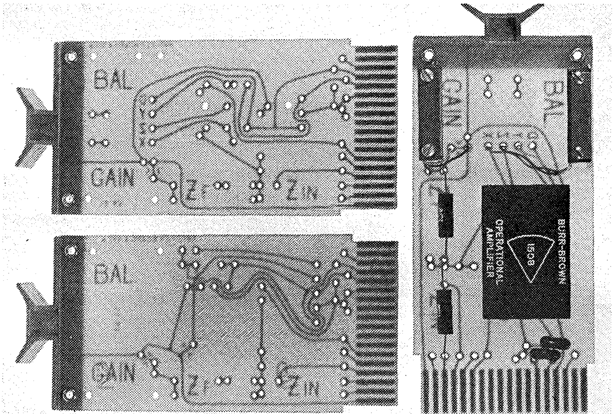
Power:
+15 volts ±1% 20 ma (pin BU)
—15 volts ±1% 160 ma (pin AV)
+ 5 volts ±1% 300 ma (pin AA)

Options:
The Input impedance of the A/D converter can be raised to greater than 100 megohms by adding an input amplifier module. A sample and hold amplifier module may also be included. The impedance of the converter with sample and hold is 10,000 ohms. Both options may be included simultaneously if high impedance and narrow aperture are both required.

A811 —$450

AMPLIFIER BOARDS
TYPES A990, A992

A SERIES



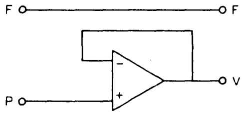
Many types of commercially available operational amplifiers can be mounted in the holes provided on these predrilled etched boards. Mounting holes and printed wires provide for balance trim, gain trim, and feedback networks required to build such common operational devices as voltage followers, inverting or non-inverting amplifiers, integrators, differentiators, summers and subtractors. Most amplifiers listed in the table below require ±15v regulated supplies which are readily available from the amplifier manufacturers. Notable exceptions are Analog Devices' Models 101, 103, and 104 which may be used with standard DEC +10v, —15v supplies at some sacrifice in voltage range (+5, —10v) and noise.

Power: Positive at pin D, negative at pin E, common at pin F for all types. Space is provided for mounting bypass capacitors used with some high frequency amplifiers.

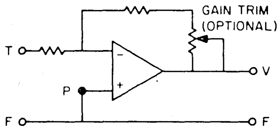
Trimming: Mounting holes on 1" centers at the handle end accept wirewound potentiometers for balance and feedback (gain) trimming. Gain rheostat may be connected in series with feedback components to allow precise adjustment of gain using inexpensive 1% feedback resistors. Board is etched to allow for use without gain trimming, and one pointed conductor must be cut at caret marks to put a rheostat in the circuit. Gain rheostat stray capacitance to ground is driven by amplifier output.

Amplifier Supplier	Types accepted by A990	Types accepted by A992 (boosters too)
Analog Devices	101, 102, 104, etc.	103, 106, 107, etc.
Burr-Brown*	1500-46, 1500-68	—
Data Device Corp.	—	most types, except boosters
Nexus	Case K or Case L	Case Q
Philbrick	—	Case PP
Union Carbide	—	most types
Zeltex	—	Case A

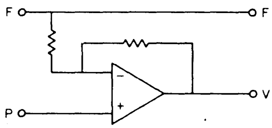
*Except Burr-Brown differential output and chopper stabilized types: Perforated board W994 or other blank module may be used to mount non-standard configurations.



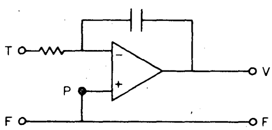
VOLTAGE FOLLOWER (NON-INVERTING)



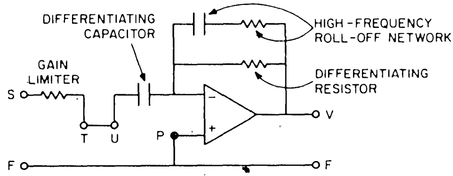
INVERTING AMPLIFIER



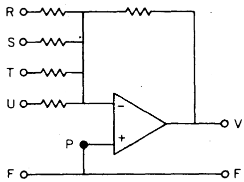
NON-INVERTING AMPLIFIER



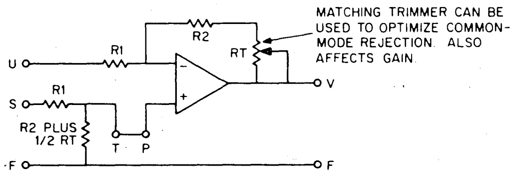
INTEGRATOR



DIFFERENTIATOR WITH DOUBLE BAND STOPS

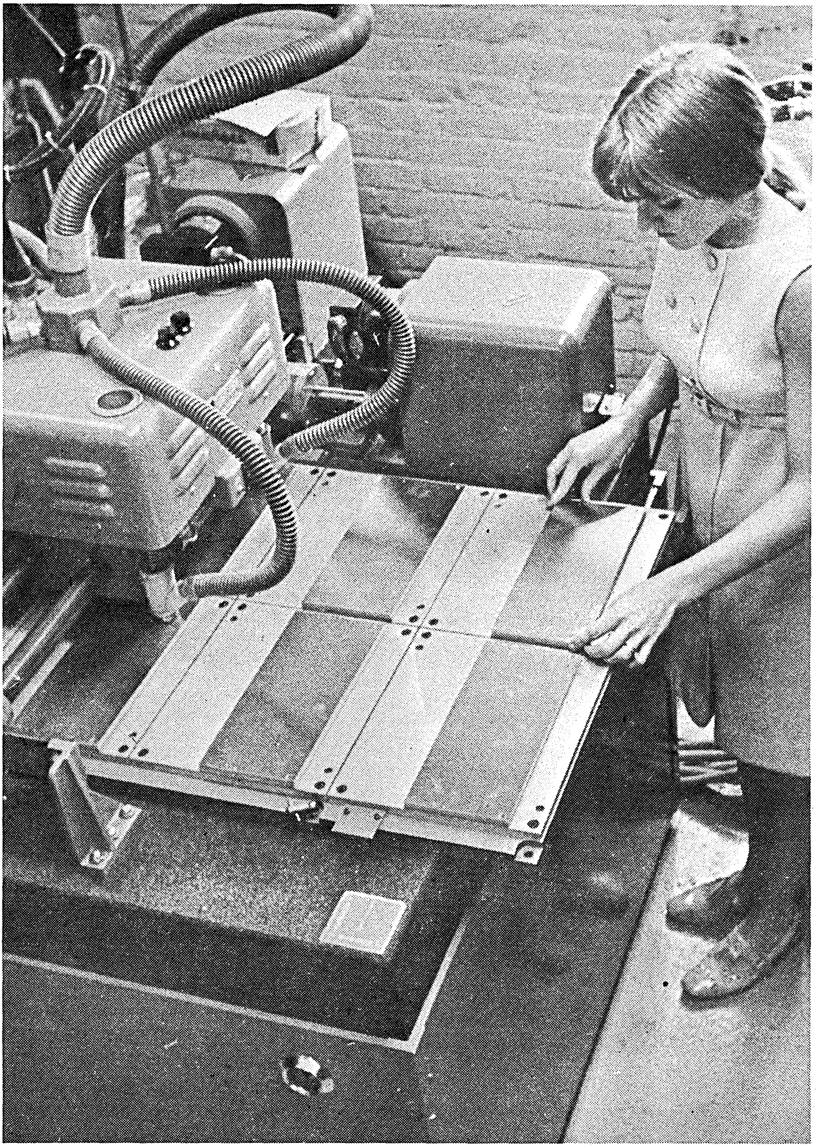


FOUR-INPUT SUMMER



SUBTRACTOR AND COMMON-MODE REJECTOR

A990 — $4
A992 — $4



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.

PART II
HARDWARE, POWER SUPPLIES AND ACCESSORIES

INTRODUCTION

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 Digitals 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. These connections are shown below along with a schematic.

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 panel is 24 for wire wrap, and 22 for soldering. The recommended size for use with H803 block and H911 mounting panel 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.

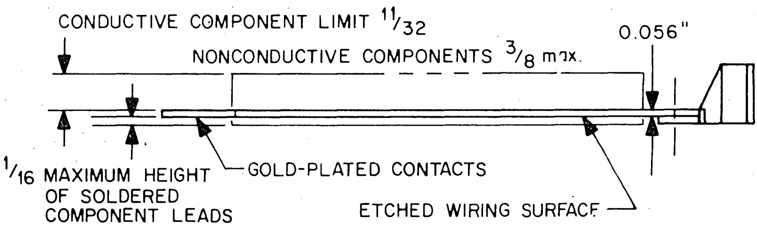
COOLING OF FLIP CHIP MODULES

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.

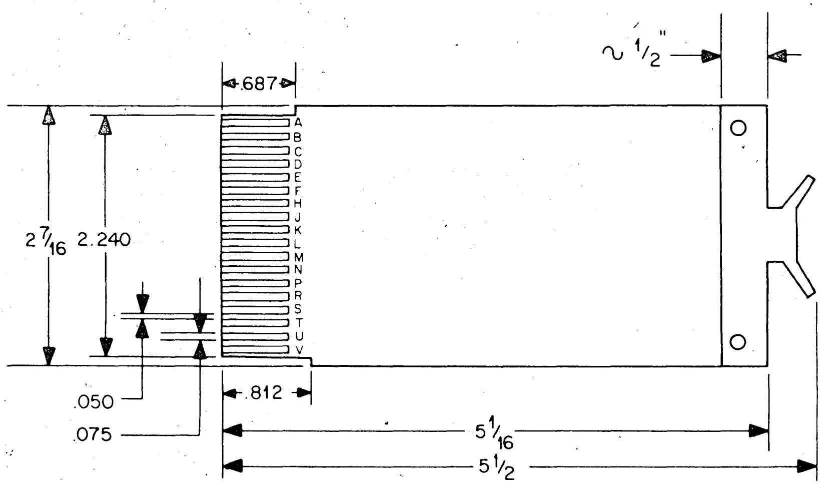
The regulating transformers used in most DEC power supplies have nearly constant heat dissipation for any loading within the ratings of the supply. Power dissipated within each supply will be roughly equal to half its maximum rated output power. If power supplies are mounted below any of the modules in a convection-cooled system, this dissipation must be included when checking against the 150 watt limit.

STANDARD MODULE SIZES

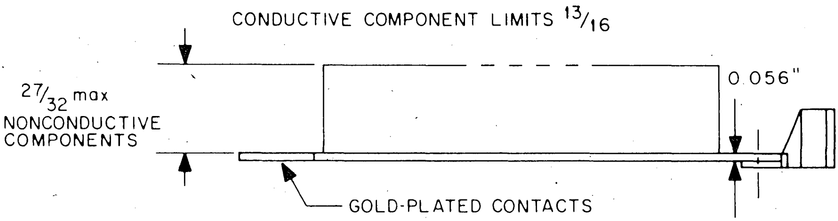
SINGLE-WIDTH FLIP CHIP MODULE



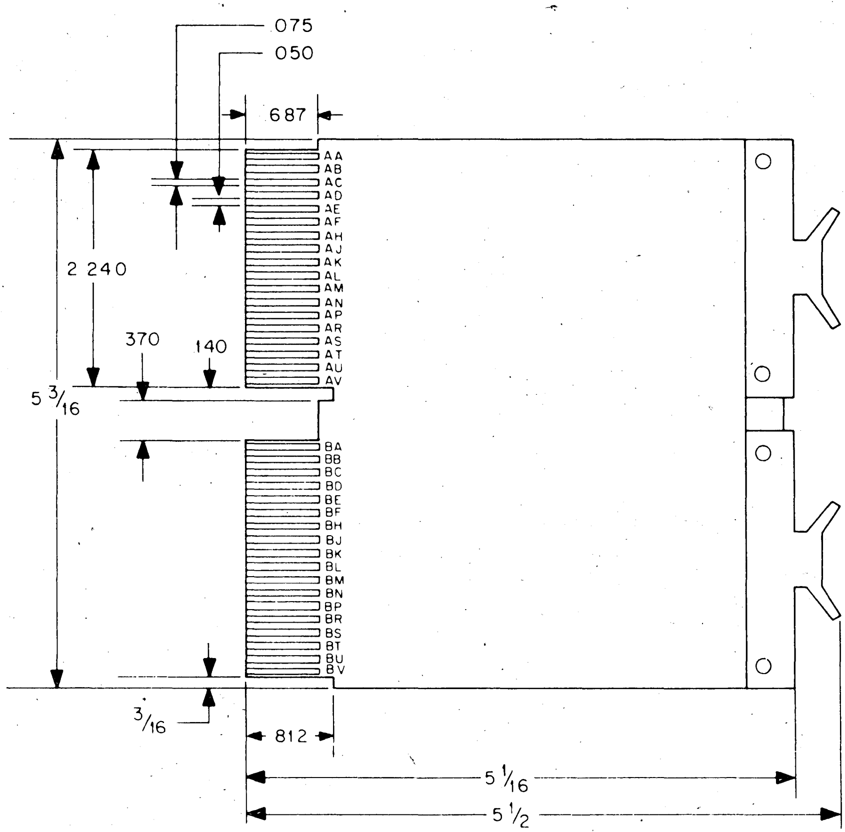
SINGLE-HEIGHT FLIP CHIP MODULE



DOUBLE-WIDTH FLIP CHIP MODULE

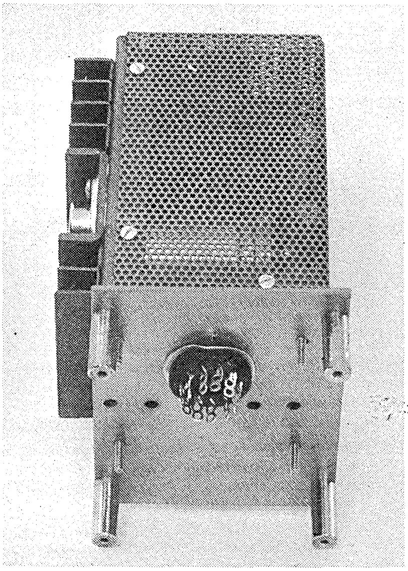


DOUBLE-HEIGHT FLIP CHIP MODULE

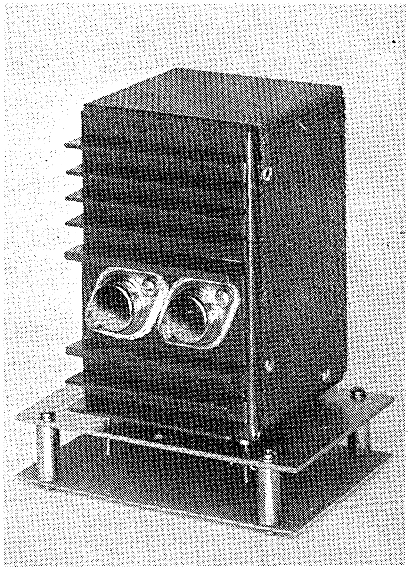


All incoming integrated circuits undergo computer controlled testing, with 40 dc and 16 ac tests performed in 1.1 seconds. This 100% inspection speeds production by minimizing the diagnosis of component failures in module test.

DUAL POWER SUPPLY
H704, H707
±15 Volts



H704



H704

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.

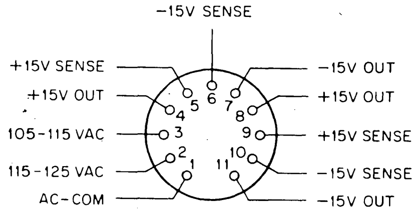
MECHANICAL CHARACTERISTICS

DIMENSIONS: 3¼ x 3⅜ x 5 in. height (H704)
DIMENSIONS: 4″ x 5″ x 5½″ 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

H704 — $200
H707 — $400

ELECTRICAL CHARACTERISTICS

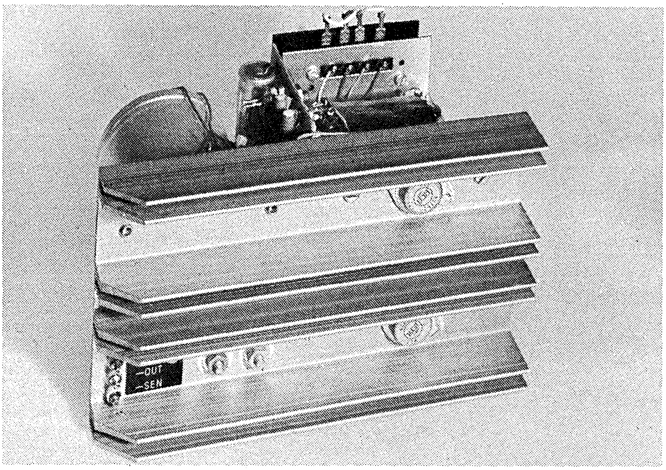
INPUT VOLTAGE: 105 to 125 vac; 47-420 cps.
OUTPUT VOLTAGE: floating ± 15v
OUTPUT VOLTAGE ADJUSTMENT: ± 1v each output
REGULATION: 0.05% line, 0.1% load for both voltages
RIPPLE: 1 mv rms max for both outputs
OVERLOAD PROTECTION: The power supply is capable of withstanding output short circuits indefinitely without being damaged.
IF REMOTE SENSING IS NOT USED, CONNECT: 5 TO 4, 6 TO 7



IF REMOTE SENSING IS NOT USED CONNECT: 5 TO 4
6 TO 7
8 TO 9
10 TO 11

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 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 module 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.

POWER SUPPLY
H710



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. shirt-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.

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.

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

H710 — $200

POWER SUPPLY
H716

POWER SUPPLY

Type H716 provides +5 volts at 4 amperes and —15 volts at 1.5 amperes with over voltage protection for +5 volts. This dual voltage power supply is designed to be mounted at the right end of any mounting panel which incorporates the Type H021 mounting frame. The supply is mounted by using the four holes in the Type H021, therefore the right end plate cannot be used when a Type H716 supply is mounted. The supply takes 2 connector blocks of Type H800, H803, or H808. This provides 48 module slots with Types H800 and H803, 24 slots with Types H800 and H803 and 24 slots when Type 808 is used.

MECHANICAL CHARACTERISTICS

Maximum Dimensions 5¼ x 4⅛ x 12 deep

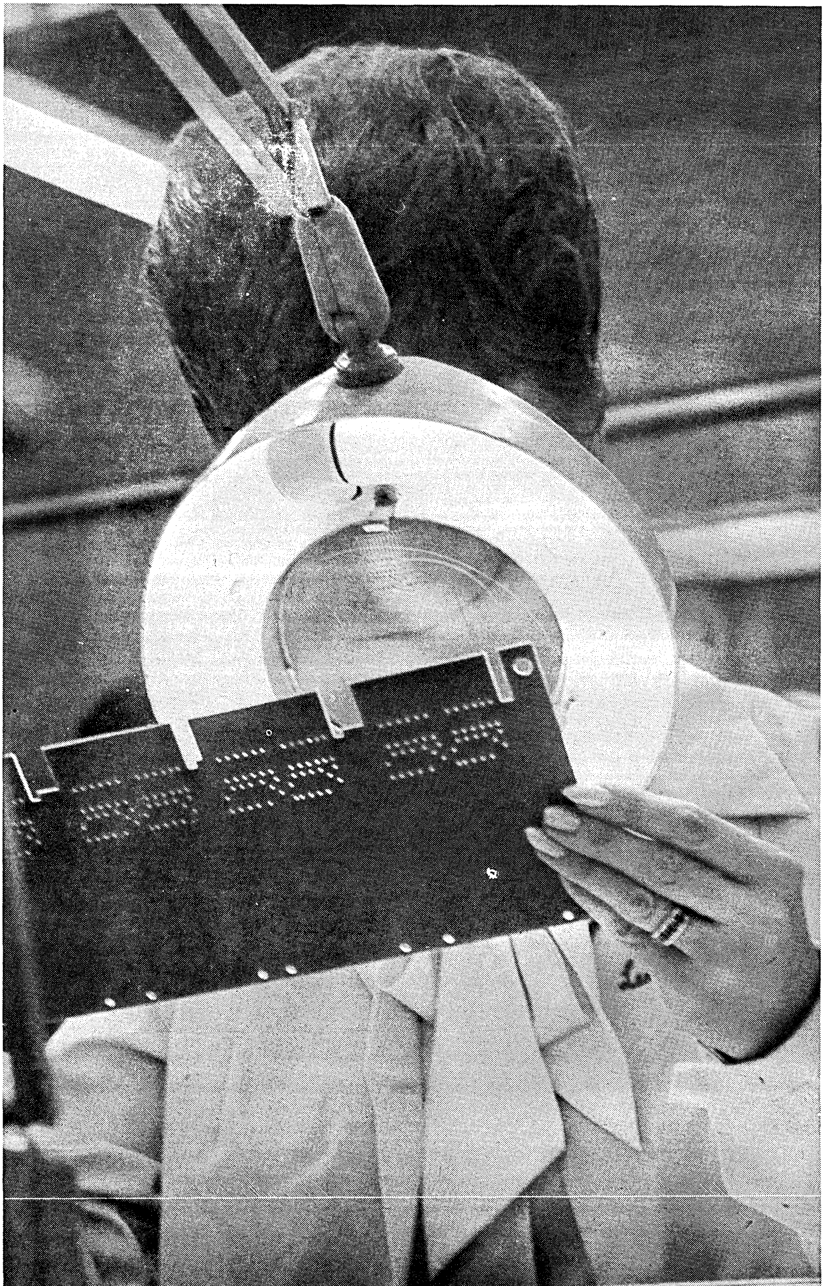
Power input via Amphenol 160-5 or equivalent connector with an Amphenol 160-5 or equivalent, in parallel.

Low voltage connections are by slip on terminals.

ELECTRICAL SPECIFICATIONS

Input:	120/240 vac ± 10%, 47-63 HZ. Normally supplied wired for 120v. For 240 volts change transformer tap connections.
Output 1:	+5v, adjustable from 4.5 to 5.5 volts at 4 amperes maximum. Line-Load-Ripple total regulation ±3%.
Output 2:	—15v ±5% at 1.5 amperes, maximum. Line-Load-Ripple total regulation ±5%.
Temp. Range:	Above specifications are over a range of 0-50°C.

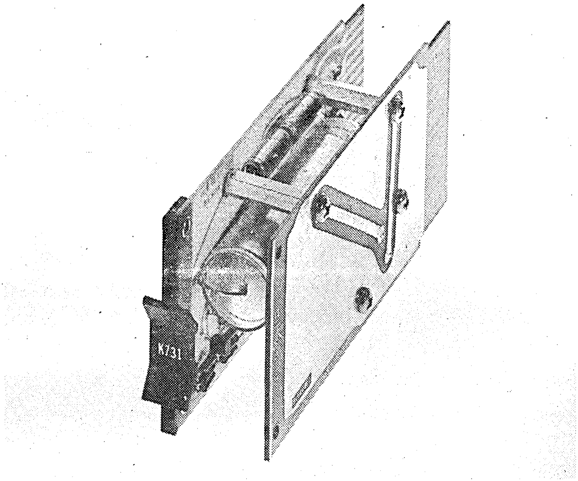
H716 — $130

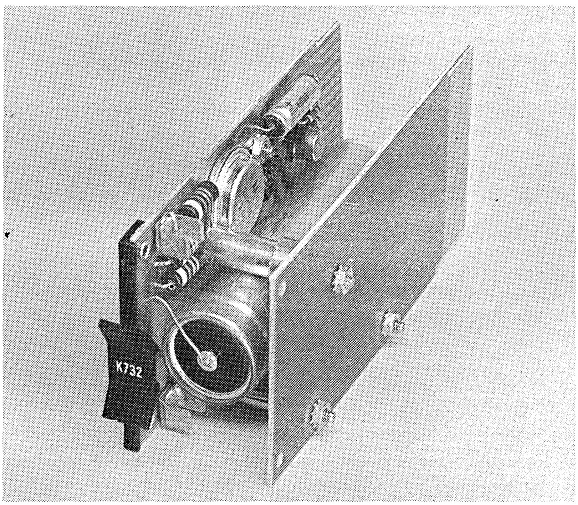


Quality of plated-thru holes is checked in our new electrochemical facility before boards go to the module assembly area.

POWER SOURCE MODULE
K731
SLAVE REGULATOR
K732

HARDWARE

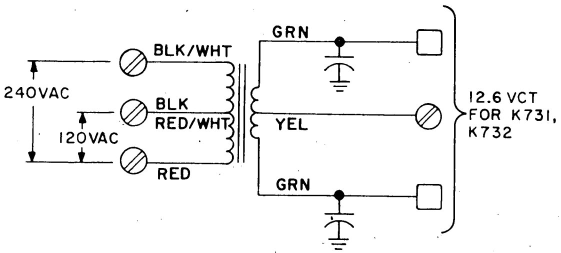


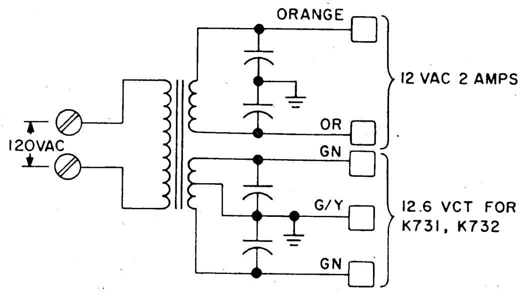


One K731 plus up to 3 K732 can provide from 1 to 7 amperes at +5v. Consult K Series text for additional characteristics and hook up information.

K731	$24
K732	$27

POWER TRANSFORMERS
K741, K743



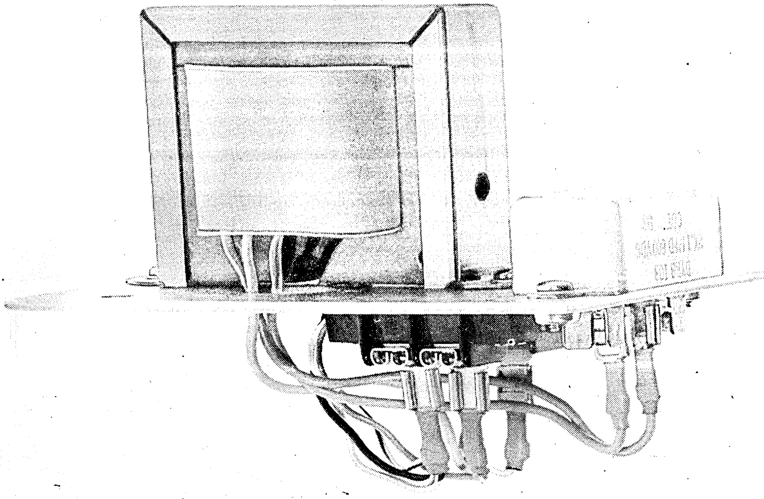


These hash-filtered, 50/60 Hz transformers supply K731 Source and K732 Slave Regulator modules. The K743 also provides an auxiliary winding for use with K580 Dry Contact Filters and K681 or K683 Lamp Drivers (requires additional bridge rectifier). Type 914 Power Jumpers are convenient for connecting 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:

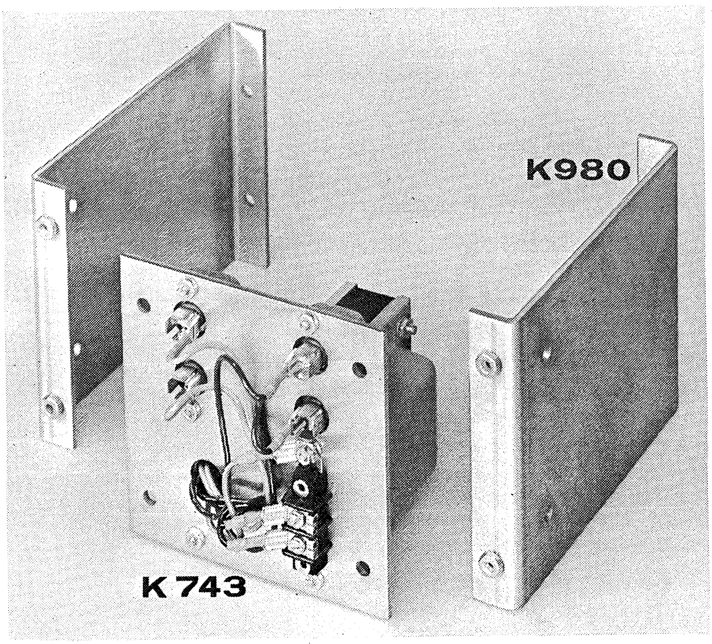
	PLATE DIMENSIONS	HOLE CENTERS	MATCHING K980 Ctrs.
K741	3½" x 5"	2½" x 3⅜"	2½"
K743	5" x 5"	4" x 3⅜"	4"

The K741 is sufficiently light in weight to be mounted on one side only, as at the end of a K943 mounting panel.

K741 — $22
K743 — $38



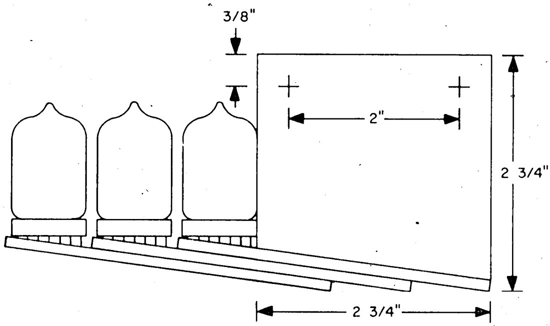
K741



K743

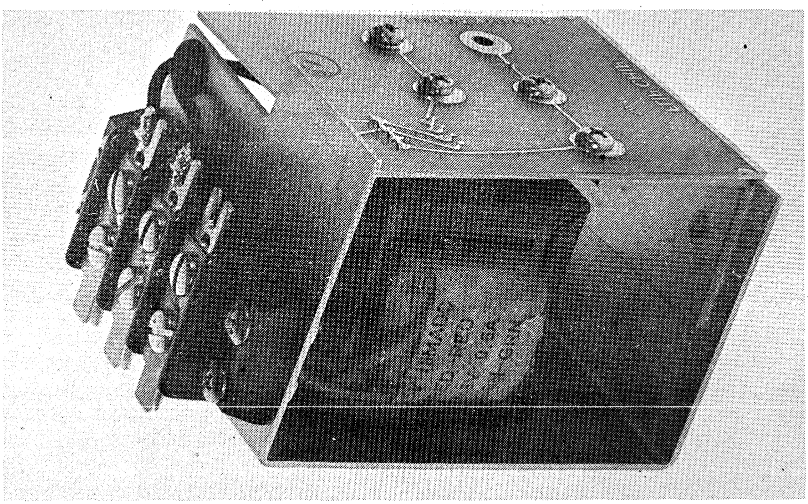
DISPLAY SUPPLY
K771

POWER SUPPLY



(SHOWN WITH 3 K671'S)

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 mouning 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" 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".

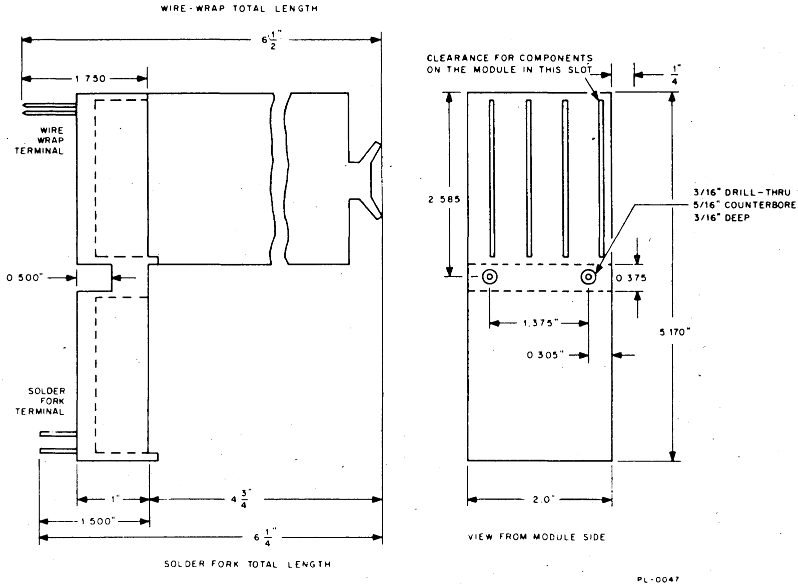


K771 — $26

CONNECTOR BLOCKS
H800-W, H800-F

HARDWARE

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

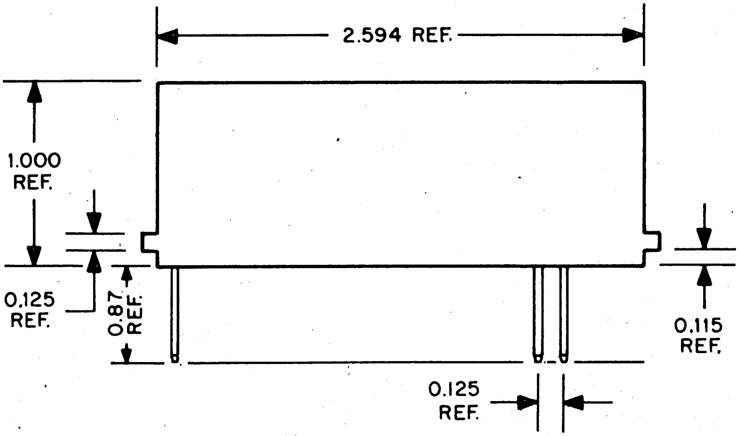
These contacts are offered in packages of 18 for replacement purposes. In each package, nine straight and nine offset contacts are included, enough to replace all contacts in one socket.

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

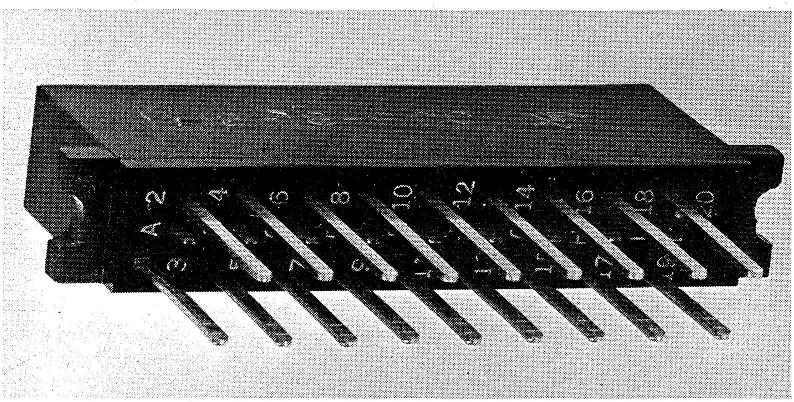
H800F — $8
H800W — $8
H801F — $2
H801W — $2

CONNECTOR BLOCK
H802

HARDWARE



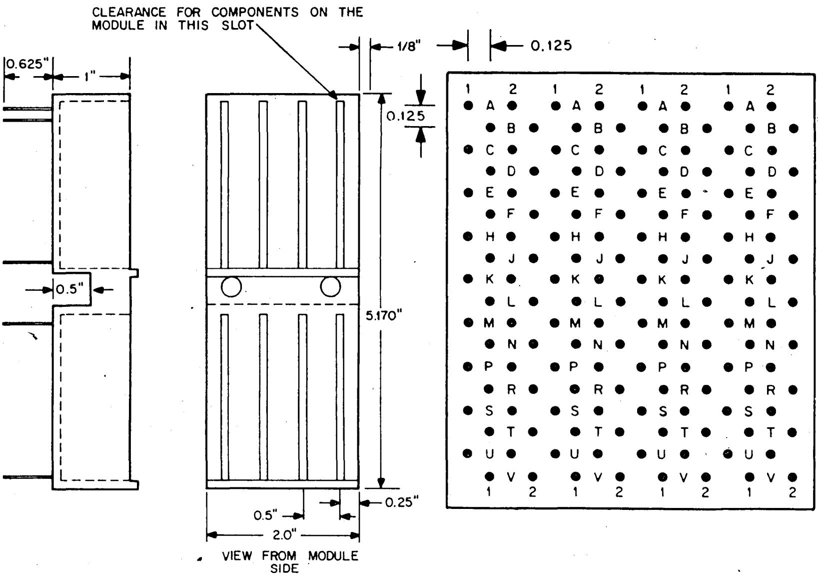
This is an 18 pin connector block for a single flip-chip module. The H802 can be used to fit a single module in a confined or irregular space. Often the H802 is used as a connector for a cable at some remote location. The H802 is only available with wire wrap pins.



H802 — $4

CONNECTOR BLOCK
H803, AND H805 PINS

HARDWARE



The H803 is the 8-module molded Jacket Assembly used in the H910 and H911 mounting panels. For each of the eight modules, it provides a 36-pin connector with the wirewrap pins forming a 0.125-inch staggered grid as shown above. This connector is designed to be used with M Series modules; however, it can also be used with all other series listed in this handbook.

The blocks have the same physical dimensions as the H800 with the exception of pin length. These blocks are only available with wire wrap pins which are designed to be wrapped with number 30 wire. Pin dimensions are 0.025 inches square. W&K Series 18 pin modules will make contact with only the 2-side pins (A2, B2, etc.).

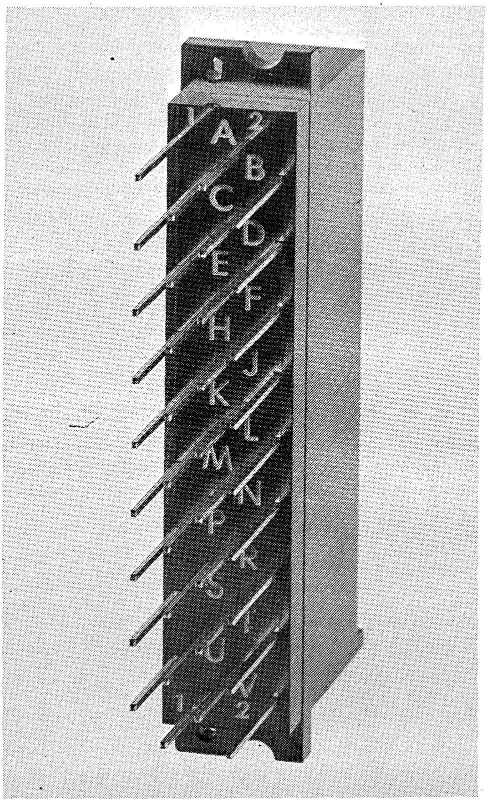
H805 is a package of 36 pins (18 left and 18 right) to be used as replacements in H803 blocks. Three types are available depending on the manufacturer of Type H803 whose name or symbol is found on the connector mounting block. For ordering purposes specify letter code as shown below: H805

A—Amphenel
C—Cinch
S—Sylvania

H803 — $13
H805 — $4

CONNECTOR BLOCK
H807

HARDWARE

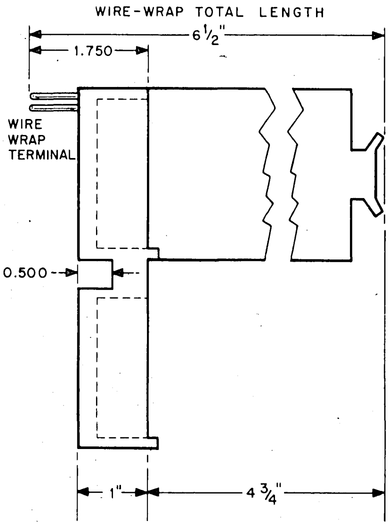


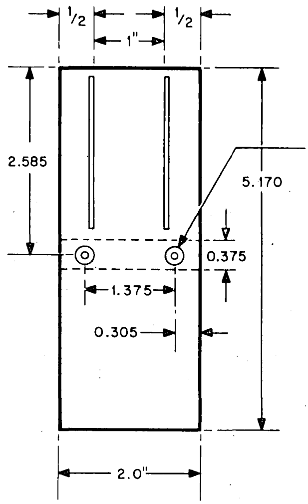
This is a 36 pin single slot connector. It is provided for M-Series modules but can be used with modules or connector boards in the K and W Series. Uses include mounting in confined or irregular spaces. Often the H807 is used to terminate a connector board at a remote location. The H807 is available only with wire wrap pins.

H807 — $5

CONNECTOR BLOCK
H808, H809 PINS

HARDWARE





VIEW FROM MODULE SIDE

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.

H808—$10
H809—$ 4

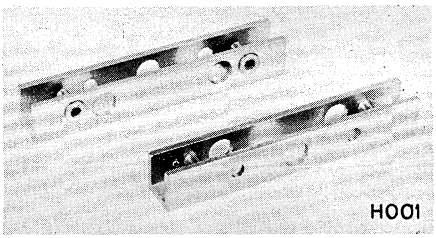
MOUNTING PANEL HARDWARE
H001, H002, H020, H021, H022

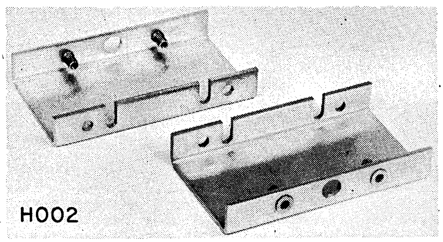
Pairs of brackets. H001 provides ¾" standoff to mount 1907 over K943 wiring. H002 provides a 2" setback so a control panel with switches, lamps, etc. can be mounted flush with mounting rack or cabinet in front of logic wiring.

The 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.

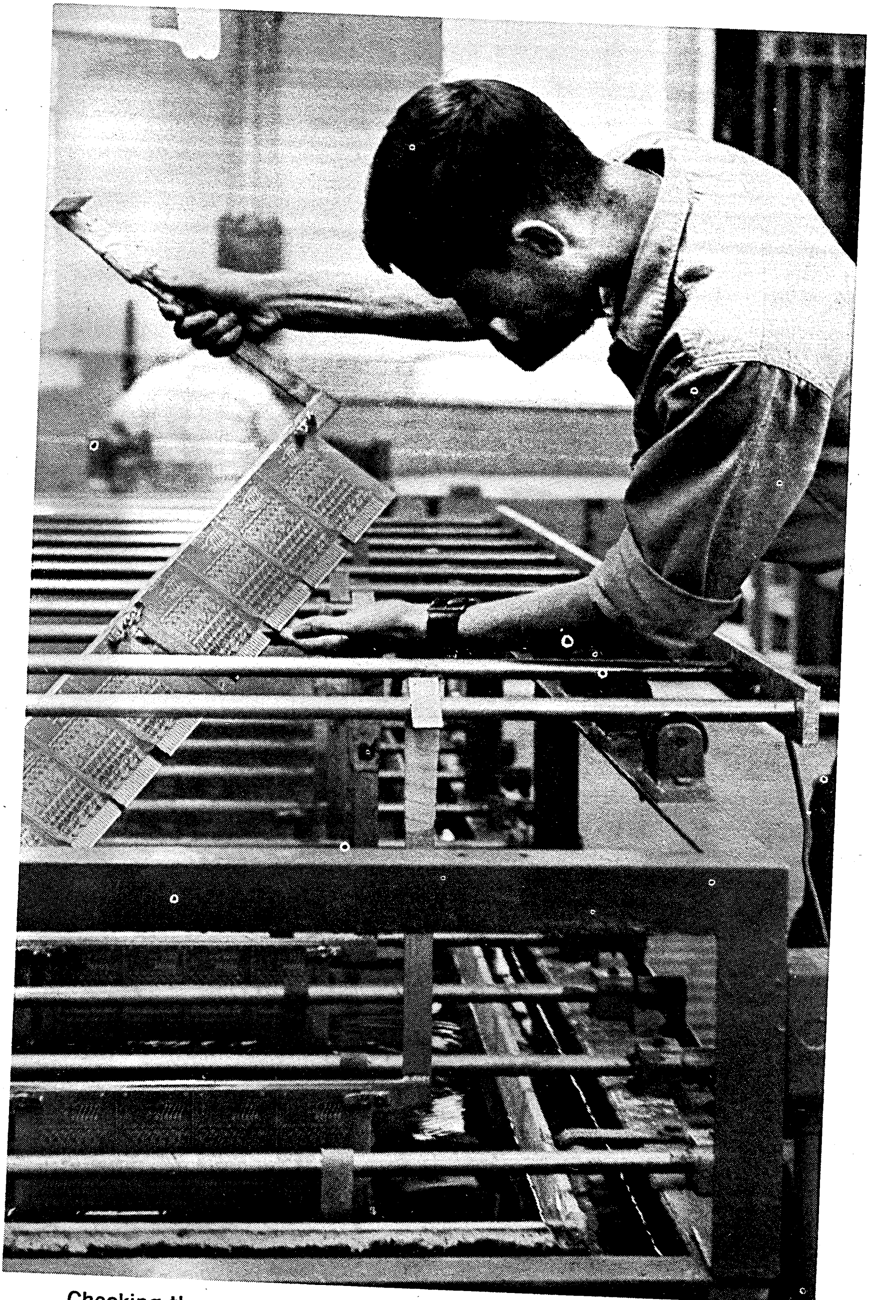
The H021 consists of a pair of offset end plates which mount to the H020.

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.


H001


H002

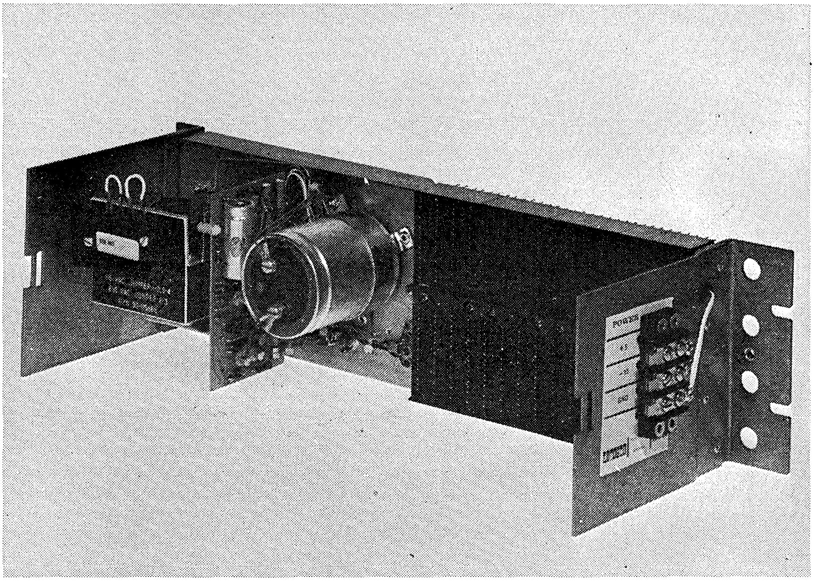
H001-PR	$8
H002-PR	$8
H020	$15
H021	$7
H022	$20

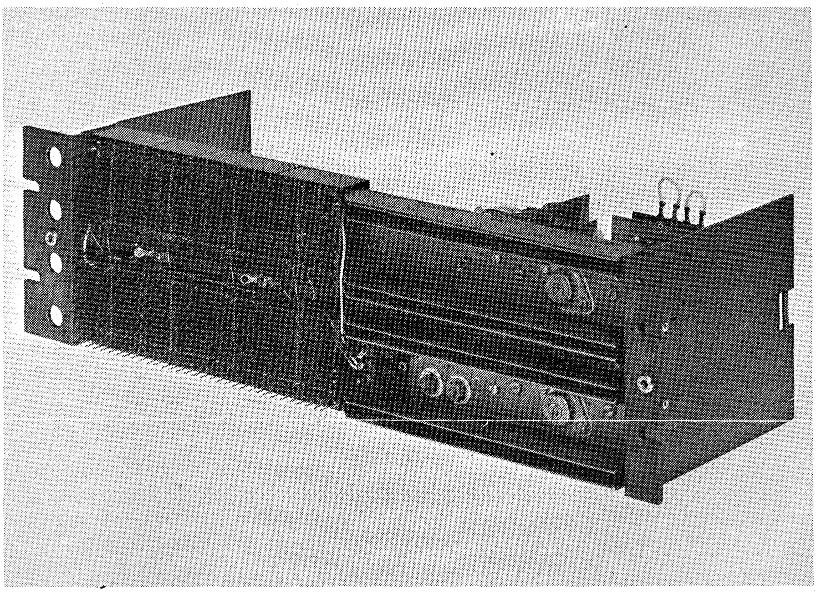


Checking the appearance of board contacts being gold-plated. Our 100 micro-inch plating is verified by periodic checking on a radiation gauge.

MOUNTING PANEL
H910

HARDWARE





This dual function mounting panel offers a way to build complete digital systems of up to 32 FLIP CHIP modules into only $5\frac{1}{4}$ in. of rack space. More power is available than is ever likely to be consumed in a 32 module system. Power in excess of that required for 32 modules can be obtained at the terminal block which si convenient to the input terminal block on any adjacent H911 or 1943 mounting panel.

The H910 panels are built from four H803 connector blocks and a 5 volt regulated supply. Wire wrap connectors for 30 awg wire only are present on the H910. The panel will hold 32, 36 pin modules. In addition, the panel is bussed with 933 bus strips on pins A2, C2, and T1 and all power wiring to the supply is connected. Power in excess of that required for the 32 modules can be obtained at the terminal block which is convenient to the input terminal block on any adjacent H911 mounting panel, generally used for M series modules.

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: $5\frac{3}{16}$ in.
DEPTH: $16\frac{3}{4}$ in.
FINISH: Chromicoat
POWER INPUT CONNECTIONS:
Screw terminals
vided on transformer
MODULES ACCOMMODATED: 32
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 $\frac{1}{2}$ in. to depth of mounting panel.

Consult following table for option and ordering information.

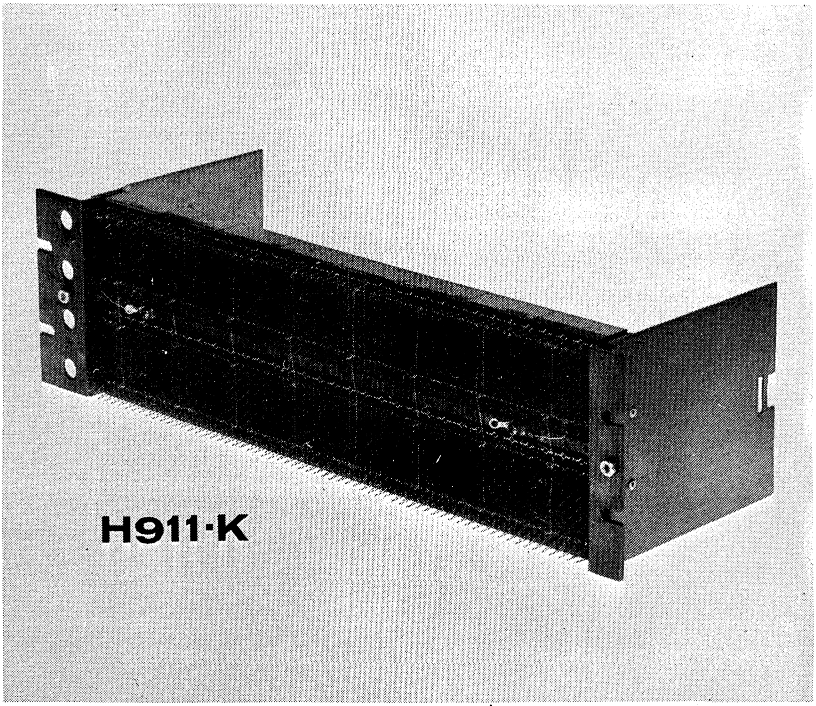
MOUNTING PANEL
H911 J, H911-K

HARDWARE

The H911 mounting panel uses eight H803 connector blocks and houses sixty four, 36 pin connectors. Mechanical dimensions are identical to those of the H910. The H911 is available with wire wrap pins only. Power wiring options are available on the H911. Generally used for M series modules.

933 BUS STRIP—For H911 mounting panel, makes wiring power and register pulse busses easy.

Consult following table for option and ordering information.



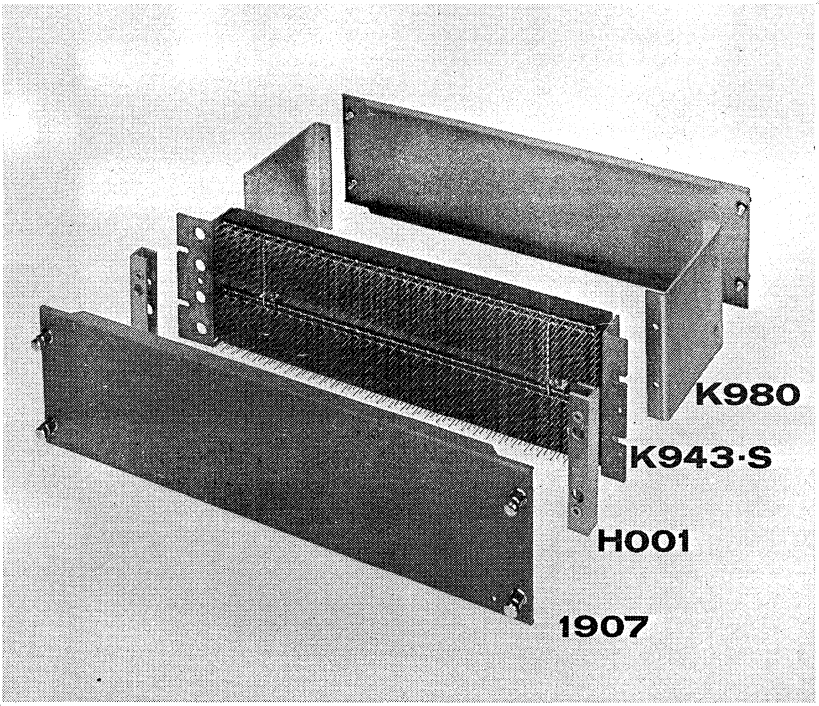
H911J—$151
H911K—$161

19" MOUNTING PANEL
K943-R, K943-S

HARDWARE

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: 5¼". See photos showing K943-S, K980, 1907, and H001.



K943R—$96
K943S—$96

MOUNTING PANEL
H913, H914, H916 & H917

HARDWARE

This 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 like those of type H910.

This 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 H911.

This panel incorporates an H020 frame on which is mounted an H716 power supply and 6 H803 (green) connector blocks. This provides 48 36 pin module slots. Although generally used for mixes of M and A series modules K and W series modules can also be accommodated.

This panel is similar to H916 except 6 low density H808 connector blocks are supplied. With this connector block 24 module slots are available allowing the use of either of the module series. Electrical and mechanical characteristics are similar to those of Type H916 with the exception of the connector block pins.

H913—$270
H914—$125
H916—$270
H917—$260

TABLE OF MOUNTING PANELS WITH & WITHOUT POWER SUPPLY

NA = Not Available.

ORDER NO.			AVAILABLE VARIATIONS				PRICE
Panel	Order Letter	Power Option	F	W	B	P	
H910	K	V	NA	X	X	X	$280
H911	J	X	NA	X	X		$151
H911	K	X	NA	X	X	X	$161
H913	L	V	NA	X	X	X	$270
H914	L	X	NA	X	X		$125
H916	M	V	NA	X	X	X	$270
H917	N	V	NA	X	X	X	$260
K943	R	X	X			X	$ 96
K943	S	X		X		X	$ 96

X = NO POWER
V = 105-125 VAC
OR 210-250 VAC
47-63 Hz.

PREWIRED POWER
(extra cost option)
Omit P if not desired.

CONNECTOR
W—for wire-wrap
F—for forked solder connectors

POWER CONNECTION
B—Power input via terminal block. Both conventional screw connections and taper tabs can be used.

Example Order: H911KX
This describes a Type H020 casting with 8 Type H803 wrie wrap connectors and ground wired to a terminal block incorporated into the end plate assembly.

END PLATES
K980

HARDWARE

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

HARDWARE

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

MODULE DRAWER AND ACCESSORIES
H920, H921, H923

The H920 Module Drawer provides a convenient mounting arrangement for a complete digital logic system. The drawer has sufficient room to house up to 20 mounting blocks in addition to the H710 power supply. The power supplies not included in the H920 but must be ordered separately. When used without the power supply, there is room for up to 24 mounting blocks. The drawer accepts both H800 and H803 mounting blocks and fits a standard 19" relay rack and all DEC cabinets. Width of the module drawer is 16¾" and depth is 19". When used with the H921 Panel, the height is 6¾". The module drawer comes equipped with a power bracket for distribution of power within the drawer, to other drawers or to mounting panels. The H920 comes with convenient mounting arrangements for both the H921 front panel and the H923 slide tracks. The H921 is a front panel designed to be used primarily with the H920 Module Drawer. It provides convenient mounting arrangements for switches, indicators, and other accessories which may be required in a logic system. The H921 comes pre-drilled and ready to mount to the H920. Height of the panel is 6¾" and width is 19".

The H923 chassis slides are designed to be used with the H920 Mounting Drawer. These slides allow the user to slide the drawer out of the cabinet or rack and tilt the drawer to any angle. H923 tracks may also be ordered directly from Chassis Trak, Inc., Indianapolis, Indiana, part number CTD 120.

H920 —	$170.00
H921 —	$ 5.00
H923 —	$ 75.00

MODULE DRAWER
H925

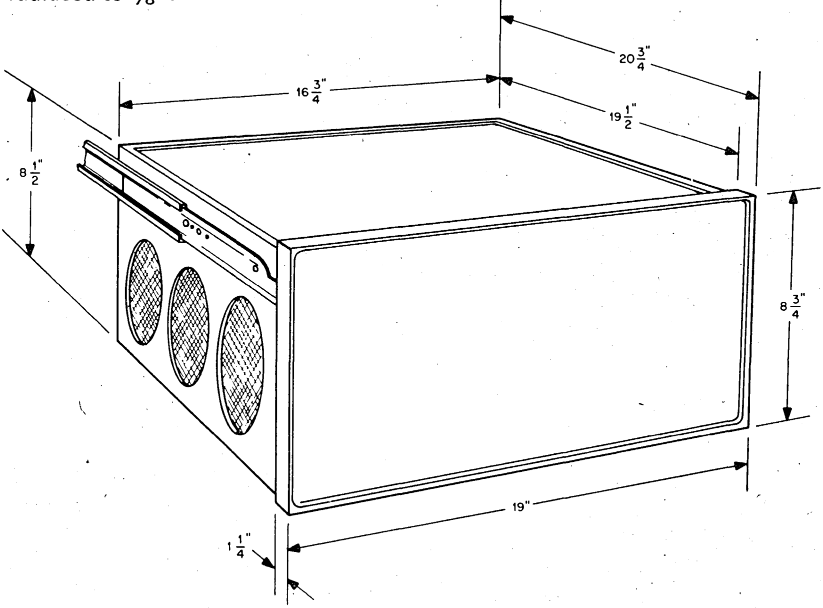
HARDWARE

This enclosure provides mounting space for up to 18 H800 or H803 connector blocks accommodating as many as 144 M or K series modules. The H808 one-half density connector may also be used for an accommodation of 72 M series modules. The connector blocks mount pins-upward for easy access during system checkout.

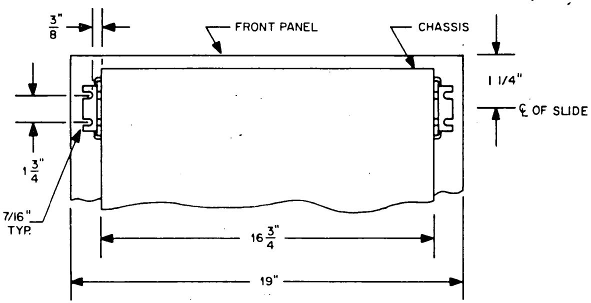
Three axial flow fans are provided and are mounted internally on the right side of the enclosure to provide cooling air flow across mounted modules and through the power supply area.

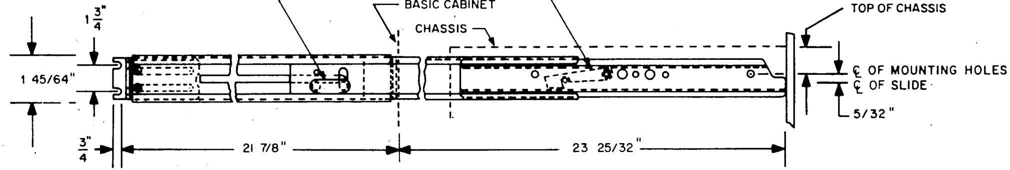
A 3¾" wide, 7¾" high, 18¾" deep space is provided in the left side portion of the enclosure for power supply mounting or other purposes. Any assembly mounted in this space should be designed in such a manner as to not obstruct the air flow from passing on through the three screened openings in the left side of the enclosure. Two non-tilting slides, similar to Grant type SS-168-NT are provided for mounting the H925. Mounting height should allow for possible servicing of the enclosure using bottom access.

Cover plates are provided for the top and bottom of the enclosure. The enclosure also includes an attractive bezel and front sub-panel. The sub-panel is manufactured of 16 gage material and is intended for the mounting of front panel controls and other accessories. The bezel allows for the installation of customer supplied dress panel. The dress panel should be manufactured of ⅛" thick material which measures 8¼" x 18⅜" with the corners radiused to ⅜".



REAR VIEW OF
MOUNTING HARDWARE





SIDE VIEW OF
MOUNTING HARDWARE

285

H925 — $325

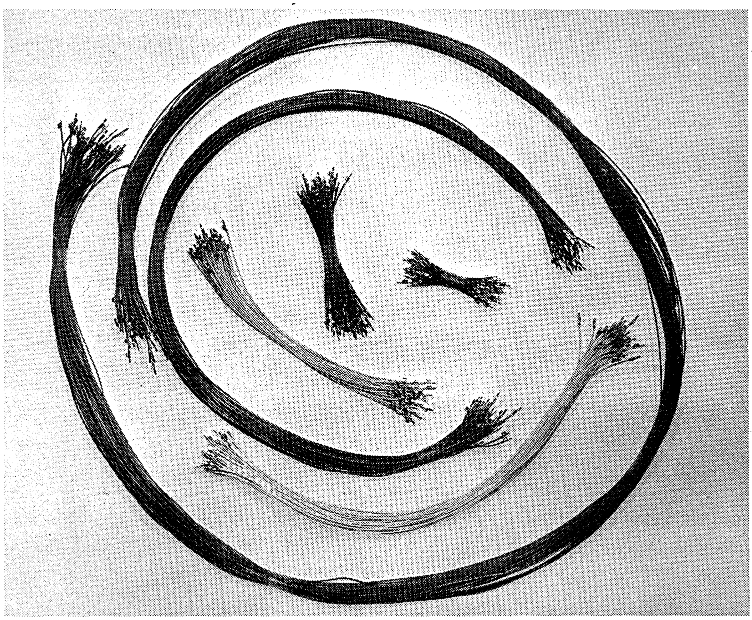
WIRING ACCESSORIES
913, 914, 915, 917
H820, H821, H825, H826

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.

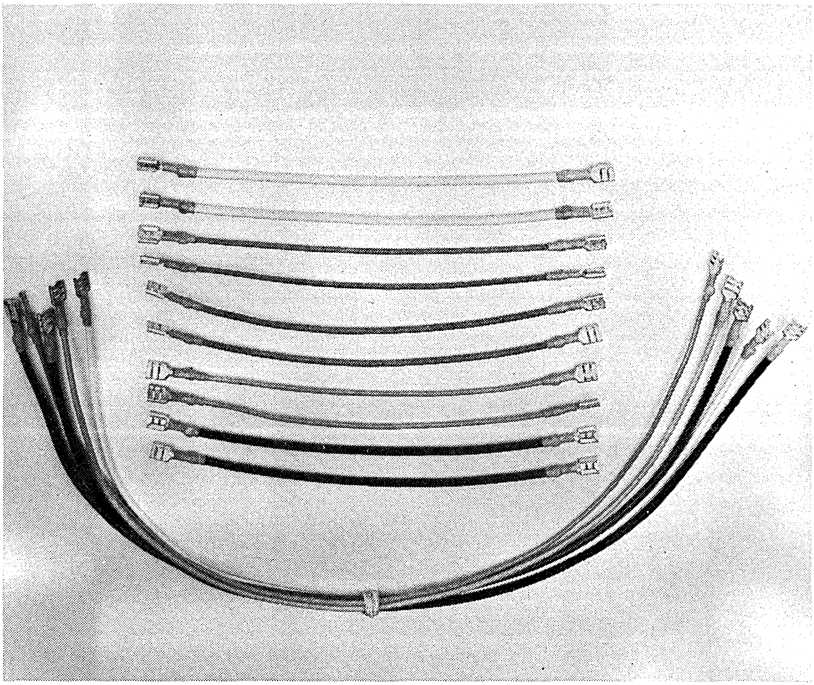


H825 HAND CRIMPING TOOL

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.

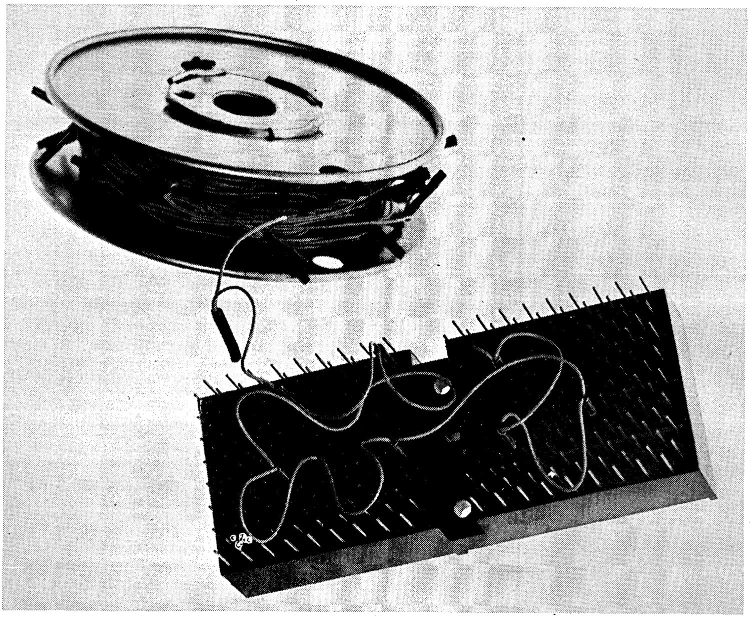
H826 HAND CRIMPING TOOL

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.



917 DAISY CHAIN

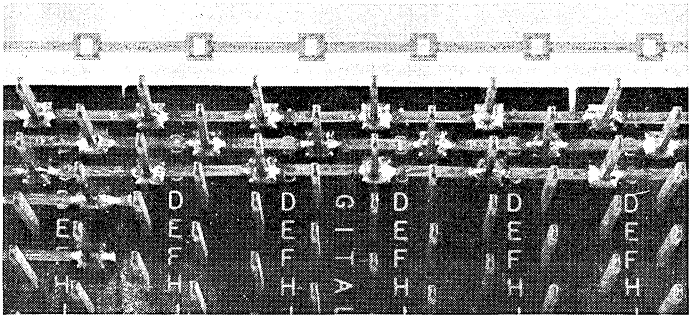
Type 917 is a continuous length of unbroken #25 AWG stranded wire. 250 gold plated and insulated terminals are crimped at predetermined intervals on each reel. In conjunction with type H803 or type H807 connector blocks and M Series modules, hand patch wiring of prototype systems is easily and quickly accomplished. All that is required is a reel of type 917 Daisy Chain and wire cutters. These dependable push on connections are also easily removeable making this wiring technique ideal in cases where wiring and unwiring for changing systems needs is required. If ever a third lead is necessary a type 915 patchcord can be used if placed on the pin before the Type 917 termination. Two contact spacings available at 2½" or 5".

917 — 2.5 — blue
917 — 5 — white

Also available from:
Berg Electronics
New Cumberland, Pa. 17070
Tel. (717) 938-6711

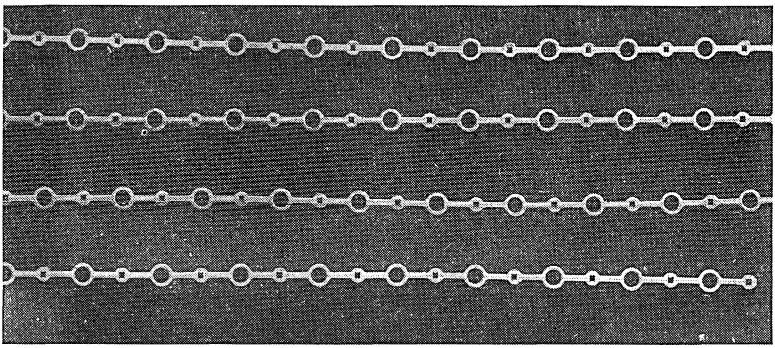
913 — $18.00/pkg. of 100
914-7 — $4/pkg.
914-19 — $4/pkg.
915 — $33.00/pkg. of 100
H820 — $48.00/pkg. of 1000
H821 — $75.00/pkg. of 1000
H825 — $146.00
H826 — $210.00

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.

932 — $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

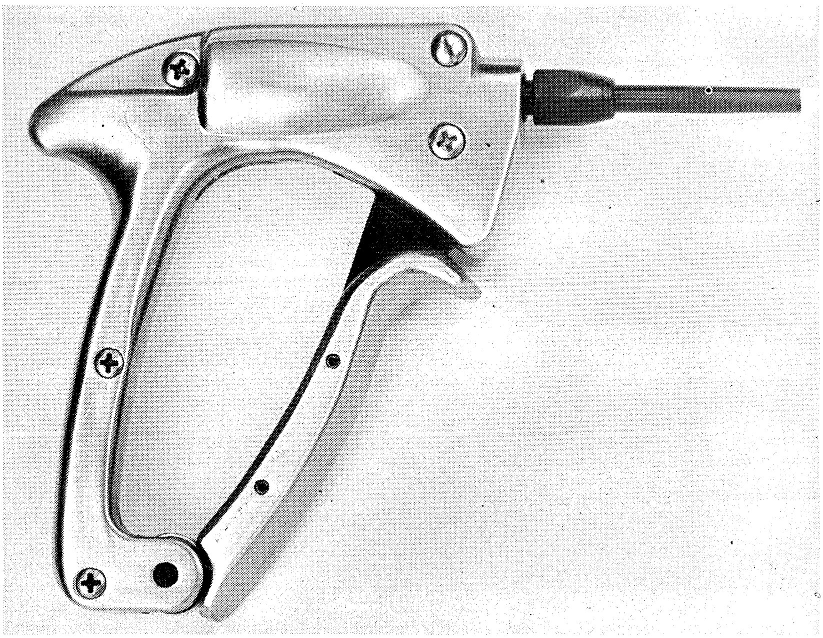
1000 foot roll or 30 gauge insulated solid wire for use with H803 connectors.

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.

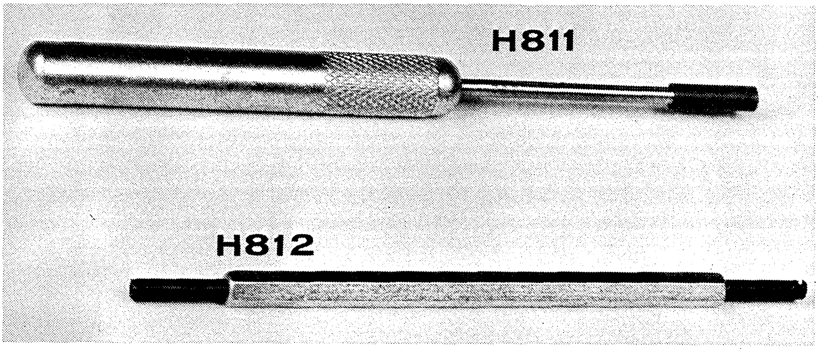
936 — $0.60



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.

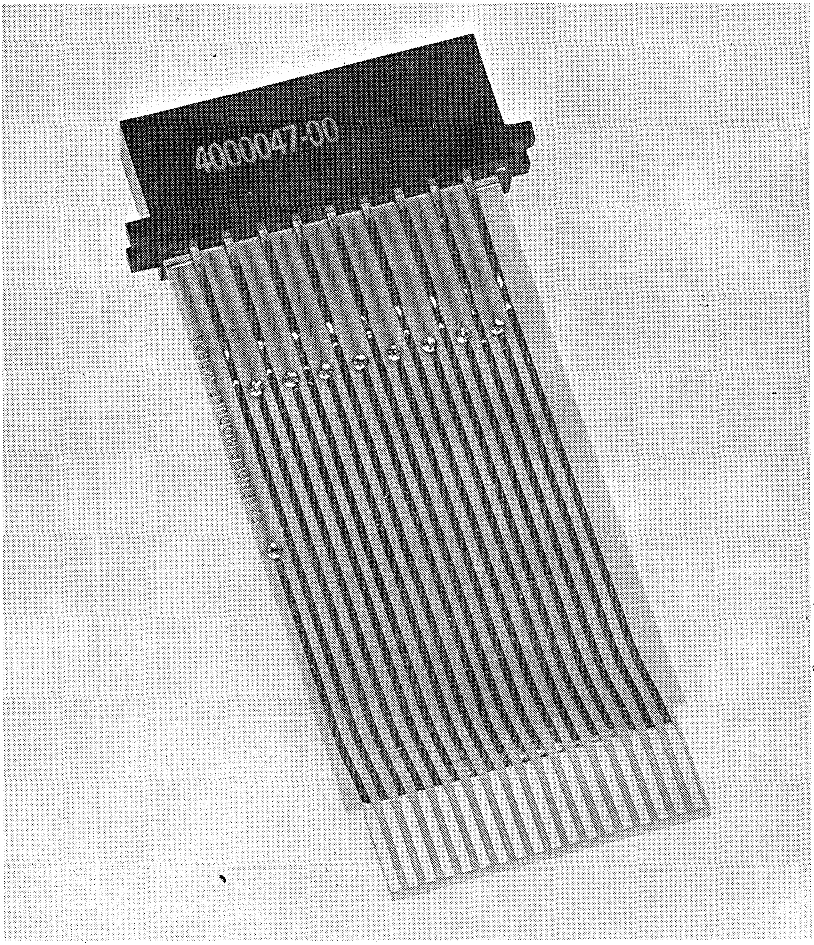
Wire wrapped connections may be removed with the Type H812 Hand Unwrapping tool. This tool may also be purchased from Gardner-Denver Co. as Gardner-Denver Part #500130.

The H811A and H12A 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.

H811(24)	— $21.50
H811A(30)	— $21.50
H812(24)	— $10.50
H812A(30)	— $10.50
H813(24)	— $30
H813A(30)	— $30
H814(24)	— $21
H814A(30)	— $21

MODULE EXTENDER W980,	HARDWARE



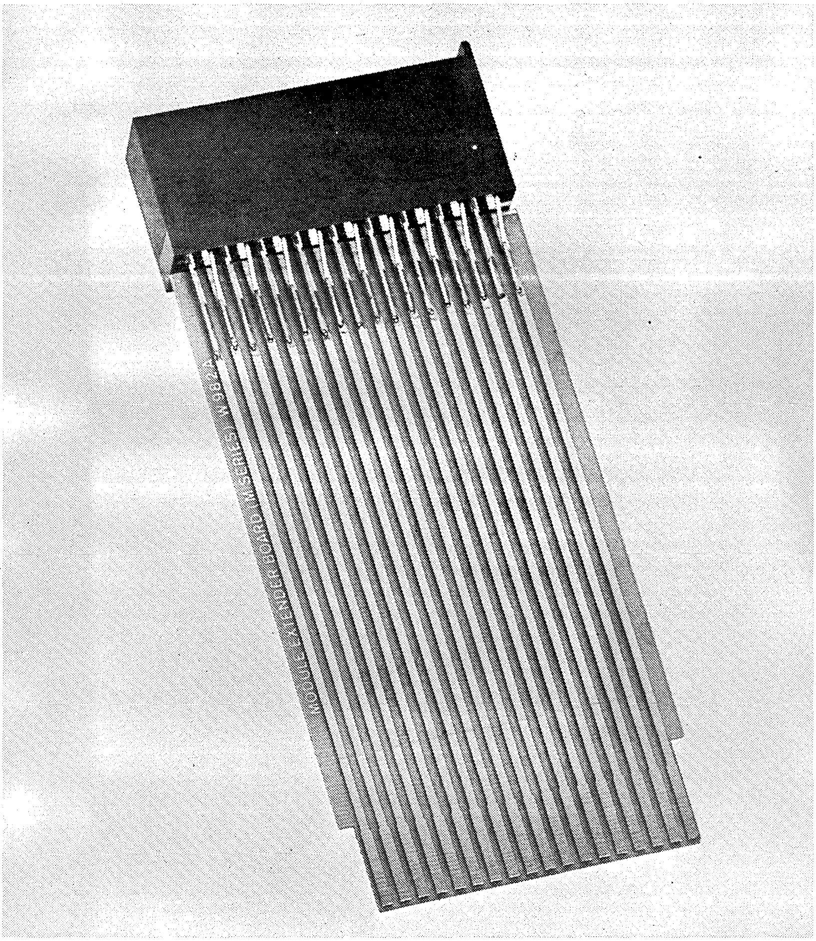
The W980 Module Extender allows access to the module circuits without breaking connections between the module and mounting panel wiring.

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

MODULE EXTENDER
W982,

HARDWARE



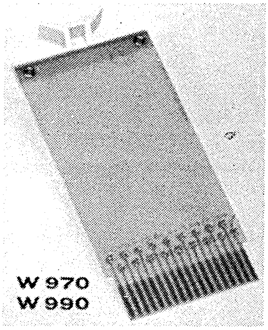
The W982 serves a function similar to the W980 except it contains 36 pins for use with M series modules. The W982 can be used with all modules in this catalog. A, K, and W series modules will make contact with only 2 side pins. A2, B2, etc.

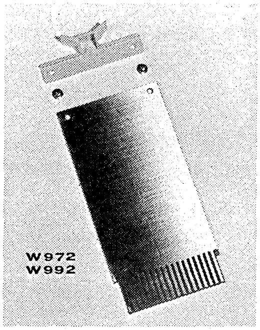
For double size M Series modules use two W982 extenders side by side.

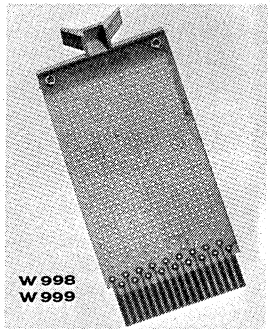
W982 — $18

BLANK MODULES
W970-W975, W990-W999

HARDWARE



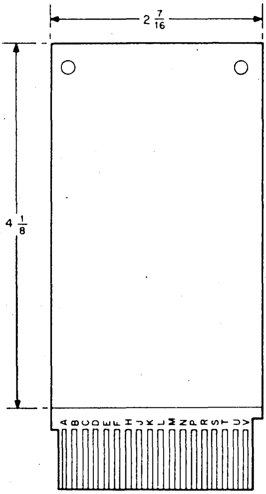




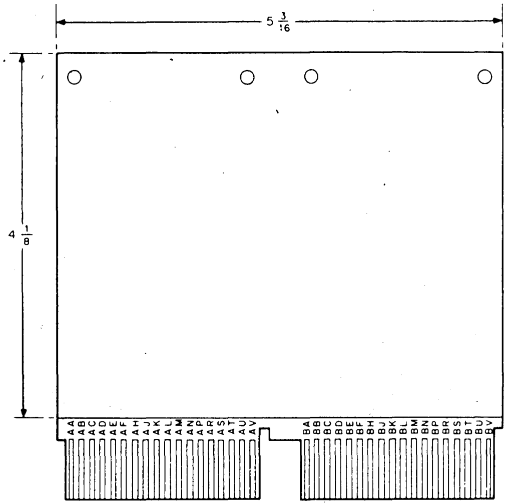
These 10 blank modules offer convenient means of integrating special circuits and even small mechanical components into a FLIP CHIP system, without loss of modularity. Both single- and double-size boards are supplied with contact area etched and gold plated. The W990 Series modules provide connector 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.

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

BLANK COPPER CLAD MODULES
W992, W993, W972, W973



W992

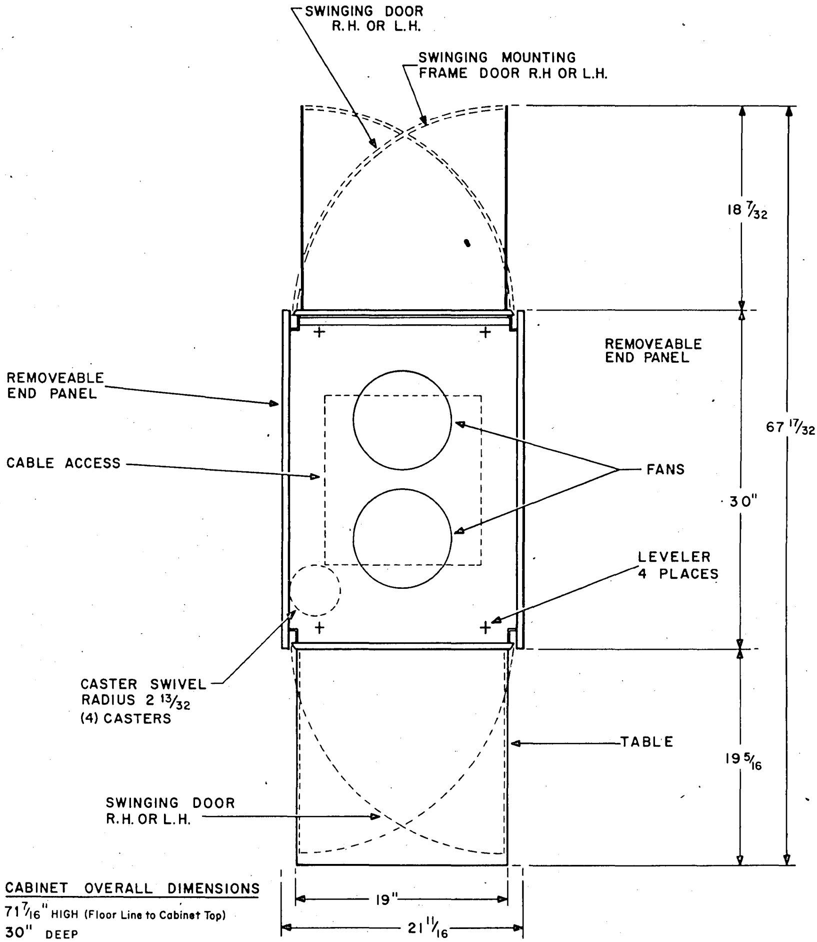


W993

Type W992 and W993 are single side copper clad boards. The diagrams above indicate the copper clad area that is usable for etching purposes. The identifying numbers are etched from the clad using a minimum of etchable area. Type W972 and W973 are equivalent to the above types but have copper clad on both sides.

W972—$4
W973—$6
W992—$2
W993—$4

	DEC Standard 71-7/16" Overall Height 63" Mounting Panel Height	Prices
Frame 19" Cabinet, 63" Mtg. Panel Height	H950-AA	$120.00
Full Door (RH)	H950-BA	35.00
Full Door (LH)	H950-CA	35.00
Mounting Panel Door (RH)	H950-DA	35.00
Mounting Panel Door (LH)	H950-EA	35.00
Mounting Panel Door—Skin	H950-FA	20.00
Short Door (covers 21" Mounting Height)	H950-HA	30.00
Short Door (covers 22¾" Mounting Height)	H950-HB	30.00
Short Door (covers 26¼" Mounting Height)	H950-HC	30.00
Short Door (covers 31½" Mounting Height)	H950-HD	30.00
Short Door (covers 36¾" Mounting Height)	H950-HE	30.00
Short Door (covers 42" Mounting Height)	H950-HF	30.00
Short Door (covers 47¼" Mounting Height)	H950-HG	30.00
Short Door (covers 52½" Mounting Height)	H950-HH	30.00
Short Door (covers 57¾" Mounting Height)	H950-HJ	30.00
5¼" Cover Panel (Snap On)	H950-PA	10.00
10½" Cover Panel (Snap On)	H950-QA	15.00
Filter	H950-SA	2.00
End Panel	H952-AA	35.00
Stabilizer Ft. (Pair)	H952-BA	45.00
Fan Assembly	H952-CA	45.00
Caster Set (4)	H952-EA	13.00
Leveler Set (4)	H952-FA	10.00



CABINET OVERALL DIMENSIONS

71 7/16" HIGH (Floor Line to Cabinet Top)
30" DEEP
21 11/16" WIDE

CABINET
H950

ORDERING INFORMATION FOR PREASSEMBLED CABLE

Standard lengths for preassembled cable are: 3, 5, 7, 10, 15 and 25 feet.

Cable price per foot is as follows:

19 conductor Ribbon cable	\$0.60
9 conductor Flat Coaxial cable	\$1.00
19 conductor 1¼" Mylar cable (BC08 only)	\$0.75

Standard charges for connection of cable to each connector is as follows:

Ribbon	\$ 9.00 per connector side
Coaxial	\$18.00 per connector side
Mylar	\$ 3.00 per connector side

STANDARD PREASSEMBLED CABLES

RIBBON

Type	CONNECTORS	Basic Price
BC02F-XX	W018-W023	31.00
BC02L-XX	W021-W021	26.00
BC02M-XX	W021-W021	27.00
BC02P-XX	W022-W022	28.00
BC02S-XX	W023-W023	26.00
BC02W-XX	W028-W028	28.00

COAXIAL

Type	CONNECTORS	Basic Price
BC03C-XX	W021-W021	44.00
BC03D-XX	W021-W021	45.00

To the above prices, add price of cable:

Example: BC02L-7 \$30.20

1—BC02L-XX	\$26.00
7 feet ribbon cable @ \$0.60/ft.	4.20
	\$30.20

A \$5.00 service charge will be applicable to all cable lengths other than 3, 5, 7, 10, 15 and 25 feet.

Example: BC02L-9 \$36.40

1—BC02L-XX	\$26.00
9 feet ribbon cable @ \$0.60/ft.	5.40
non standard length service charge	5.00
	\$36.40

ORDERING INFORMATION FOR PREASSEMBLED CABLE

Standard preassembled cables; X shall equal 3, 5, 7, 10, 15 or 25 feet.

STANDARD M SERIES CABLES

M903-M903
1¼" Mylar Cable

BC08A-3	$41.50
BC08A-5	44.50
BC08A-7	47.50
BC08A-10	52.00

M904-M904
Flat Coax. Cable

BC08B-3	$106.00
BC08B-5	110.00
BC08B-7	114.00
BC08B-10	120.00

M903-2 W031
1¼" Mylar Cable

BC08C-3	$34.00
BC08C-5	37.00
BC08C-7	40.00
BC08C-10	44.50

M904-2 W011
Flat Coax. Cable

BC08D-3	$101.60
BC08D-5	105.60
BC08D-7	109.60
BC08D-10	115.60

CABLE CONNECTORS FOR INDICATOR AMPLIFIERS

TYPES W018, W023

W SERIES

The W018 and W023 provide 18 line ribbon cable connections to FLIP CHIP mounting panels. In the W018 connection to each pin is through a series low leakage silicon diode. The W023 provides unbroken signal lines from the cable to the connector pin.

When these cables are used with 4917 or 4918 indicators, the W018 must be located at the FLIP CHIP panel and the W023 inserted in the indicator socket connector. Cables may be ordered with connector modules on both ends or on one end only. Cable length may be specified in increments of 1 inch.

For ordering information, see W021, W022, and W028 on next page.

Care should be taken when using the W023 for other purposes, since the Power Pins (A, B) are unprotected.

Type	Price without Cable
W018	$9.00
W023	$4.00

CABLE CONNECTORS FOR LEVELS AND PULSES

TYPES W021, W022, W028

W SERIES

The W021, W022, and W028 provide cable connections to the FLIP CHIP 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.

In the W021, the signal leads are connected directly to the signal pins. In the W028, jumpers are available for series or shunt terminators. The Type W022 has a 100-ohm shunt terminator from each signal wire to the shield.

W021 — $4.00
W022 — $5.00
W028 — $5.00

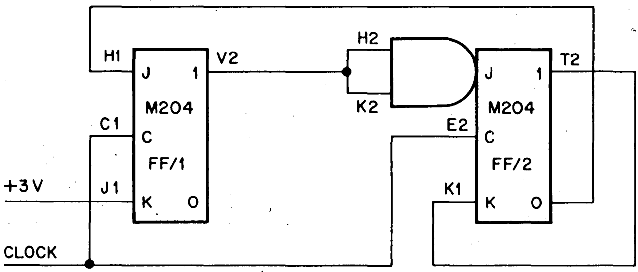
PART III
APPLICATIONS

COUNTER APPLICATIONS
TYPE M204

The arrangement of the J-K flip-flops on the M204 was designed to allow its use as a general purpose clocked counter with a minimum of external gating. This note describes configurations up to modulus 10 (binary coded decimal). In this range only modulus 7 requires additional hardware. The basic design principle used in these counters is to detect the present state of the counter and decide whether or not to complement the flip-flops on the next clock pulse.

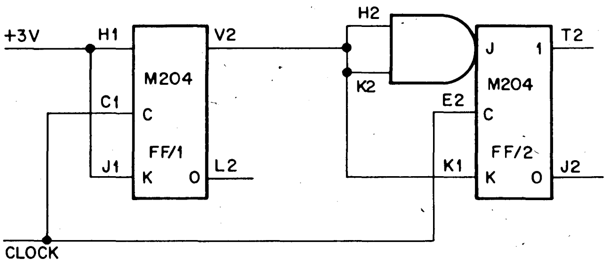
Other techniques exist for making counters of this type making use of pulse amplifiers etc., but these usually represent a significant increase in price.

It must be noted that the line defined as "Clock" requires a positive pulse which is the logical inversion of the standard pulse. One gate of an M117 can be used to perform this inversion. Since each clock input presents two unit loads to the source, more than 5 stages of counting requires the use of one gate of an M627. (Refer to the "Timing Considerations" section of the Logic Handbook.)



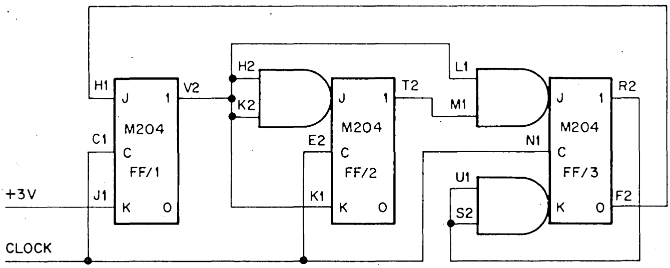
2	1
0	0
0	1
1	0
0	0

MODULUS 3



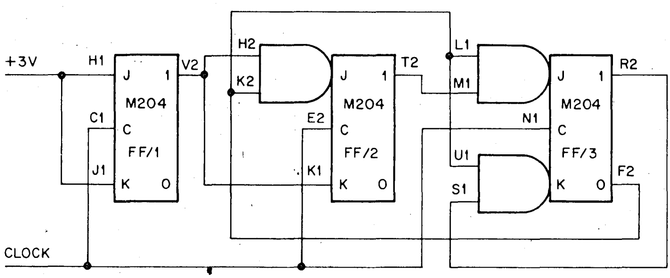
2	1
0	0
0	1
1	0
1	1
0	0

MODULUS 4



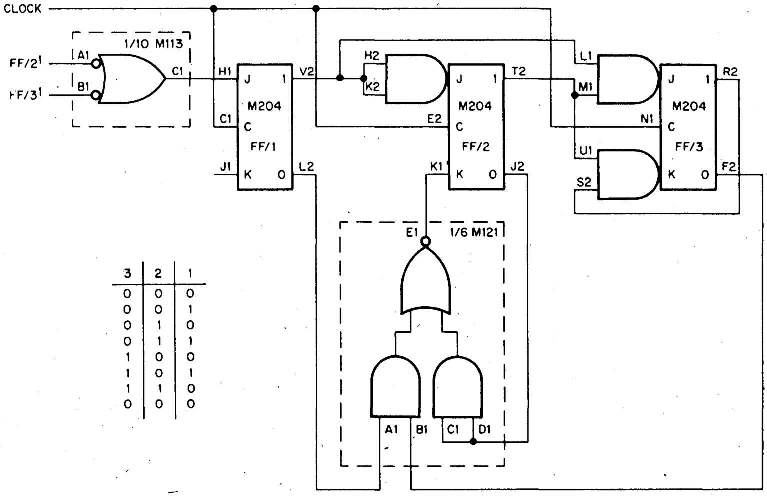
3	2	1
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
0	0	0

MODULUS 5



3	2	1
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
0	0	0

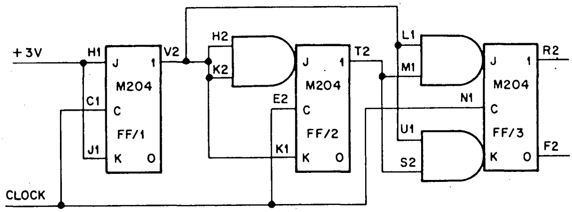
MODULUS 6



3	2	1
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
0	0	0

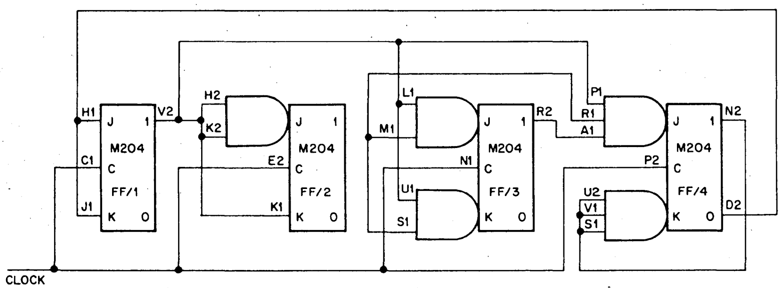
MODULUS 7

The modulus 7 counter requires external gating and cannot be implemented with the M204 alone.



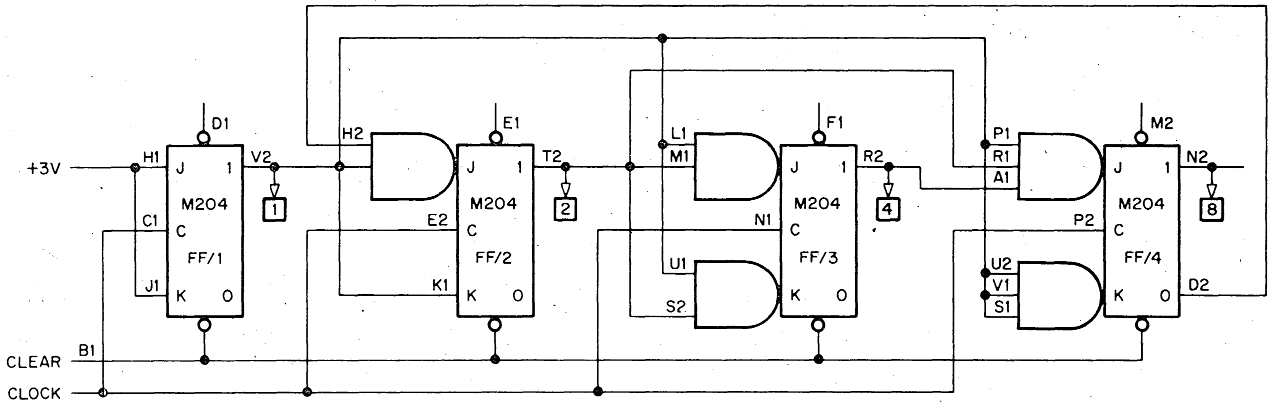
3	2	1
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1
-	-	-
0	0	0

MODULUS 8



MODULUS 9

4	3	2	1
0	0	0	0
0	0	0	1
0	0	1	0
0	0	1	1
0	1	0	0
0	1	0	1
0	1	1	0
0	1	1	1
1	0	0	0
0	0	0	0



8 FF/4	4 FF/3	2 FF/2	1 FF/1
0	0	0	0
0	0	0	1
0	0	1	0
0	0	1	1
0	1	0	0
0	1	0	1
0	1	1	0
0	1	1	1
1	0	0	0
0	0	0	0

MODULUS 10 (BCD 8421)

Discrete components for DIGITAL Modules are positioned and crimped in place at rates up to 2,200 per hour on pantograph controlled inserting machines. Board layouts put like parts in rows, minimizing the effort required to follow the template. Several templates for each module type are generated by numerically controlled milling machines.

EQUALITY AND RELATIVE MAGNITUDE DETECTION

INTRODUCTION

This application describes one method of comparing two binary numbers for equality (A = B) and relative magnitude (A > B). Figure 1 shows 2 bits of a detector using M113, M117 and M121 modules. A 4-bit section requires sixteen two input NAND gates (1 3/5 M113), five — four input NAND gates (5/6 M117), and four AND/NOR gates (2/3 M121).

Each bit of the comparator functions with two independent circuit sections; the equality detector and the magnitude detector.

THE EQUALITY DETECTOR

Figure 2 shows just the equality detector used in each bit. The two AND gates in the AND/NOR gate actual detect $A_N \oplus B_N$ ($\oplus$ is exclusive OR) but since the output section of the AND/NOR gate also performs an inversion, the result is $\overline{A_N \oplus B_N}$ or equivalently $A_N = B_N$. This result can be verified in the truth table in Figure 3. If only equality detection is required, the output from a group of these detectors can be NANDed together with one gate of an M117 to give an "$\overline{A = B}$" signal at the output. For expansion to 16 bits, the "$\overline{A = B}$" signal from four 4-bit sections can be fed into a negative input OR gate (ie. another gate of an M113) to give an "A = B" signal from each 4 bits and then NANDed again with an M117 to provide up to 16 bit equality detection.

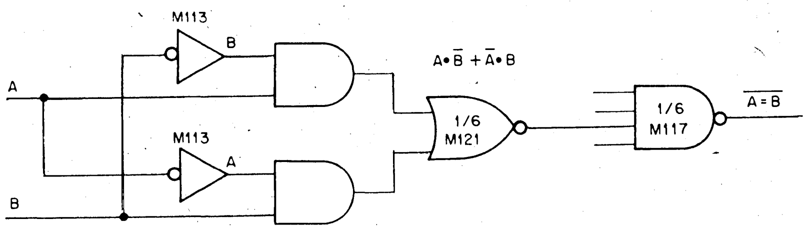
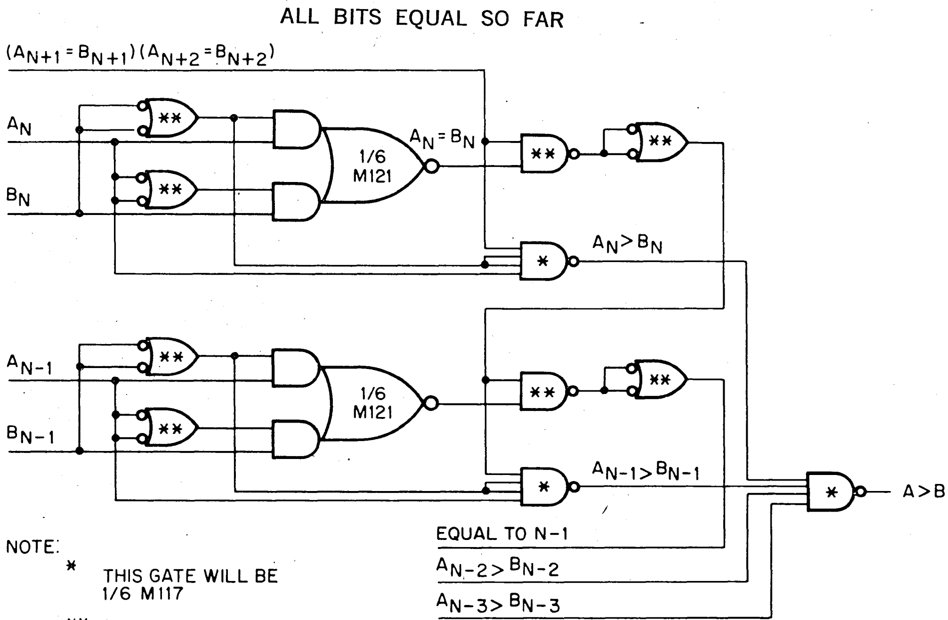


Figure 2.

A_N	B_N	$A \bullet \overline{B_N}$	$\overline{A} \bullet B_N$	$(A_N \bullet \overline{B_N})$ A $(\overline{A_N} \bullet B_N)$	$A_N = B_N$
0	0	0	0	0	1
0	1	0	1	1	0
1	0	1	0	1	0
1	1	0	0	0	1

Figure 3.

NOTE: $\overline{(A_N\ \ B_N) + (A_N \bullet B_N)} \Leftrightarrow A_N = B_N$
ALSO: "0" = Low
"1" = High



NOTE:

* THIS GATE WILL BE 1/6 M117

** THIS GATE WILL BE 1/10 M113

*** THIS GATE WILL BE 1/6 M117 FOR 4 BITS, 1/3 M119 FOR 8 BITS

FIGURE 1. EQUALITY AND MAGNITUDE DETECTOR

THE RELATIVE MAGNITUDE DETECTOR

The relative magnitude detector at bit "N"

— receives "A_N", "$\overline{B_N}$", and "($A_N = B_N$)" signals from the equality section,

— receives an "Equal so far" signal from "N + 1"

— generates output signals "Equal so far" and "$\overline{A_N > B_N}$".

The input signal "Equal so far" from bit "N + 1" indicates that all bits more significant than N are equal if HIGH (ie. +3 volts). Conversely, if LOW (ground) it indicates that at least one of the more significant bits is not equal. The output "Equal so far" from bit "N" being HIGH indicates that all bits up to and including bit N are equal. A LOW indicates an inequality at or before bit N. The "$\overline{A_N > B_N}$" signal will be LOW if $A_N = 1$ and $B_N = 0$ and all more significant bits are equal. By conditioning the "$\overline{A_N > B_N}$" signal with equality information from more significant bits, it is insured that if $B_N = 1$ and $A_N = 0$, an "$\overline{A_{N\text{-}X} > B_{N\text{-}X}}$" signal cannot be enabled to give a false A > B signal at the output (bit "N-X" is simply some bit less significant than bit "N"). Thus only the most significant level of inequality is considered if two numbers are unequal. In addition to the bit schematic of Figure 4, Figure 5 shows the truth table for the relative magnitude detector part of each bit.

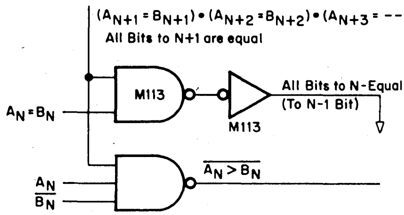


Figure 4.

INPUTS TO BIT N			OUTPUTS FROM BIT N	
Equal to Bit N + 1	A_N	B_N	"Equal to Bit N"	$A_N > B_N$
0	0	0	0	1
0	0	1	0	1
0	1	0	0	1
0	1	1	0	1
1	0	0	1	1
1	0	1	0	1
1	1	0	0	0
1	1	1	1	1

Figure 5.

A true XOR gate may be implemented using four-tenths of an M113, economizing by one (1) gate over the XOR in figure 3.

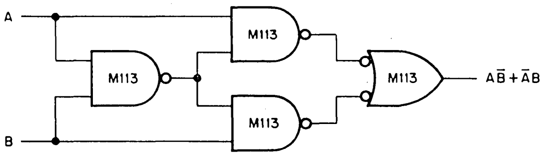


Figure 6.

USING THE EQUALITY AND RELATIVE MAGNITUDE DETECTOR

Figure 1 shows the construction of a two bit section of the detector. There are two outputs "A > B" and "Equal to bit N-1". The "A = B" output from the detector will always come from the least significant bit regardless of the number of bits in the detector. Figure 7 summarizes the meanings of the various possible output signals.

As in the case of the equality detector, the relative magnitude detector can be expanded to 16 bits by the method shown in Figure 8. It can be expanded further to as many bits as necessary by using "A > B" outputs from 16 bit sections to feed an extender such as that in Figure 8.

Since equality information must propagate from the most significant bit to the least significant bit, the propagation delay should be considered in each application. Each bit has a 30 nanosecond delay and if the extension in Figure 8 is used there is an extra 30 nanosecond delay for the total detector. Thus a 16 bit equality and magnitude detector would have a propagation delay of (16) (30 nsec) + 30 ns = 520 nanoseconds.

DETECTOR OUTPUT SUMMARY

A > B	A = B (at least significant bit)	Output Indication
0 (low))	0 (low)	B > A
0 (low)	1 (high)	A = B
1 (high)	0 (low)	A > B
1 (high)	1 (high)	impossible

Figure 7

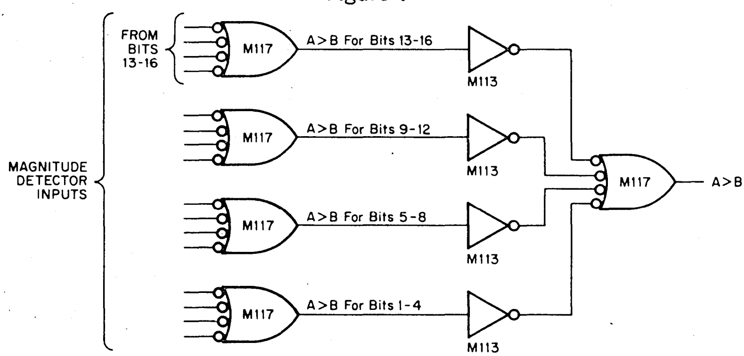


Figure 8

Table 1 gives the modules and pro-rated cost of a four bit equality detector.

Table 2 gives the modules necessary and the cost of a 4 bit equality and relative magnitude detector pro-rated according to module range. The gates required to extend the A > B output for more than four bits (see figure 8) are available as spare gates on the modules mentioned for each 4 bit section.

TABLE 1

DESCRIPTION	MODULE	QUANTITY	TOTAL PRICE
2 Input NAND gates	M113	4/5	$16.00
4 Input NAND gates	M117	1/6	3.50
AND/NOR gates	M121	2/3	16.60
			$36.16

TABLE 2

DESCRIPTION	MODULE	QUANTITY	TOTAL PRICE
2 Input NAND gates	M113	1 3/5	$32.00
4 Input NAND gates	M117	5/6	17.50
AND/NOR gates	M121	2/3	16.66
			$66.16

VOLTAGE CONTROL OF THE M401 VARIABLE CLOCK

The pulse repetition frequency of the M401 may be controlled or modulated by applying a variable voltage to the base of Q1. This may be accomplished as follows:

1. Open the connection between the base of Q1 and the junction of the resistor R1 & R2.
2. Insert a 750Ω, ±5%, ¼ watt resistor between the base of Q1 and one of the unused module terminals, F, H, L or M.
3. If the rate at which the frequency is to be changed or controlled is not excessive, add a .01 μfd. disc capacitor between the base of Q1 and ground for noise filtering.

The voltage swing applied to the resistor connected to the base of Q1 should be limited to ±0.25 volts about a center voltage of +1.5 volts. Table 1 shows the frequency excursions which one might expect when the frequency adjust potentiometer is adjusted to its full counterclockwise and full clockwise positions.

CAPACITOR	Freq. Adj. Pot.	+1.25V	+1.50V	+1.75V
No Ext. Cap.	CW CCW	12.9Mhz. 1.02Mhz.	13.1Mhz. 1.32Mhz.	13.2Mhz. 1.81Mhz.
.001 mfd.	CW CCW	2.70Mhz. 72.8Khz.	3.37Mhz. 97.4Khz.	4.14Mhz. 142.9Khz.
.01 mfd.	CW CCW	382.6Khz. 8.19Khz.	504.5Khz. 11.04Khz.	720.4Khz. 16.42Khz.
0.1 mfd.	CW CCW	34.46Khz. 722hz.	46.54Khz. 972hz.	68.93Khz. 1444hz.
1.0 mfd.	CW CCW	3.622Khz. 83hz.	5.144Khz. 112hz.	8.052Khz. 167hz.

PARITY GENERATION USING THE M162	APPLICATIONS

The M162 consists of two complete parity circuits, each of which will accommodate four lines.

4 LINE ODD PARITY GENERATION

The following condition must exist with four line odd parity generation:

$$A \oplus B \oplus C \oplus D \quad => \quad P$$

where $\oplus$ = the modulo 2 sum.

Also, in general, the following is usually desired:

$$\overline{A} \cdot \overline{B} \cdot \overline{C} \cdot \overline{D} \quad => \quad P$$

or

$$(A \oplus B \oplus C \oplus D) + (\overline{A} \cdot \overline{B} \cdot \overline{C} \cdot \overline{D}) \quad => \quad P$$

The M162 connected as illustrated in figure 1 will satisfy the odd parity generation as per the following truth table:

	A	B	C	D	P
0	0	0	0	0	1
1	1	0	0	0	0
2	0	1	0	0	0
3	1	1	0	0	1
4	0	0	1	0	0
5	1	0	1	0	1
6	0	1	1	0	1
7	1	1	1	0	0
8	0	0	0	1	0
9	1	0	0	1	1
		↓etc.			

It will be noted that the modulo 2 sum of the five bits (4 bits + parity) always yields 0 (an odd number of bits).

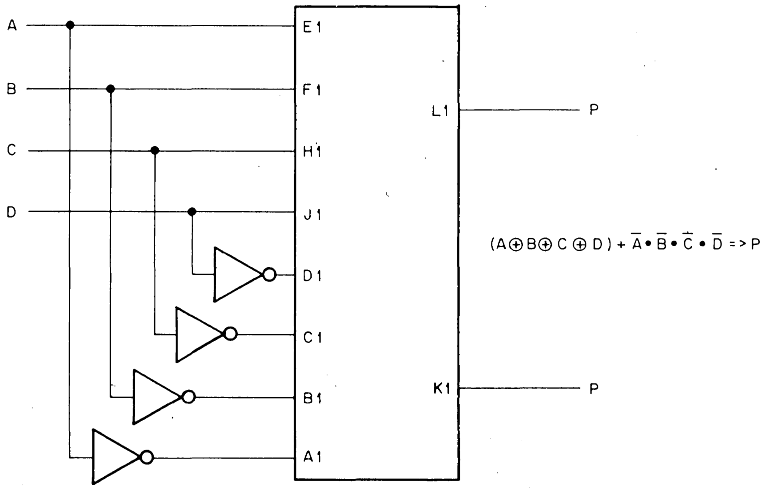


Figure 1.

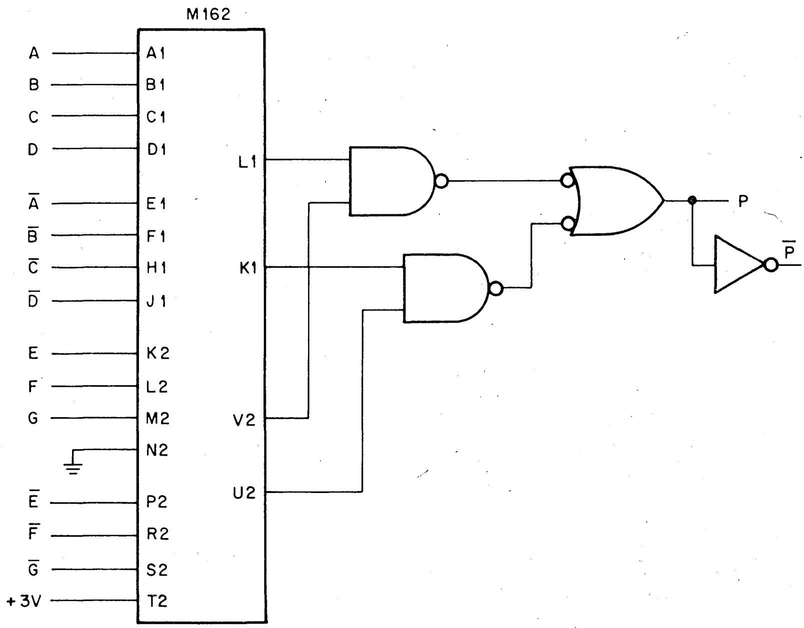
The odd parity generation with the condition $\overline{A} \cdot \overline{B} \cdot \overline{C} \cdot \overline{D} \Rightarrow P$ will always yield an odd number of bits in the resulting character.

7 LINE ODD PARITY GENERATION

In this case the following would be desired:

$$(A \oplus B \oplus C \oplus D \oplus E \oplus F \oplus G) + (\overline{A} \cdot \overline{B} \cdot \overline{C} \cdot \overline{D} \cdot \overline{E} \cdot \overline{F} \cdot \overline{G}) \Rightarrow P$$

This result may be obtained by connecting the M162 as shown in figure 2.



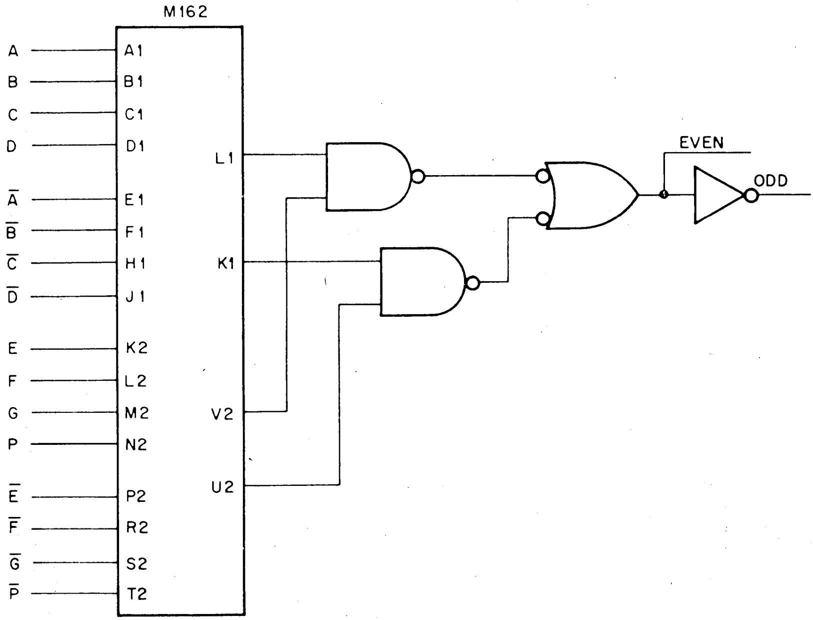
$$P = (A \oplus B \oplus C \oplus D \oplus E \oplus F \oplus G) + \overline{(\overline{A} \cdot \overline{B} \cdot \overline{C} \cdot \overline{D} \cdot \overline{E} \cdot \overline{F} \cdot \overline{G})}$$

Figure 2

ODD PARITY RECOGNITION

Figure 3 illustrates the connections for odd parity recognition and the following equation would be valid.

$$ODD = 1 = \overline{(A \oplus B \oplus C \oplus D \oplus E \oplus F \oplus G \oplus P)}$$



$$OUT = 1 = \overline{(A \oplus B \oplus C \oplus D \oplus E \oplus F \oplus G \oplus P)}$$

Figure 3

Odd parity generation for a larger number of bits may be accomplished by using the P and P outputs as if they were the L, and K, outputs of the M162 shown in figure 2. Figure 4 illustrates this expansion.

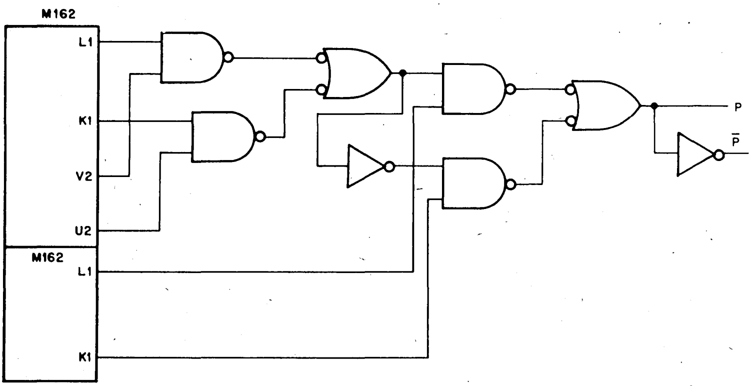


Figure 4

Decoding for the larger number of bits would be accomplished in exactly the same manner illustrated in figure 4 with the P output indicating a logic 1 for odd parity. However, remember that all unused direct inputs must be grounded and all NOTed unused inputs must be connected to +3 volts.

PROBABILITY GENERATOR

This application note deals with the generation of pulses which have a set probability of occurring with respect to an input function. It is sometimes desirable to utilize a device which will emanate a pulse which has a definite probability relationship with respect to an input. That is to say if an input pulse is applied to the device there exists a definite set probability that an output will occur. Figure 1 illustrates one method in which this might be accomplished utilizing "M" series logic modules.

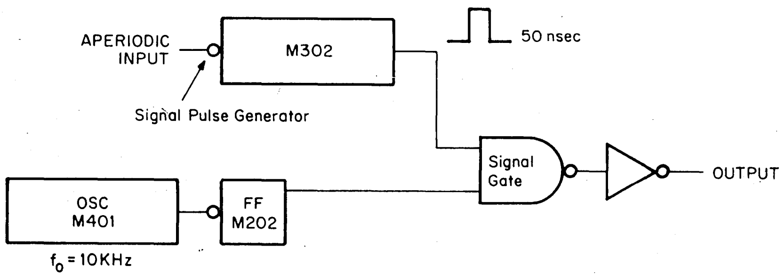
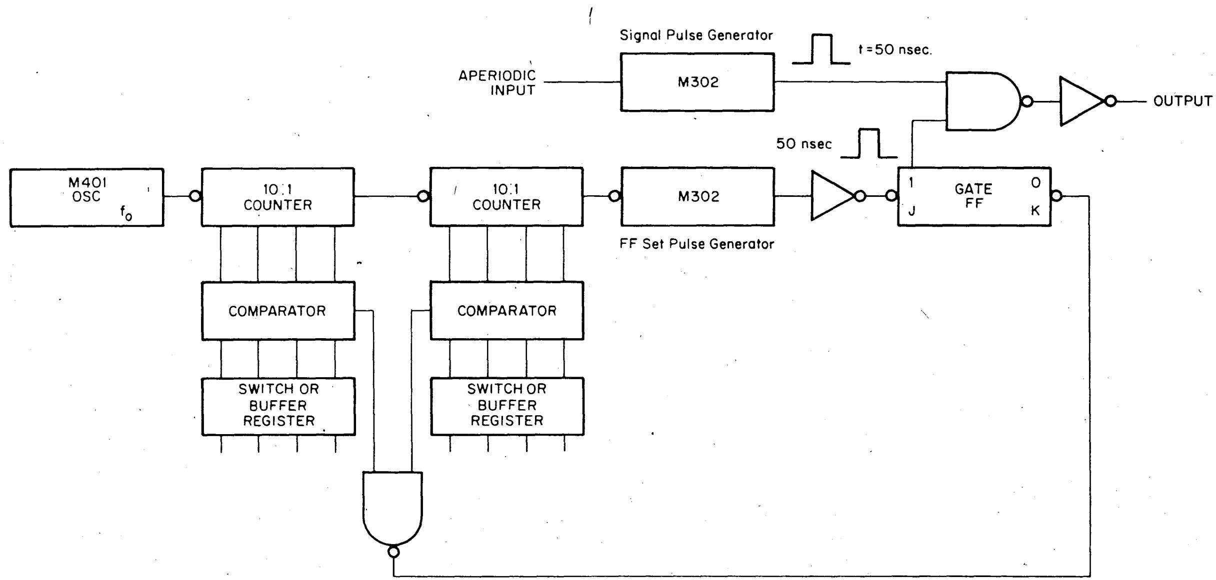


Figure 1

The circuit of figure 1 yields a 50% probability that an output will occur when an input is applied to the circuit. Two conditions must be met to assure the set probability.

1. The pulse width output of the flip-flop going to the signal gate must be very much greater than the 50 nsec pulse width output of the signal pulse generator.

2. The input must be aperiodic. (Usually obtained from animal response.) It is sometimes desired that the percentage probability be altered during the course of the experiment. Figure 2 illustrates the generation of a variable percentage probability.



APPL. 18

VARIABLE PERCENTAGE PROBABILITY GENERATION

Figure 2

The two counters represent a complete counter with a modulus of 100 with a radix of 10. Using a counter with a modulus of 100 will yield a percentage resolution of 1%. A counter with a modulus of 1000 would yield a resolution of 0.1% probability. The input is usually derived from an animal response, either human or otherwise, and the minimum time between inputs would be approximately five to twenty milliseconds. The minimum time between inputs determines the minimum frequency of the oscillator. A probability resolution of 1.0% could be easily accomplished if the oscillator frequency is approximately 10 KHz. The stability of absolute frequency is unimportant. The output of the counter is passed to a M302 "FF set pulse generator" and then to an inverter as the unconditional set terminals of the flip-flop requires a logical 0 to set the flip-flop. The flip-flop is reset by the output of the comparator circuit which emanates a pulse only when the counter flip-flops match the conditions indicated by the switch decades or buffer register. The buffer register would be used if it were desired to change the probability by the use of a computer. The signal gate flip-flop will now have a duty cycle represented by the set probability and would be expressed in percent.

Application

In behavioral research, probability generated pulses may be used to change or not change certain stimuli or to reinforce or not reinforce a subject on a random basis with a set probability.

ELIMINATING THE EFFECTS OF SWITCH CONTACT BOUNCE USING M203*

The circuit of Figure 1 below illustrates one approach to the elimination of switch contact bounce. It is a circuit which is commonly used for this purpose. However this circuit has two inherent disadvantages. In the first case the current which the switch contacts make or break is limited to a maximum of 1.6 ma. which is in many cases not sufficient to maintain a low resistance switch contact surface. The second disadvantage is that one of the gate inputs is open at all times. As the input resistance of the typical TTL gate is of the order of several thousand ohms, the inherent noise rejection is minimal.

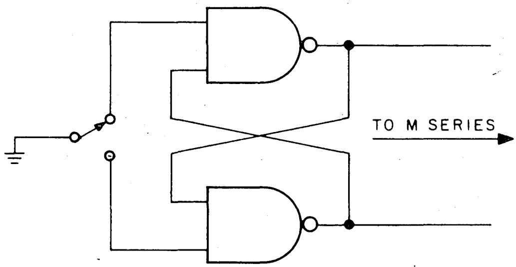


Figure 1

The circuit of Figure 2 provides better noise immunity as the typical resistance of the output of a TTL gate in the logic 1 state is of the order of 70 ohms. The instantaneous contact current of the switch will be between 18 and 55 ma.

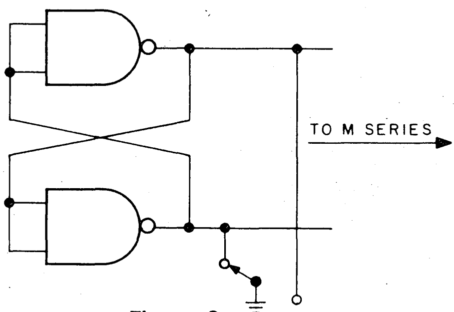


Figure 2

The M908 could be used for interconnection between the switches and flip-flops; up to 18 switches could be accommodated for each M908 used.

* This application note is of concern to only those persons not requiring the high noise immunity afforded by "K" Series.

INTERFACING K AND M SERIES LOGIC TO NEGATIVE VOLTAGE LOGIC

NEGATIVE VOLTAGE TO K SERIES

It is recommended that an output of negative voltage logic be interfaced to K Series logic via the diode inputs of the K134 inverter module. Figure 1 illustrates one method of interfacing the output of negative voltage logic to the input of the K Series modules. The K134 will appear to the negative voltage logic as two unit loads. The W994 perforated blank module could be used to mount these resistors.

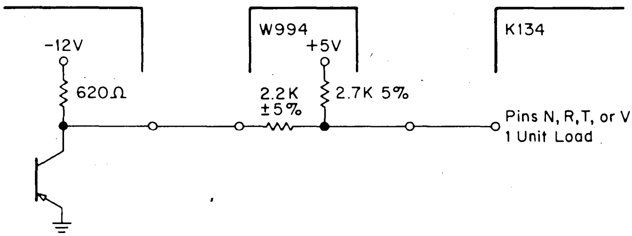


Figure 1

K SERIES TO NEGATIVE VOLTAGE

The output of the K Series may be interfaced to the negative voltage logic by the use of the M050 module. The M050 has no pull-up resistors and resistors must be supplied and connected to a source of —12 volts. The resistors used as pull-up should have a value of 620 ohms with a tolerance of 5%. The W994 perforated blank would provide a convenient means for mounting these resistors. This arrangement will provide five unit loads of drive into negative voltage logic.

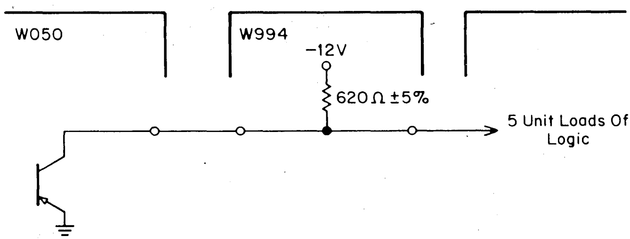


Figure 2

NEGATIVE VOLTAGE TO M SERIES

Interfacing the negative voltage logic to M Series would be accomplished using the circuit shown below in Figure 3. The output of the network should be passed through two M Series inverters to assure proper rise time required in M Series logic. The M111 would provide sufficient inverters to convert eight lines of negative voltage logic. This interface would represent 2 unit loads to the negative voltage logic.

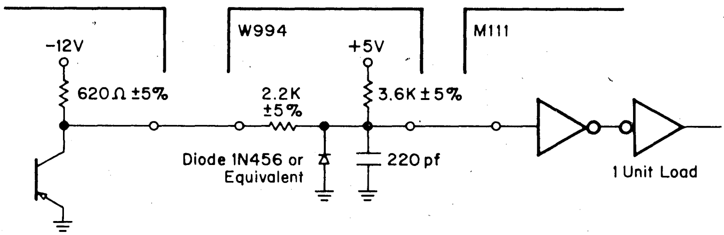


Figure 3

M SERIES TO NEGATIVE VOLTAGE

This conversion would be accomplished in exactly the same manner as illustrated in figure 2.

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°C to 65°C (0°F to 150°F) except K202, K210, K220, and K230 which are limited to 0°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. K273, K604, K644, K731, K732, and K303 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 ninged 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° 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 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 Locations

a. End Sockets (K941)

The first sockets to assign are those for K731 and K732 regulators, and for 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 ⅝" 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.

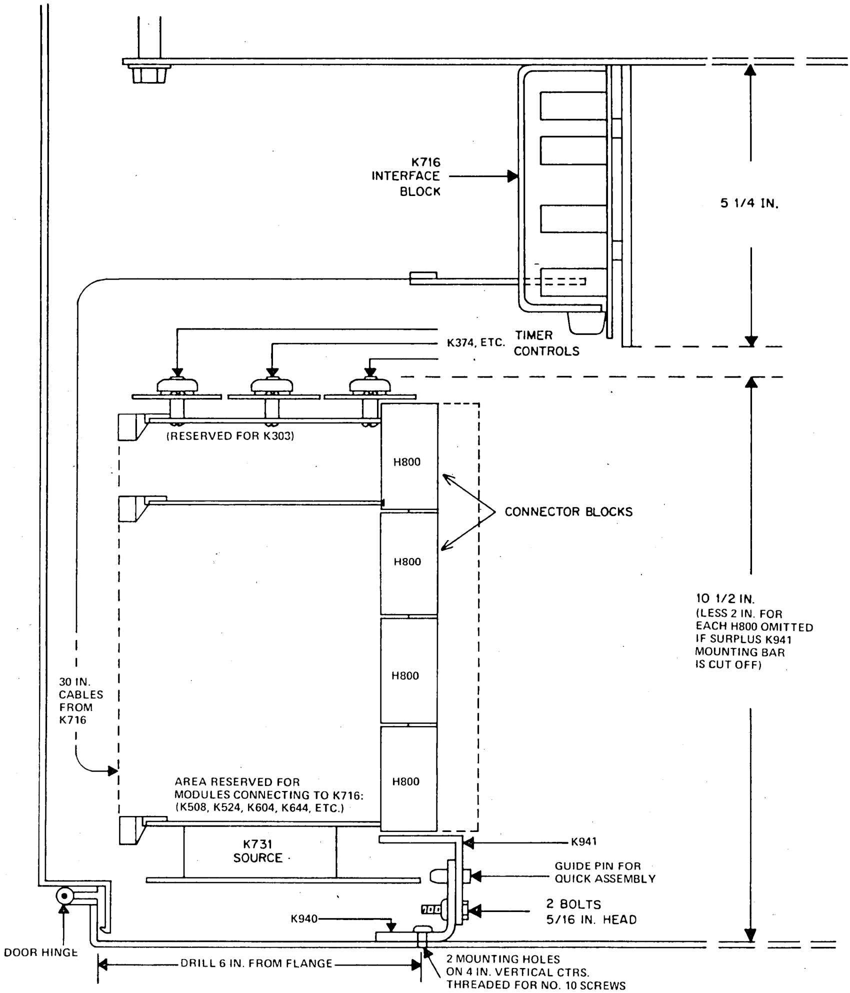
After K716 locations and assignments have been selected, assign socket positions for interface modules (K508, etc.). The order should be coordinated so the combined ribbon cables will lie flat together. Excess ribbon cable can be easily and neatly folded away. Lengths other than 30" are not available 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.

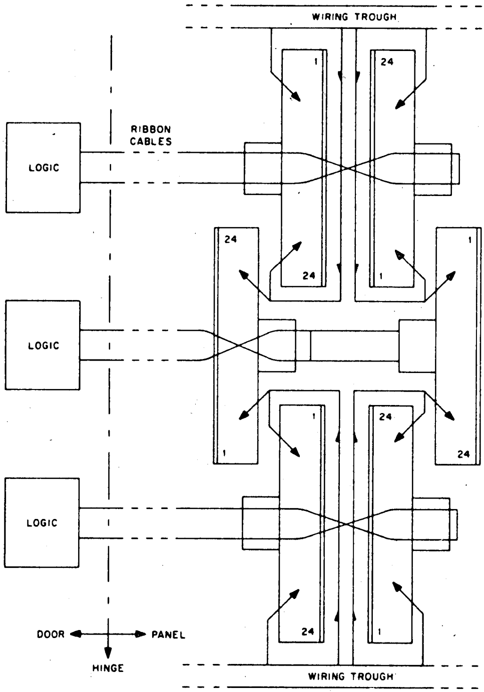


K-SERIES LOGIC IN A NEMA-12 ENCLOSURE,
16 IN. DEEP
TOP VIEW

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.



K716S IN INDUSTRIAL ENCLOSURE

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 ¾ ampere rating on resistive loads at 12.6v, or with two 6.3v windings rated ¾ 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

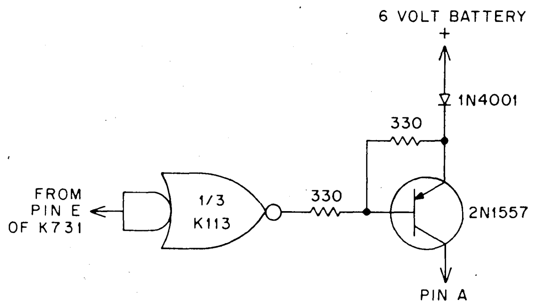
Any source of 5 VDC ± 10% may be used for K series systems at ordinary room temperatures, provided noise, hash, spikes, turnon-overshoot, etc. are reasonably well controlled. K series modules are far less sensitive to noise on power lines than computer-speed circuits, but it is still possible to cause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

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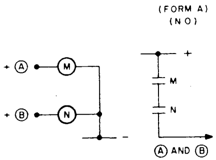
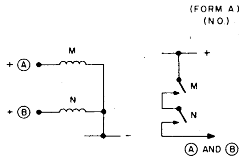
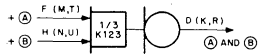
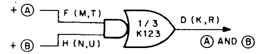
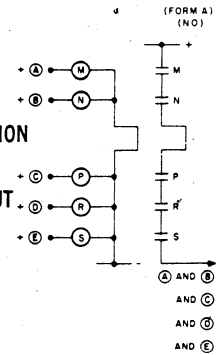
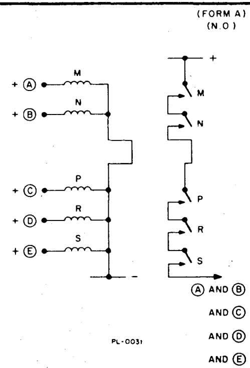
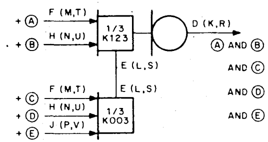
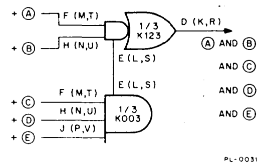
2-INPUT AND				
EXPANSION TO 5-INPUT AND				

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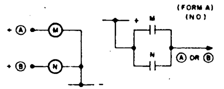
<td>
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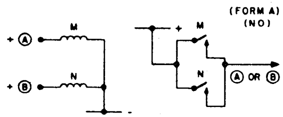
<td>
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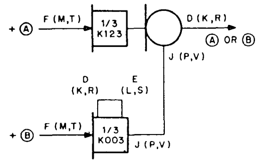
<td>
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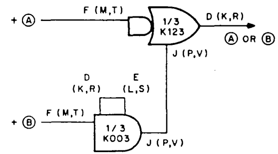
<td>
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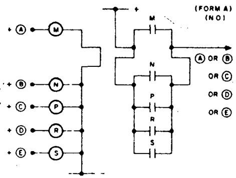
<td>
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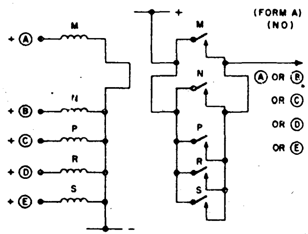
<td>
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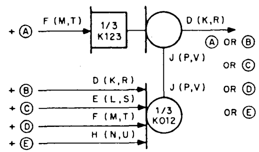
<td>
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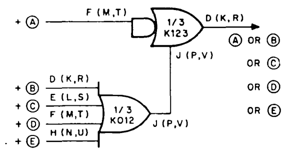
<td>
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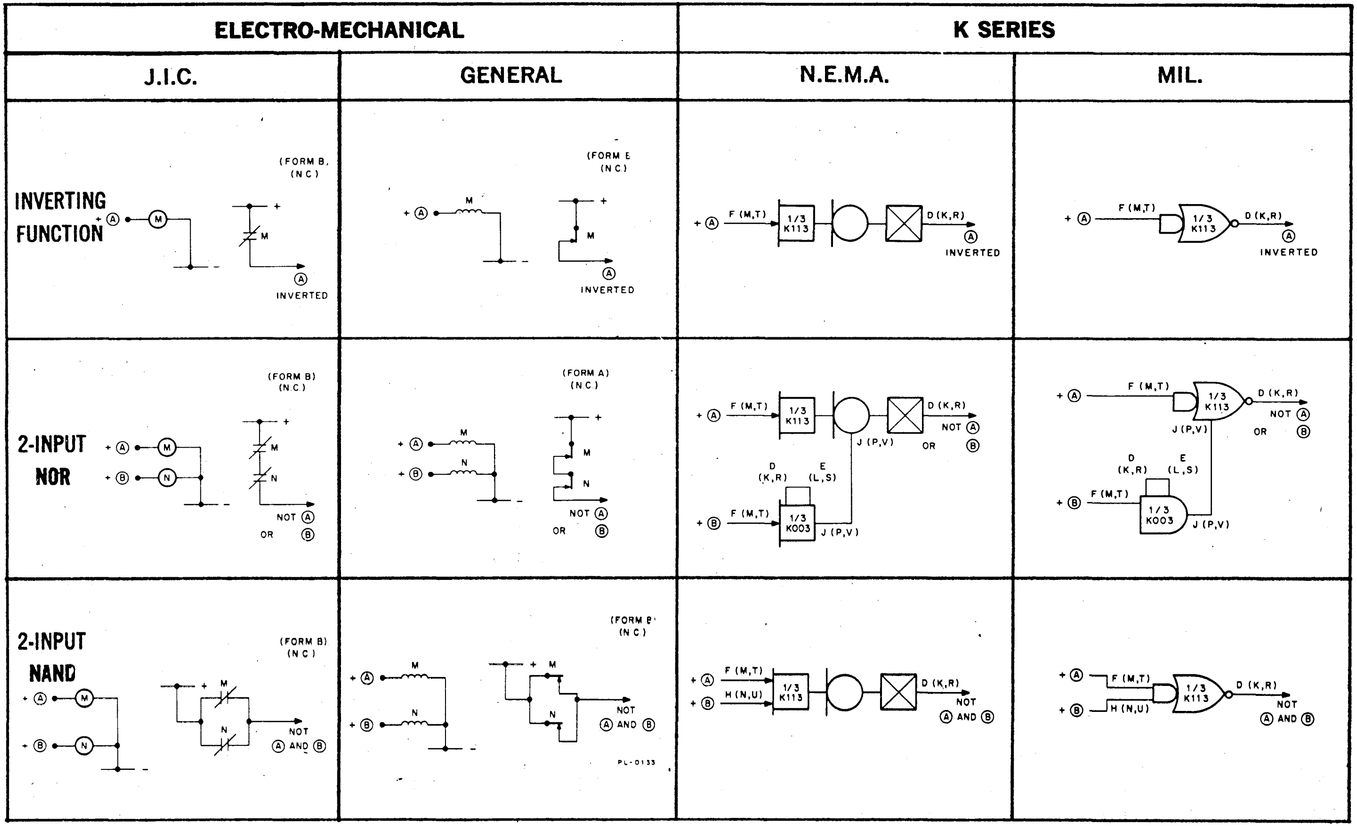
ELECTRO-MECHANICAL
K SERIES
J.I.C.
GENERAL
N.E.M.A.
MIL.
INVERTING FUNCTION
(FORM B) (N.C.)
(FORM B) (N.C.)
+ Ⓐ
M
+
Ⓐ INVERTED
F (M,T)
1/3 K113
D (K,R)
2-INPUT NOR
(FORM B) (N.C.)
+ Ⓑ
N
NOT Ⓐ OR Ⓑ
J (P,V)
D (K,R)
E (L,S)
1/3 K003
2-INPUT NAND
H (N,U)
NOT Ⓐ AND Ⓑ
PL-0133

	ELECTRO-MECHANICAL		K SERIES	
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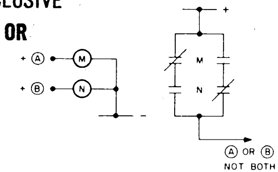
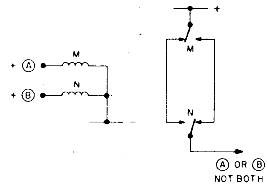
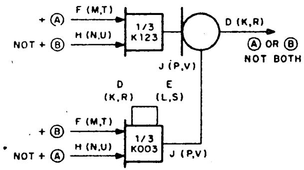
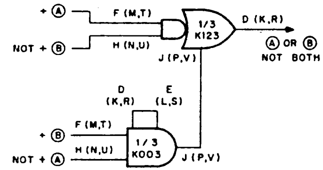
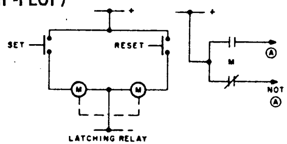
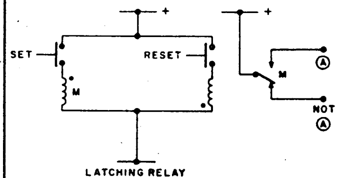
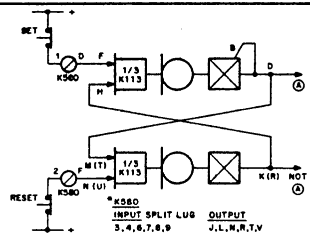
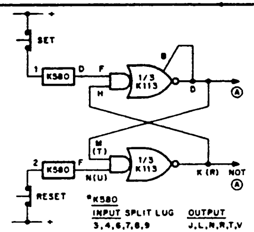
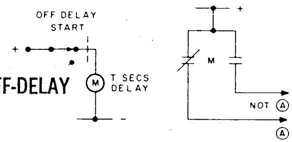
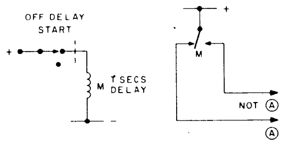
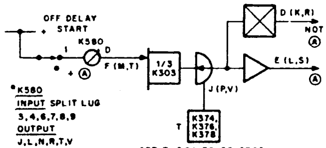
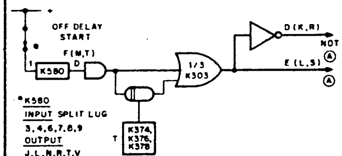
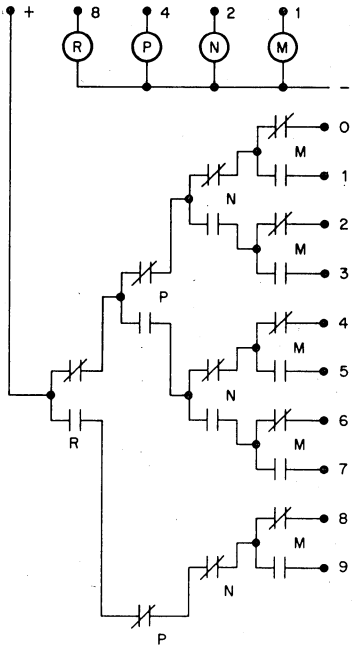
2-INPUT EXCLUSIVE OR	(FORM C) 	(FORM C)  PL-0134		
BISTABLE (FLIP-FLOP)				
OFF-DELAY	(FORM C)  CONTACTS SWITCH T SECS AFTER START SYNCHRONOUS MOTOR OR PNEUMATIC TIMER	(FORM C)  CONTACTS SWITCH T SECS AFTER START SYNCHRONOUS MOTOR OR PNEUMATIC TIMER PL-0134	 SET T, .001 TO 30 SECS OUTPUT LEVELS CHANGE T SECS AFTER START	 SET T, .001 TO 30 SECS OUTPUT LEVELS CHANGE T SECS AFTER START

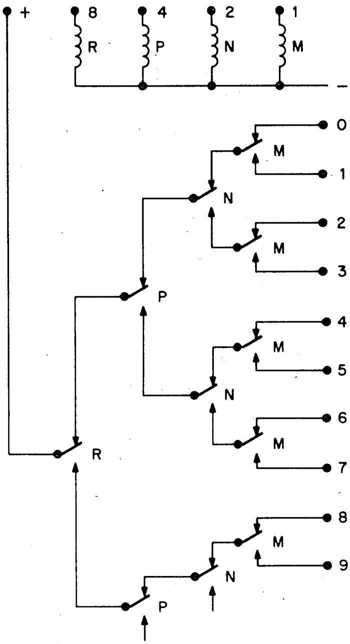
ELECTRO-MECHANICAL

DECODER: BCD TO 10 LINE

J.I.C.

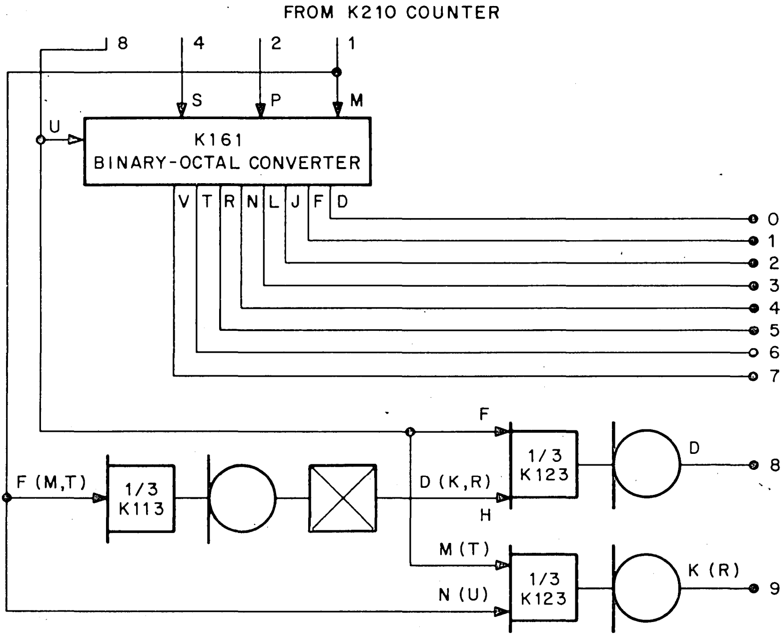


GENERAL

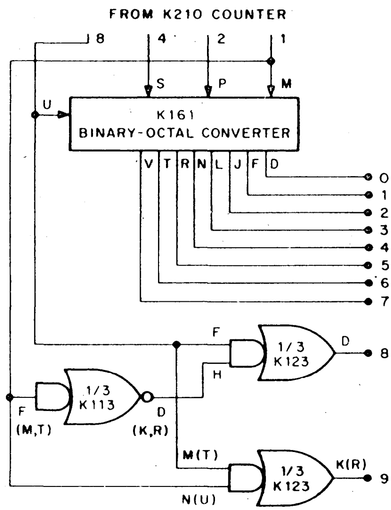


K SERIES

N.E.M.A.



MIL.



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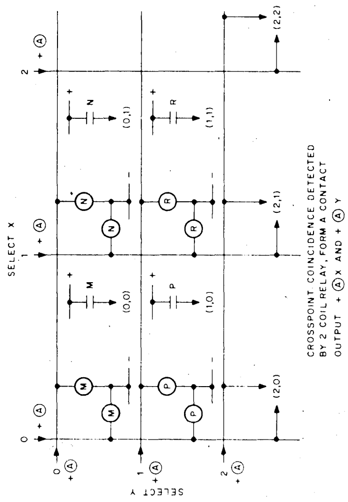
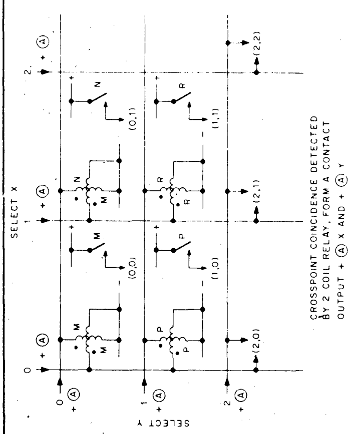
<tr><td>CROSSBAR SELECTOR</td><td>
</td><td>
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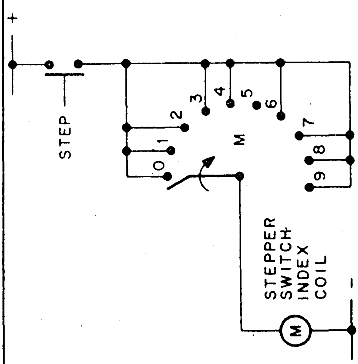
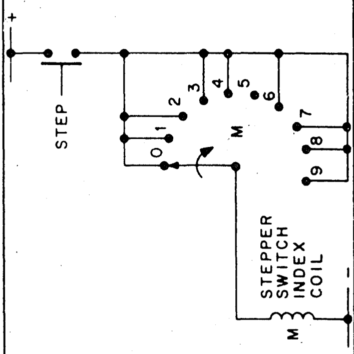
<tr><td>HOME-TO-5</td><td>
</td><td>
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K SERIES

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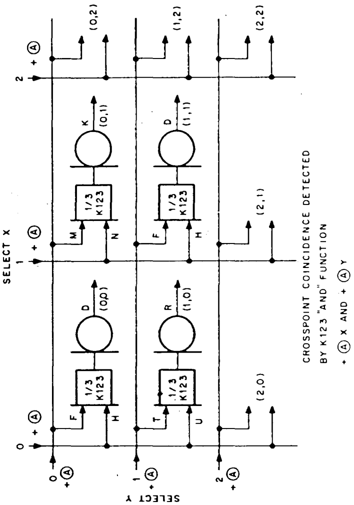
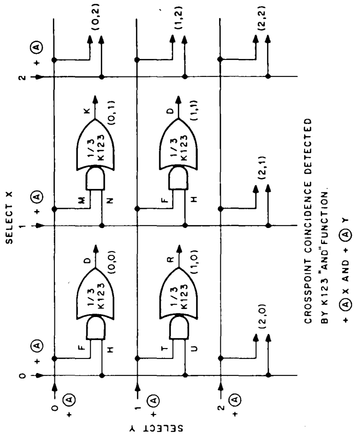
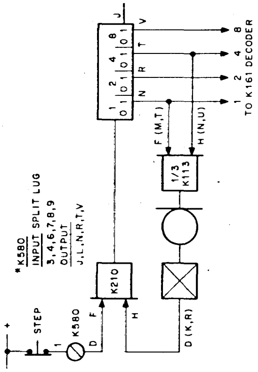
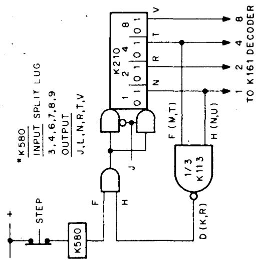
	
	

K SERIES SEQUENCERS — GENERAL

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 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, pentaflop, hexaflop, septaflop, and octaflop.

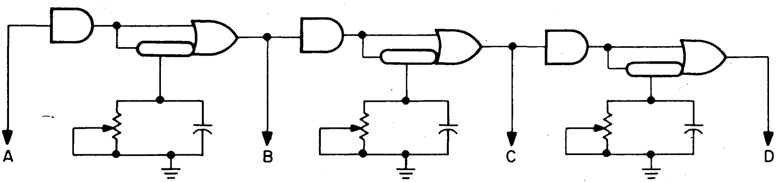
The general polyflop is built from as many K113 inverting gates as there are states required, each with input AND expansion sufficient to gate together all outputs by the one that gate controls. Thus any one low output will force all other outputs high. Polyflops do not establish any fixed order through 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.

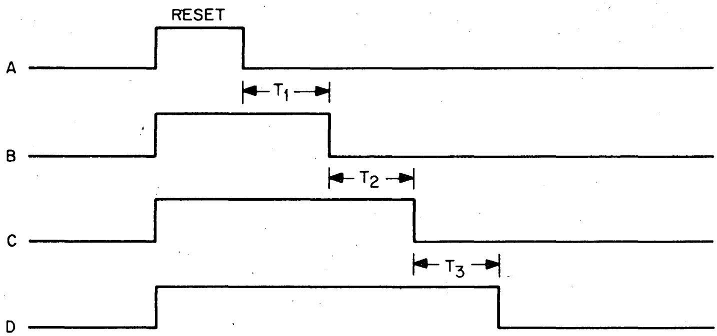
SUMMARY

Sequencer Type	Relative Cost per State	Modification Flexibility	Other Features
Timer	highest	easiest	Can be self-stepping
Counter	low-med	fair	Best for many states, few outputs
Shifter	medium	good	Suitable for patch panel setup
Polyflop	medium	fair	States may be forced in any order

TIMER SEQUENCERS

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 T_2 and T_3 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 V if normal relations between timing RC and time delays are to be maintained.

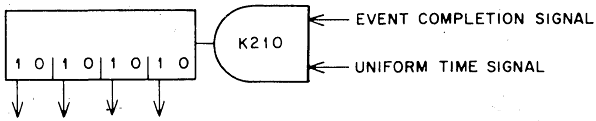
Three inversions, or any odd number of inversions must be contained within a self-recycling loop.

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.

COUNTER SEQUENCERS

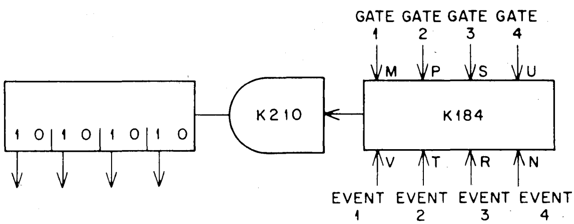
Counter sequencers offer the largest number of discrete steps for the money, since for N flip-flops up to 2^N states are obtainable. A single K210 counter, for example, offers up to 16 states for $27.

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.

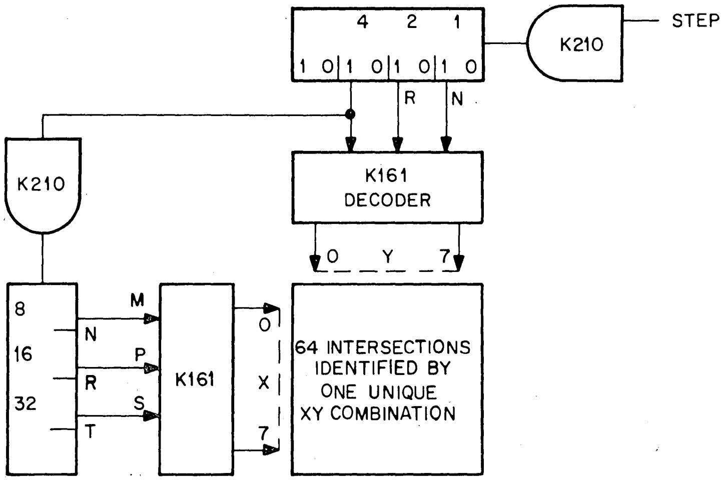
stitute for time signals is to use a K184 Rate Multiplier as if it were four separate differentiating pulse generators with ORed outputs.



USING K184 TO GENERATE EVENT COMPLETION PULSES

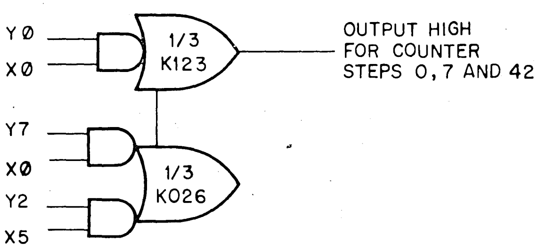
The principal disadvantage of counter sequencers is gating complexity, if many outputs must be derived which are not simply the flip-flop outputs themselves. Counter sequencers are most suitable for high-resolution sequencing of relatively few outputs whose relationship to sequencer states is unlikely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



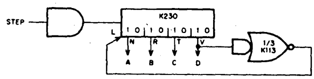
64 STATE CROSSPOINT SEQUENCER

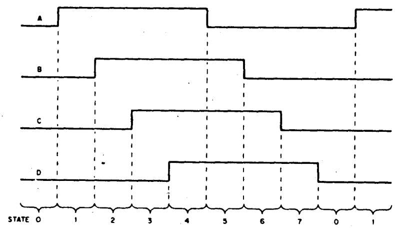
The desired states may be detected one-by-one using any two-input AND gate such as those of gates K113, K123, or K134, or two-input gates on other modules like K210 counters, K230 shift registers, K303 timers, K604 or K614 AC switches, K644 or K656 DC drivers, etc. Or several states may be combined by ORing the outputs of several two-input AND gates as shown below.



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.

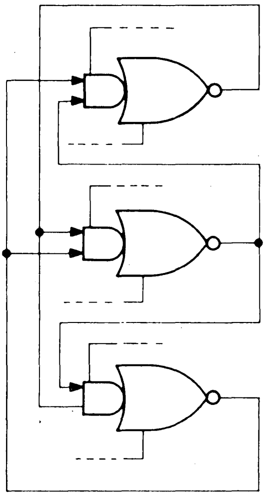
START	A ◎	B ◎	C ◎	D ◎	$\bar{A}$ ◎	$\bar{B}$ ◎	$\bar{C}$ ◎	$\bar{D}$ ◎
FINISH	$\bar{A}$ ◎	$\bar{B}$ ◎	$\bar{C}$ ◎	$\bar{D}$ ◎	A ◎	B ◎	C ◎	D ◎
STATE	1	2	3	4	5	6	7	0

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.

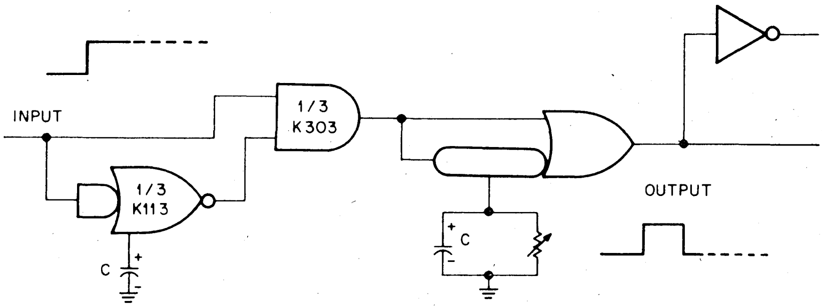
POLYFLOP	K113	K003	MODULE COST
TRIFLOP	1	0	$11.00
QUADRAFLOP	1-1/3	1-1/3	$20.00
PENTAFLOP	1-2/3	1-2/3	$25.00
HEXAFLOP	2	2	$30.00
SEPTAFLOP	2-1/3	4-2/3	$44.33
OCTAFLOP	2-2/3	5-1/3	$51.00
NONAFLOP	3	6	$57.00

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 AS ONE-SHOTS

By itself, a K303 timer goes to the one state when its input goes high and waits there, not starting to time-out until the input returns low. Sometimes, however, it is convenient to start the entire cycle on an input change from low to high, without waiting for the input to return low. This behavior is that of the "one-shot" (also called single-shot or monostable multivibrator).

A K113 gate with a capacitor tied from its OR expansion node to ground can be used to obtain the necessary differentiating action. This capacitor should be the same size as the timing capacitor being used on the associated K303 circuit.



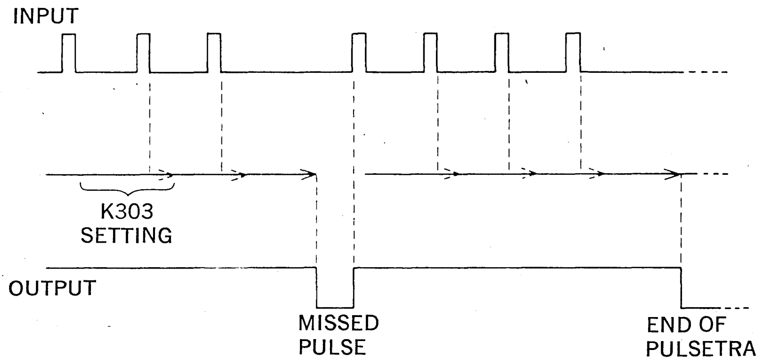
K303 AS ONE-SHOT

The K113 delay is about 3% of the maximum delay obtainable when using the same capacitor with a 250 KΩ timing resistor on the K303. The delay of the K113 is fixed, so the minimum K303 delay obtainable in this use is larger than normal.

The input must remain high for this same 3% interval, and should dwell in the low state at least twice this long for good repeatability.

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.



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.

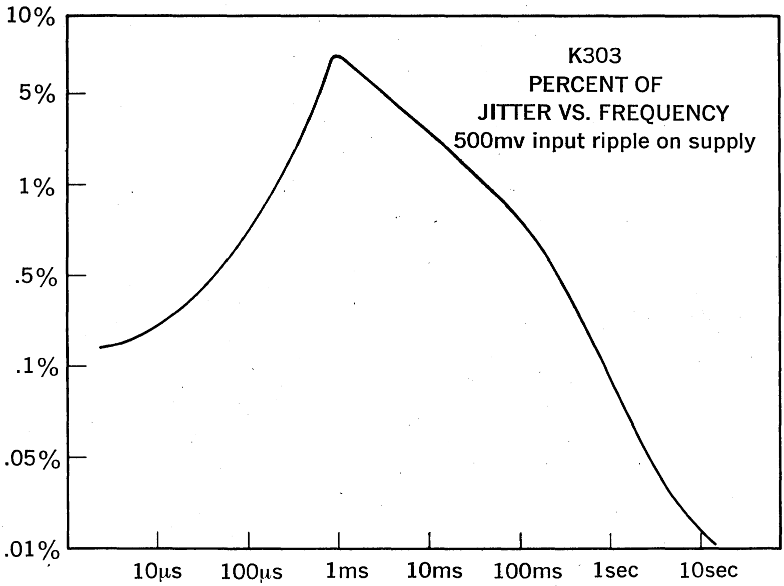
By cascading timers, pulses as short as 300 nanoseconds may be stretched to any length needed. However, pulses less than several microseconds in length do not produce consistent or predictable time delays from the K303, and are only recommended for pulse-stretching (using built-in 0.002 mf timing capacitor).

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 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 .3% 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.



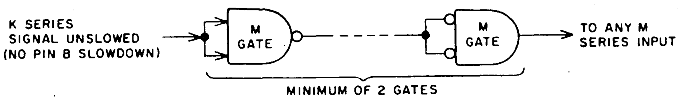
COMBINING K WITH M-SERIES MODULES

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



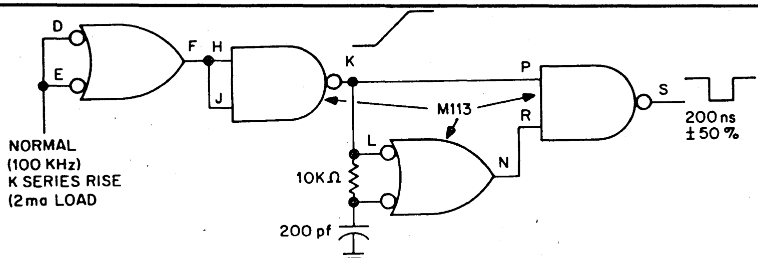
K TO M-SERIES LEVEL CONVERTER

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



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 μsec (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

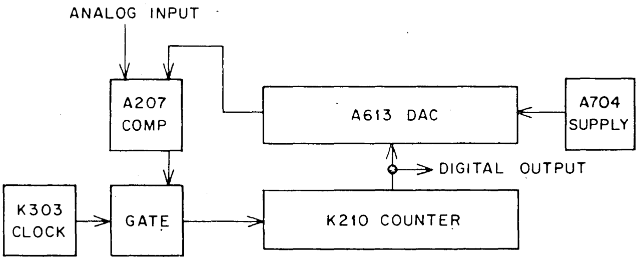
Driving M from K Series modules, each risetime-insensitive input should be regarded as a 2ma K Series load, and K Series inputs may be freely mixed with M Series inputs up to the total K Series fanout of 15 milliamperes. M Series inputs could be regarded as 1.6ma each if more complicated rules and qualifications 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.



BASIC COUNTER CONVERTER FEEDBACK LOOP

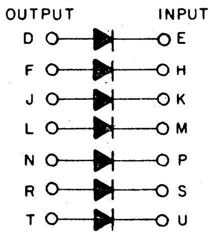
In operation, the counter starts at zero and counts up until the D to A converter output just exceeds the analog input. As the comparator inputs reverse their polarity relationship, the comparator output switches and inhibits the clock. The counter is left holding a number representing the analog input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

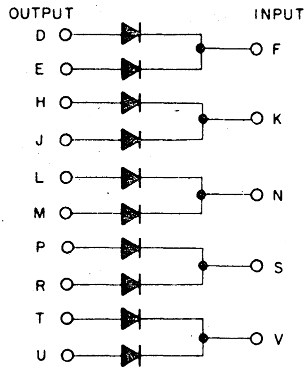
COMBINING K WITH R SERIES MODULES

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

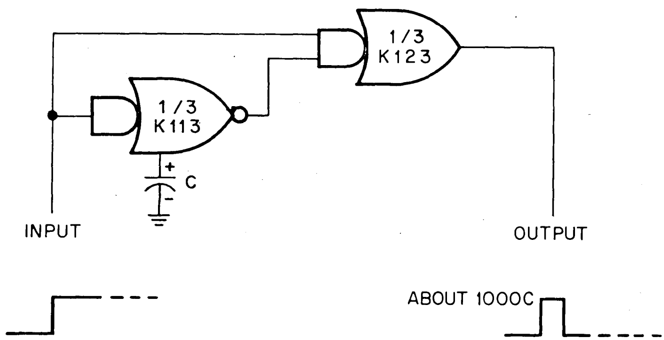


R002 DIODE NETWORK

R001 — $4
R002 — $5

PULSE GENERATOR

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.



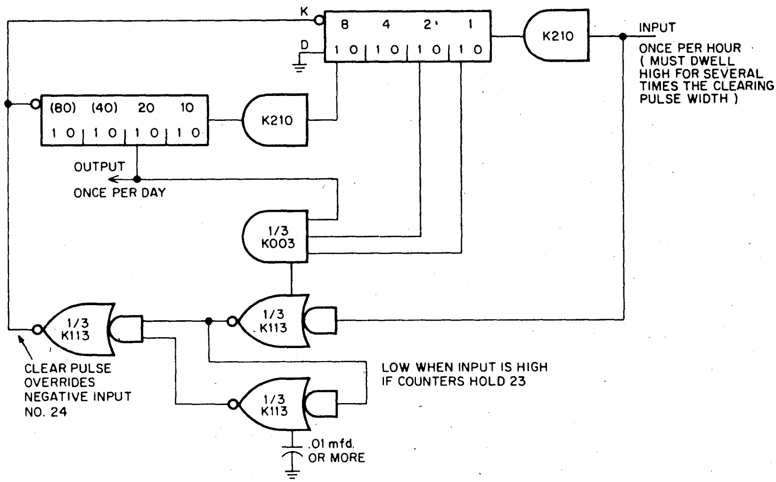
PULSE GENERATOR

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.

USING K210s FOR LONG ODD-MODULUS COUNTERS

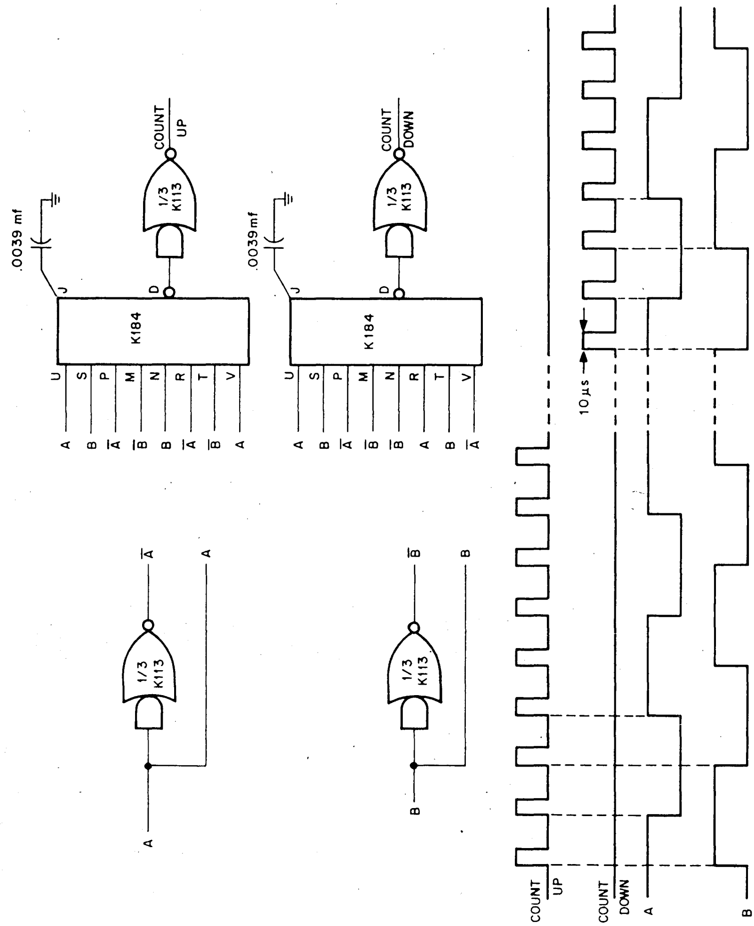
The pulse generator shown on the previous page can be incorporated with K210 counters to obtain counts at non-binary moduli above 16, the limit for a single K210. Below is shown a modulus 24 counter, as would be required for a digital clock.



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.

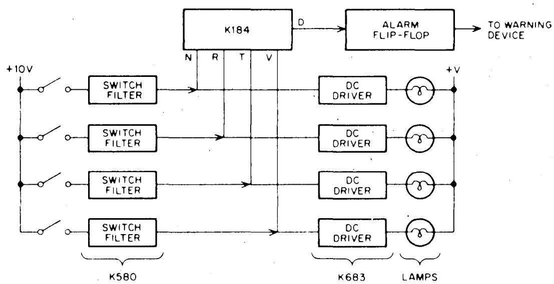
Shaft Angle Pickup Quadrature to Pulse Converter

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.



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 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.



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:

ALARM STATUS	ANNUNCIATOR LAMP STATUS
1. No Alarm	Off
2. Alarm — Unacknowledged	Flashing (2Hz)
3. Alarm — Acknowledged	Steady
1. No Alarm — Memory Cancelled	Off

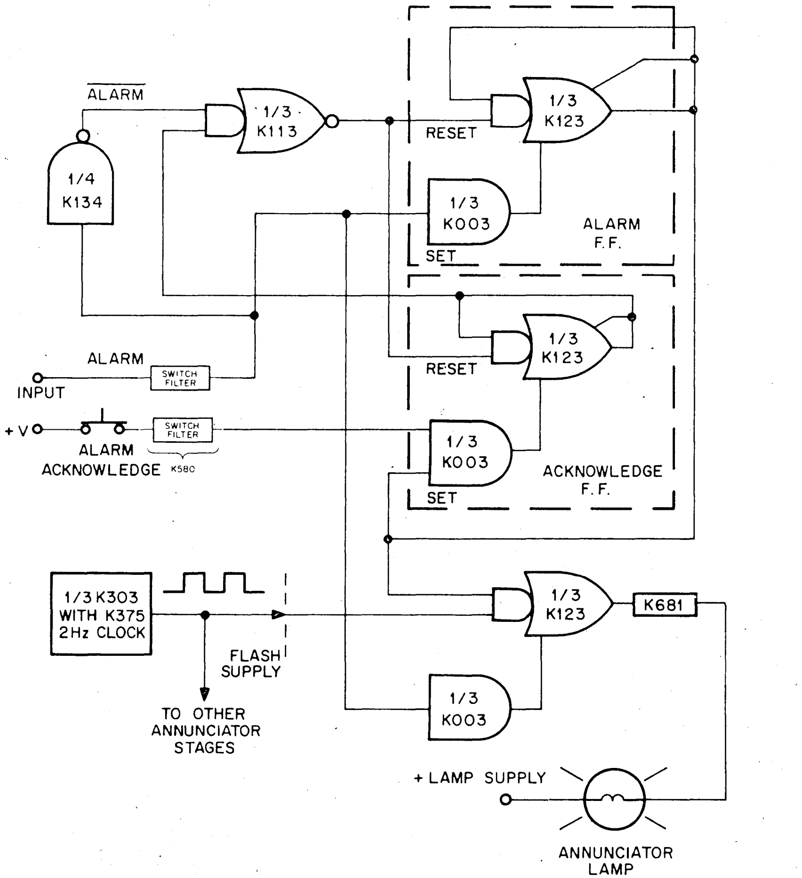
The Flash Supply is generated at a suitably low frequency by a K303 Clock with K375 Timer Control. This supply is available for distribution to other similar stages in a system.

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

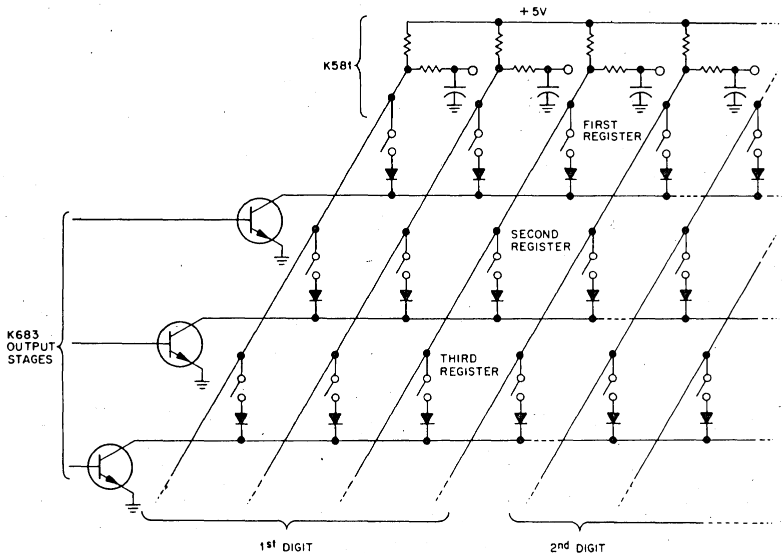
MODULE TYPE	NUMBER REQUIRED	NUMBERS OF CIRCUITS USED	COST PER LINE
K003	1 @ $ 4.00	3 of 3	$ 4.00
K113	1 @ $11.00	1 of 3	$ 3.60
K123	1 @ $12.00	3 of 3	$12.00
K134	1 @ $13.00	1 of 4	$ 4.33
K580	1 @ $20.00	1 of 8	$ 2.50
K681	1 @ $15.00	1 of 8	$ 1.80
		TOTAL	$28.23

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.



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.

Digitran part number 8788 offers two 8000 series switches with diodes mounted on a printed circuit board like a single-height FLIP CHIP module, and several of these may be connected to provide multiplexed registers as shown. Each such Digitran 8788 takes one module slot, but one extra socket per register pair is required to accept the extra thickness of the most significant digits.



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.

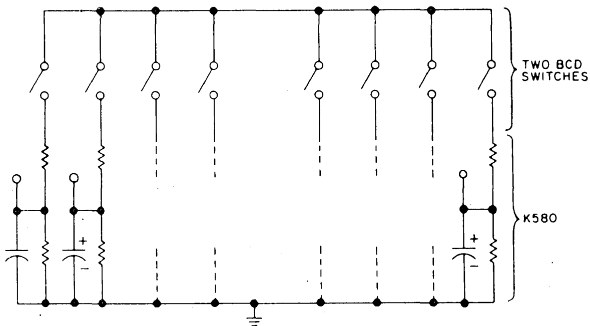
THUMBWHEELS AND MULTIPLEXING THEM WITH K581

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

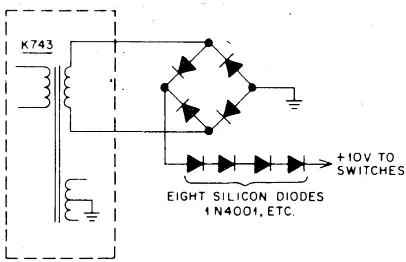
MANUFACTURER'S TYPE	PANEL CUTOUT HEIGHT	WIDTH PER DIGIT*
Digitran 315	1.380″	0.500″
Digitran 13015	2.000″	0.500″
Digitran 715	0.980″	0.500″
Digitran 8015	0.980″	0.500″
Digitran 9015	1.375″	0.600″
EECo 5305	0.960″	0.500″

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

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

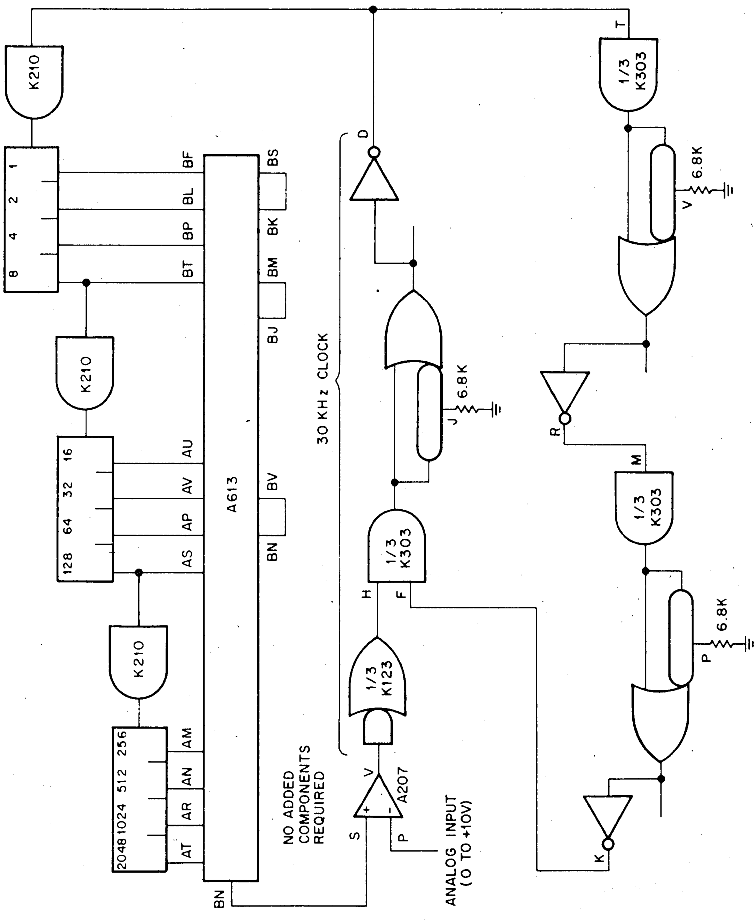


Power for the unmultiplexed system can be obtained from a 10 volt DC power supply or by using the circuit shown here with the auxiliary 12.6v winding on the K743 transformer.



OBTAINING +10V FROM K743

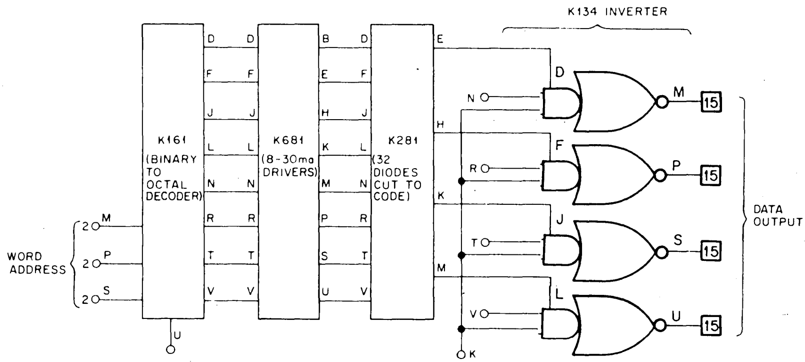
A faster converter may also be built using up/down counters or by building a successive-approximation type of converter.



12 BIT ANALOG TO DIGITAL CONVERTER

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 pin K inhibit on K134s to select 8 words
b) Duplicate K281 and K134, tying K134 outputs together
c) Use same K161 and K681
d) Up to 40 4-bit words may be obtained (fanout down to 3)
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.

PARALLEL COUNTERS

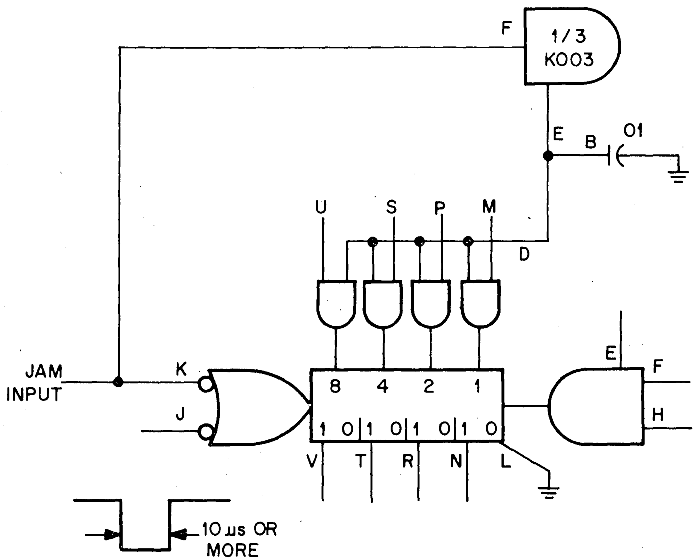
The counters shown elsewhere in this handbook are "serial" counters: that is, the input to a counter module of high significance is the simple output of the next less significant flip-flop, resulting in a time difference between groups of outputs (within a given K210, K220, or K230 module all outputs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

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).

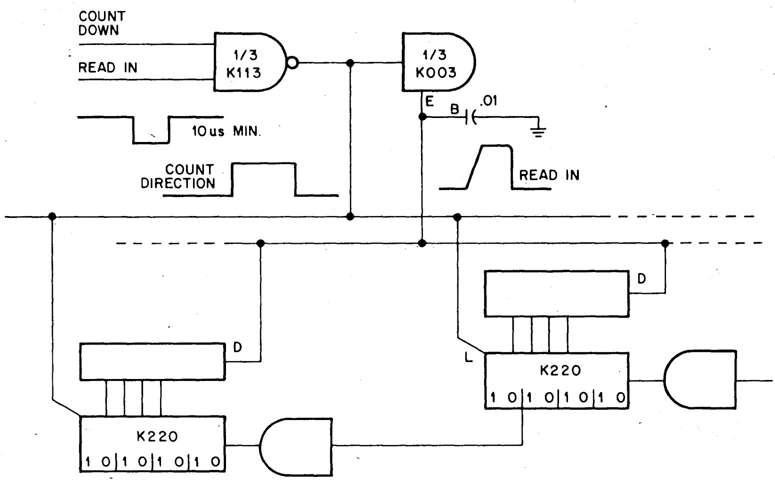
Several "read ones" inputs may be driven from a single K003 section, provided the capacitance is multiplied by the same number. However, the heavy capacitive loading may cause slow falltimes on the jam input line. Pin D inputs on K220 and K230 may be regarded as 1 milliampere loads in this application.

K220 READIN ON DOWN-COUNT

Because of the simple one-wire cascading feature built into the K220 up/down counter, a restriction is placed on the readin capability to prevent "borrow" from propagating erroneously.

If a "1" is read into the most significant *flip-flop* of one K220, the next more significant K220 *module* will receive a low-to-high transition at its count input. If this module has zero volts at its pin L, it will regard this low-to-high transition as a borrow signal and will accordingly count down one step.

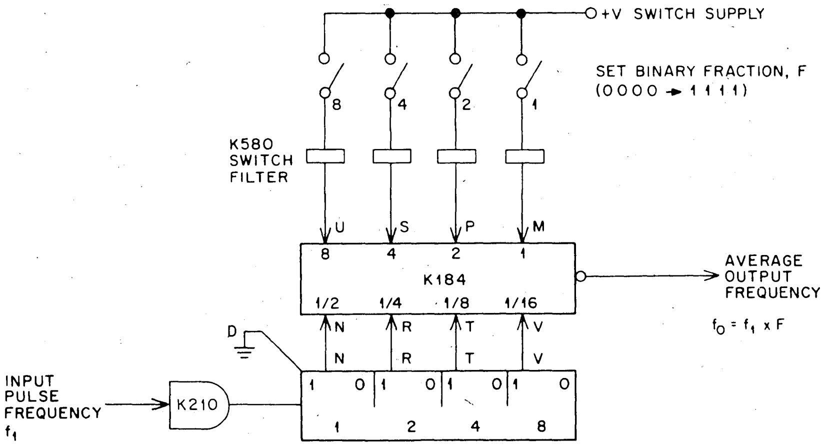
To prevent such erroneous down-counts, it is necessary to raise the count direction line to a logic "1" (count *up*) for at least 4 μsec before and 4 μsec after the low-to-high transition at the readin gate, pin D. The diagram below shows how this may be accomplished, using the same delay technique shown on the preceding page.



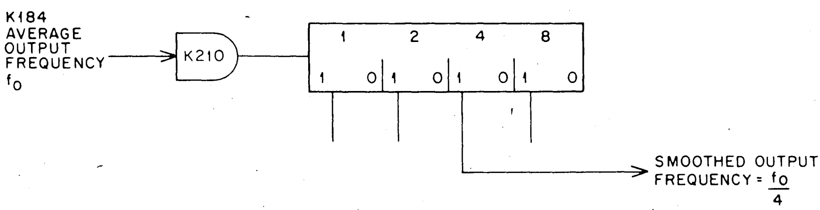

DEC Module assembly lines combine automated manufacturing steps with visual inspection and computer controlled testing.

K184 RATE MULTIPLIER

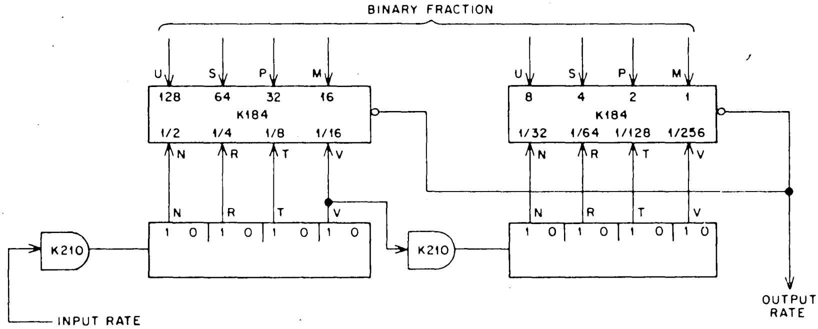
The K184 Rate Multiplier accepts an input pulse frequency f_1, via a Binary Counter, multiplies this by a Binary Fraction F, and emits a pulse train, with *average* frequency $f_0 = f_1 \times F$. Note that f_0 is always less than f_1, also that the Counter and Fraction are Binary; the Fraction being 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_0.



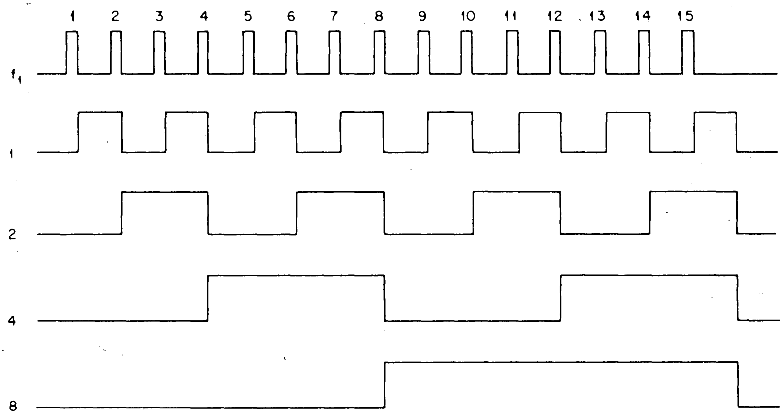
Since this frequency is average, and not periodic, some digital smoothing may be added; f_1 can then be preselected, to control Hydraulic or Pneumatic Valve opening and closing rates, Stepping Motor velocities etc.



The resolution of the system is increased by cascading K184 modules and Counters. The K184 outputs, f_0, are simply commoned in this case.



8 BIT RATE MULTIPLIER



BINARY-CLOCK COUNTER OUTPUTS GENERATED BY f_1

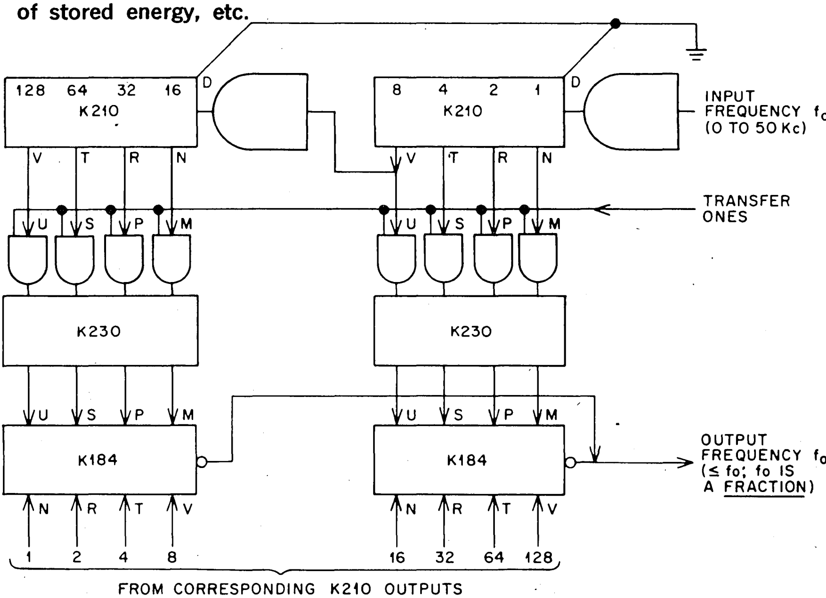
PRINCIPLE OF K184 OPERATION

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→1 transitions. Note that no two 0→1 transitions are ever in coincidence. Also notice that of all possible pulses, all but one are obtainable if each 0→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.

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.

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

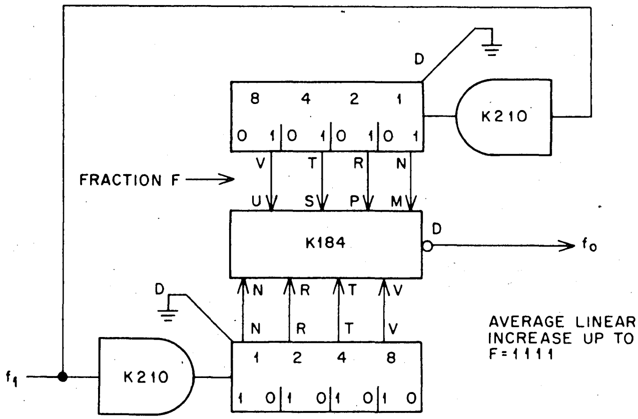
0. K230 holds previous rate number; K210s cleared
1. Gate f_0 to K210 counter for fixed period
2. Stop counter at end of internal; clear K230s and read in
3. Clear K210 and return to step 1.

MODULE COST	
2 K210 @ $27.	$ 54.00
2 K230 @ 36.	$ 72.00
2 K184 @ 18.	$ 36.00
TOTAL excluding control	$162.00

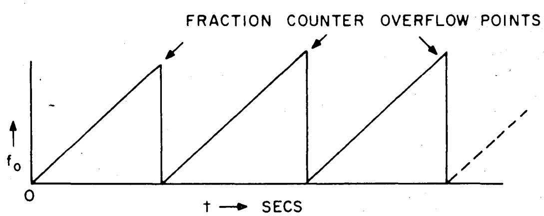
NOTE: f_0 is regarded as a fraction, where 1.0 is that frequency which just fills the counter during the count interval. Average output rate is the product of current count rate times the average rate in the previous interval.

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.

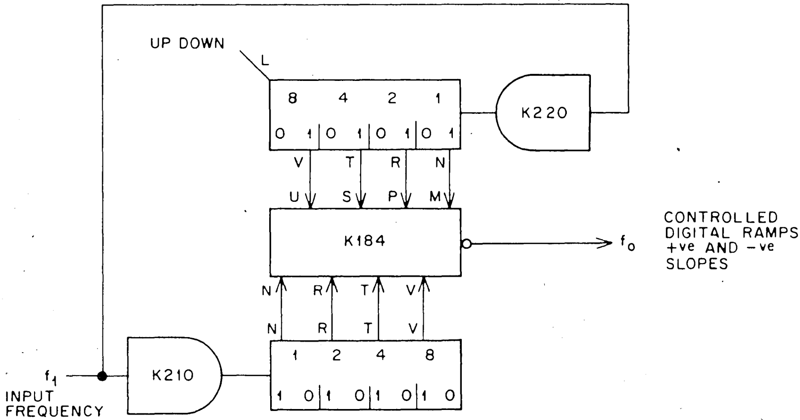


As shown below, if the FRACTION K210 overflows from 1111 to 0000, f_0 will fall to zero and begin again to increment as before. The result is a Digital Sawtooth generator. f_0 against time t is shown here.

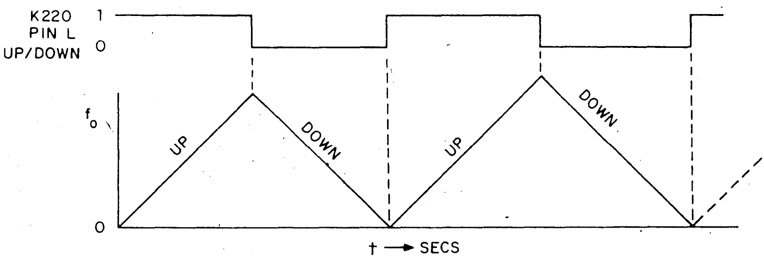


Resolution can be increased by module cascading. If the Fraction Counter is a K220 UP/DOWN Counter connected for Binary operation,* then the slope of f_0 can be reversed and controlled symmetrically.

*(Pins BD, BE grounded)



The output of the K184 shown above, is on 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.

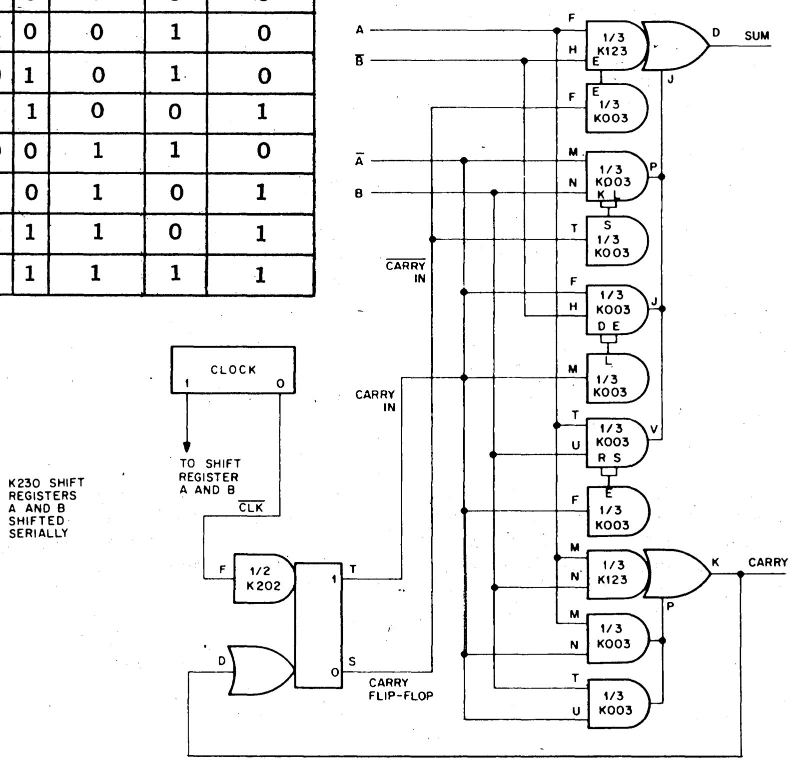
SERIAL ADDER

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, ie Carry or No-Carry.

A	B	carry in	sum	carry out
0	0	0	0	0
1	0	0	1	0
0	1	0	1	0
1	1	0	0	1
0	0	1	1	0
1	0	1	0	1
0	1	1	0	1
1	1	1	1	1



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 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.)

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 Rpp 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:

$$\frac{V_T}{V_S} = \frac{L_{Off}}{L_{On}} = \frac{R_L + R_P + R_{PP}}{R_L + R_p}$$

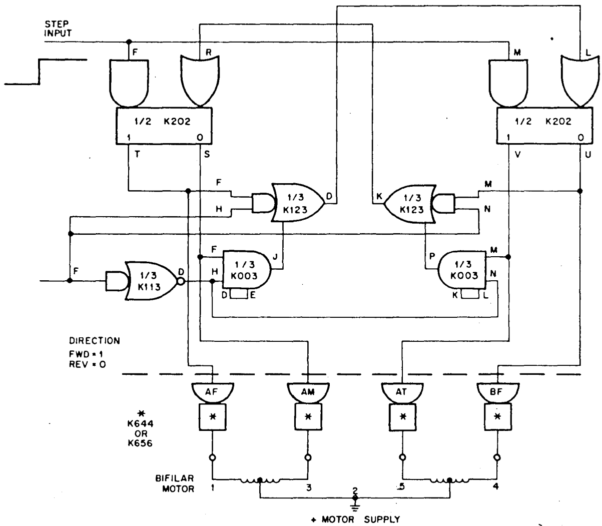
Operating within the stepper's limitations of torque, friction, and stiffness during acceleration and decelelration is trickier than it looks, especially since some crucial constant may be omitted from published specifications for the device. There is often the wish to avoid abrupt (full frequency) starts 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.

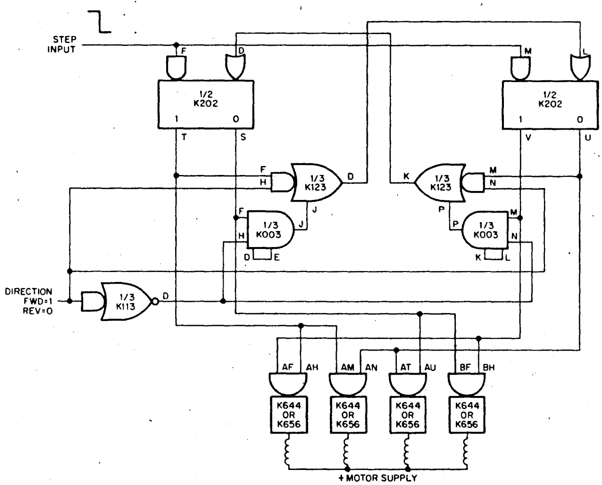


*SLO-SYN is a trademark of Superior Electric Co.

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.

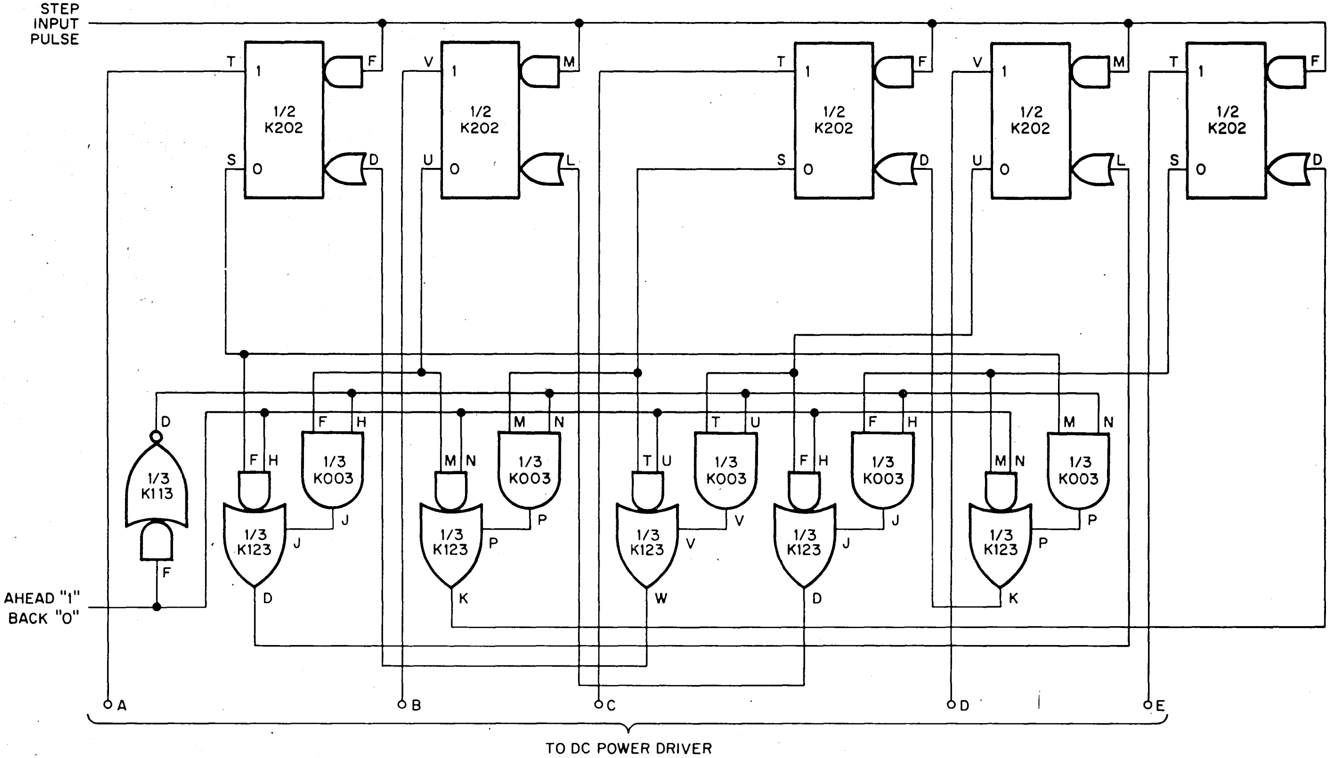
*RESPONSYN is a trademark of United Shoe Machinery Corp.



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).

STEP	A	B	C	D	F
0	X	X			
1	X	X	X		
2		X	X		
3		X	X	X	
4			X	X	
5			X	X	X
6				X	X
7	X			X	X
8	X				X
9	X	X			X



FUJITSU STEPPER MOTOR SEQUENCE.

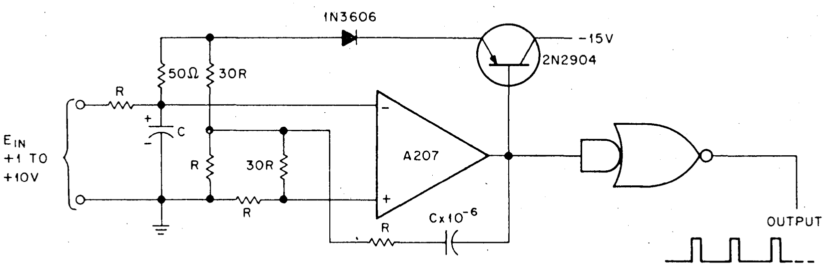
ANALOG-TO-FREQUENCY CONVERTERS

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.

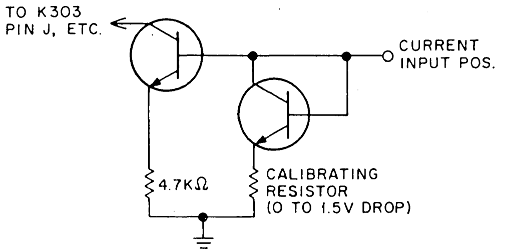
The diagram below shows how an operational amplifier may be utilized to provide direct conversion from an analog voltage to an equivalent frequency with errors in the tens of millivolts. This scheme measures how long current in the input resistor R takes to charge the capacitor C ten millivolts. Each 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=1000Ω, 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.

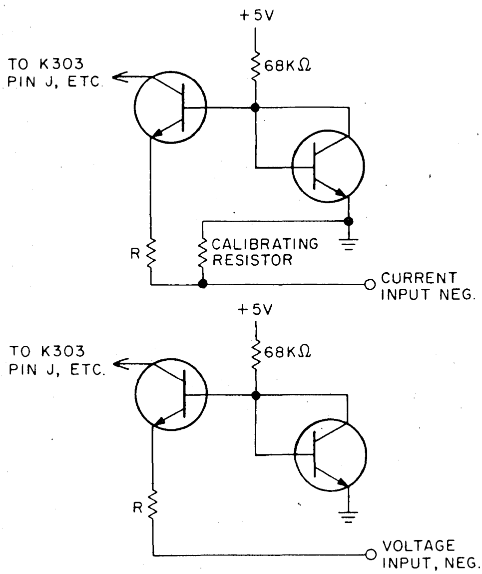
K303 clock circuits can be modified by the additional parts shown below to achieve lower performance conversion at a saving. Basically, a current source controlled by the input signal being converted replaces the action of the timing resistor R shown in the Handbook diagrams. Transistors can be any high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



NOTE:
THE SMALL VOLTAGE DROP (1.5V MAX) AVAILABLE LIMITS LINEARITY TO ±5% OR SO FOR THIS CIRCUIT.

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.



NOTE:
USE LARGEST PRACTICABLE VOLTAGE SWING. RESISTOR R SHOULD BE APPROXIMATELY 3KΩ FOR EACH VOLT OF FULL-SCALE INPUT SWING. LINEARITY CAN BE IMPROVED TO ABOUT ±1% OF FULL SCALE BY USING INPUT VOLTAGE SWINGS UPWARDS OF 10 VOLTS.

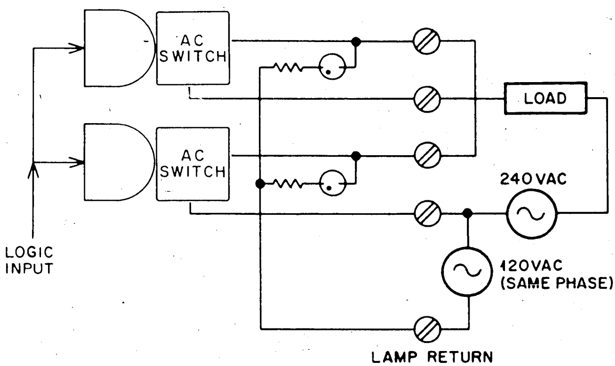
FOR NEGATIVE INPUTS

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 breakover 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.



SERIES CONNECTED AC SWITCHES

DEC PRODUCT SUMMARY

DIGITAL manufactures a broad line of general purpose computers and offers a unique line of peripheral equipment and options. PDP-10 is the largest DIGITAL PDP (Programmed Data Processor) computer. PDP-10 is an industry leader in multi-program time-sharing with over one million user hours already logged and proven software. The 36-bit PDP-10 will time-share, batch process, and run hybrid-simulation all simultaneously at an amazingly low price. The 18-bit PDP-9/I and 9/L are medium sized DIGITAL computers at small computer prices. PDP-9/I offers extensive processing power, background/foreground programming, and many real-time capabilities. And the 12-bit PDP-8 family has made DIGITAL the world's leading manufacturer of small computers. PDP-8, the all time winner, was the first computer to break the $20,000 price barrier and then the PDP-8/S broke the $10,000 barrier. Now, their faster, more economical and more compact successors PDP-8/I and PDP-8/L offer TTL integrated circuit module construction. Many manufacturers have found PDP-8 family computers ideal to build into an integrated system. DIGITAL, for example, builds PDP-8 family computers into an expanding group of systems called Computerpacks. These are integrated hardware and software packages for turnkey use in a number of computer applications. DIGITAL has several Computerpacks for the laboratory, others for typesetting, navigation, education, industrial control and outer acq. and small computer time-sharing. Many original equipment manufacturers use PDP-8 family computers as the central processor for their systems.

PDP-8/I and PDP-8/L

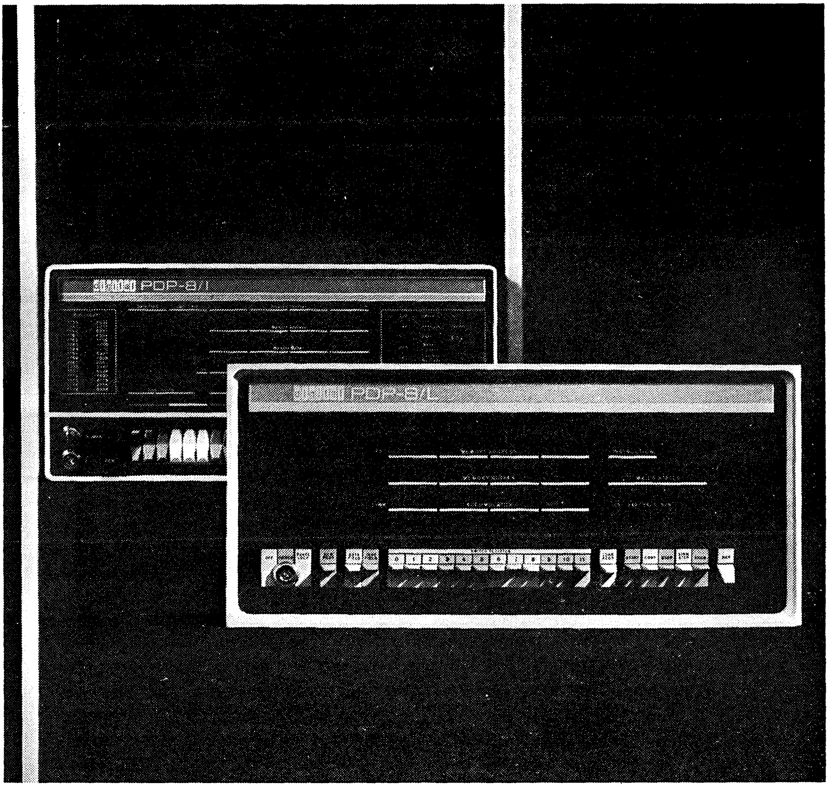
PDP-8/I and PDP-8/L are the latest members of the PDP-8 Family of general purpose computers. They are the faster, smaller and more economical successors to the over 3,000 PDP-8 Family computers installed all over the world.

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 8196 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-8/I
PDP-8/L

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 of 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 an 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 concurrently 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)
- 8 data channels
- Up to 256 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.


digital

PDP-10

PDP-10 is an expandable, 36-bit computer system. All PDP-10 systems begin with two basic hardware elements: 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. The modules vary in size, speed, and cost.

The PDP-10 includes an extremely powerful processor with 15 index registers, 16 accumulators, and from 8,192 to 262,144 words of 36-bit core memory, a 300-character-per-second paper tape reader, a 50-character-per-second paper tape punch, a console teleprint, and a seven-level priority interrupt subsystem. The PDP-10 features an I/O bus which provides 200K word/sec transfer rate; interfaces up to 128 devices with processor. It has 366 instructions, all different and logically complete.

The PDP-10 is designed for on-line and real-time, time-sharing, batch processing, and hybrid simulation applications such as physics and biomedical research, process control, as a departmental computation facility, in simulation and aerospace, chemical instrumentation, display processing and as a science teaching aid.

The software package includes real-time FORTRAN IV, BASIC, a control monitor, a macro assembler, a context editor, a symbolic debugging program, an I/O controller, a peripheral interchange program, a desk calculator and library programs. All software systems assure upward compatibility from the standard 8,192 words of memory through the multiprogramming and swapping systems at both the symbolic and relocatable binary level.

PDP-10 features a 1-microsecond cycle time, a 2.1-microsecond add time, I/O transfer rates up to 7,200,000 bits per second and a modular, proven software package that expands to make full use of all hardware configurations. Memory can be expanded in 8,192 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.

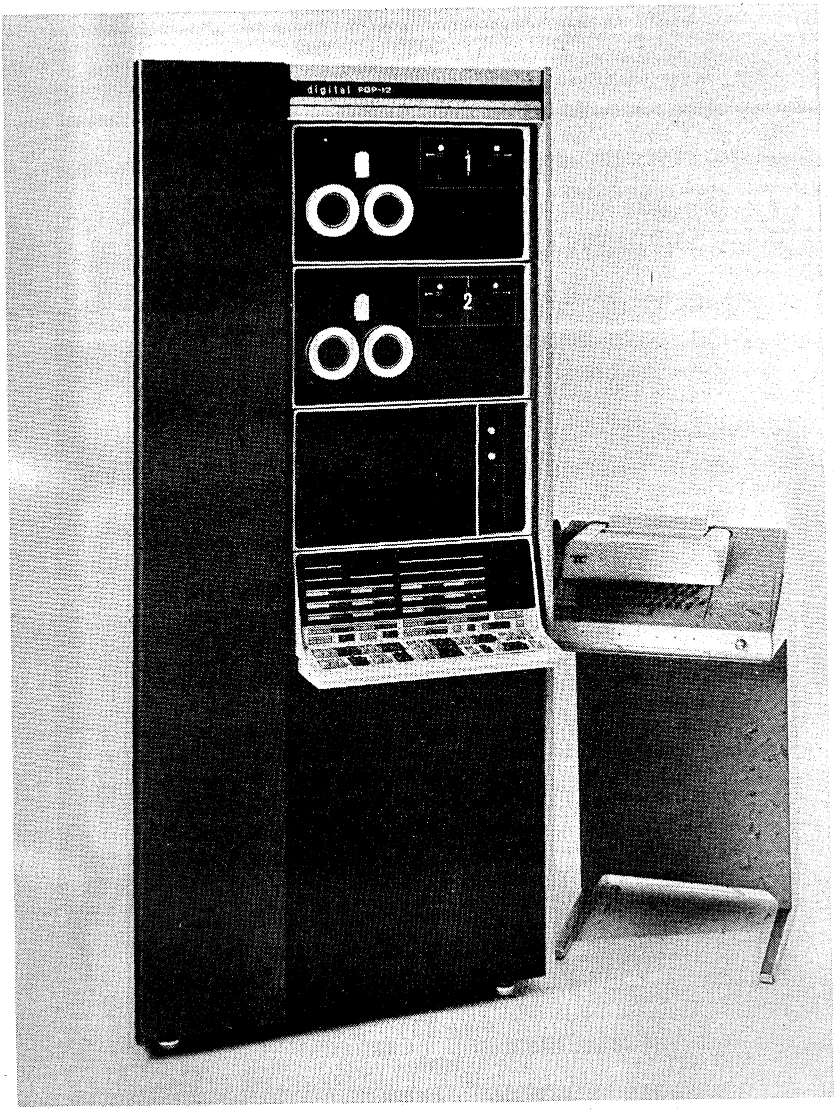
Performance characteristics of the PDP-12 have been optimized around a complete hardware/software system, rather than an expandable minimum configuration. The PDP-12 systems concept works to the advantage of users at all levels of programming sophistication. By simplifying programming tasks, the PDP-12 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"x9" 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
- 1.5 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


digital PDP-12

COMPUTER LAB

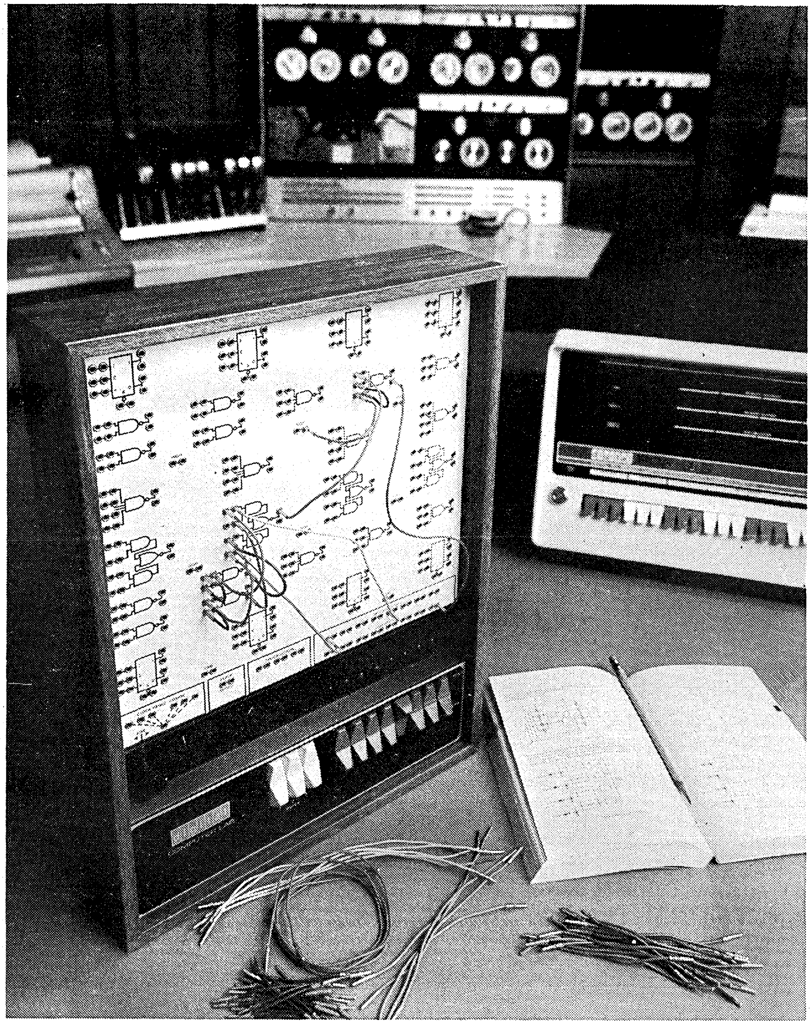
The COMPUTER LAB is a new high performance low-cost digital logic trainer. The COMPUTER LAB uses the same monolithic integrated transistor-transistor logic circuitry used in DIGITAL's latest PDP computers.

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, and course plans.
- Low cost: COMPUTER LAB, Workbook and Patchcord set, ready to use $445.00



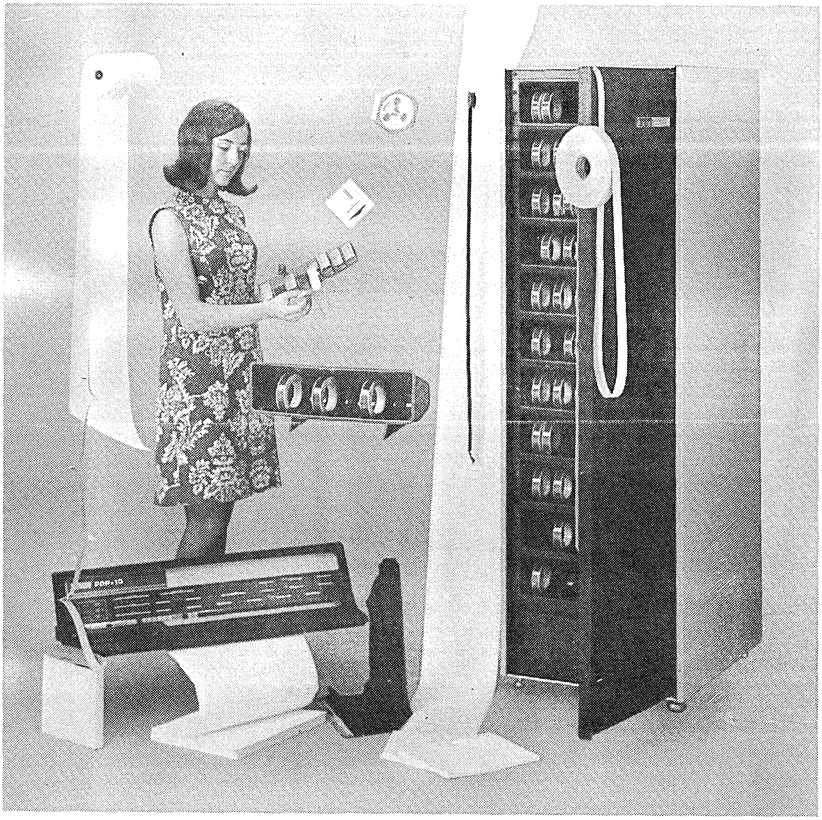
DEC SUPPLIES

Digital Equipment Corporation offers a complete line of computer operating supplies. These supplies are guaranteed to work with all PDP computers. In fact, DEC equipment performs best when used with DEC supplies! The DEC Field Service personnel are trained to make adjustments in accordance with the specifications of DEC-sold supplies. These adjustments differ for supplies provided from other vendors.

The most important reason for using DEC supplies is their low cost. DEC supplies are, in some cases, 50% lower in price than those offered by other major suppliers. This is of particular significance when you realize how many of these items you purchase during the year.

DEC now provides fast delivery on all operating supplies because many are stocked locally at regional offices. All orders will be shipped within 48 hours to assure you the fastest delivery possible.

Part No.	Description	Price
74-3860	DECtape	$ 7.00 ea.
74-3860-1	LINC Tape	7.00 ea.
36-05363	Fanfold Paper Tape (1" wide)	45.00 case
36-05360	Oil rolled tape	36.00 case
36-05364	Paper Tape Trays (9¼" x 12")	3.30 ea.
18-09128	Empty DECtape Reels	.50 ea.
18-0932-01	DECtape Storage Racks (Cabinets)	9.00 ea.
18-09232-02	DECtape Storage Racks (Desk)	7.50 ea.
18-09139N	Printer Ribbons for DEC Line Printers	15.00 ea.
18-09137	Teletype Ribbon	20.00 box
36-05361	Printer Paper	15.00 box
18-09211	Paper Tape Gauge	8.40 ea.
18-09138	Roll Paper Tape Winders	3.50 ea.
18-09157	PDP-10 Console Cover	75.00 ea.


PDP-10

WIRE WRAP SERVICE POLICY AND PRICES

Wire Wrap Service Policy and Prices
As a service to those customers who are building multiple units, we will provide an automatic wire wrap service. This service will be available to anyone who has at least five like systems to be wired.

Inputs:
The customers should provide us with a deck of IBM cards for input to the wire list program. The deck must be prepared in accordance with the Standard DEC format and procedures.

Key Punching:
If a customer does not have a key punching facility available, we can provide punching services at the rate of $0.05 per card when cards have been listed on our forms DR-22.

One Time Charges:

24 Gauge Wire Wrap:
$320 minimum charge for up to four panels (1943, or equivalent in any other mounting arrangement) $25 for each additional panel.

30 Gauge Wire Wrap:
$200 minimum charge for up to two panels (H911 or equivalent in any other mounting arrangement) and $50 for each additional panel.
One time charges are not discountable.

File Maintenance Service:
If desired, DEC will maintain on file a magnetic tape record of the original source information for a period of two years. A service charge of $50, not discountable is assessed for this service.

In many cases the customer will want to maintain the magnetic tape in his own EDP center and DEC will provide him a tape in card image for $35.00/reel.

Purchase Orders:
A separate P.O. # must be issued to DEC for any Wire Wrap service. This is necessary for the following reasons.

1. Pricing of the wire wrap job cannot take place until the actual processing of the source deck has been completed (to determine wire count and charges for correction and re-run).
2. The module and mounting panels on the same order would be unnecessarily delayed by the above because the order could not be entered without complete price information. This could mean several weeks delay to the customer.

Errors/Corrections:
No ECO work will be performed on wired panels. This means DEC will not up-date wired frames to incorporate changes that may come into the house before shipment of the panel.

In addition, in those cases where errors have been found in a customer supplied card deck, the customer will be contacted to establish corrections. The customer will be charged a flat fee of $50.00. Correction charges are not applicable to discount.

Bussing:
Special bussing will be performed by DEC should it be required. The customer will be charged at the rate of $0.10 per point for special bussing not including the cost of the bus strip. For a charge of $5.00 DEC will provide to the customer a vellum of the appropriate mounting panel. Bussing will be done according to an appropriate marked up DEC drawing only. Special bussing will add at least two weeks to the normal delivery time.

Delivery:
The normal delivery for wire wrap panels is 4 to 6 weeks after receipt of both the purchase order and an accurate card deck. Additional time should be allowed for delivery if key punching and/or special bussing is required.

Prices:
The cost per wire for wrapping #24 wire is 33¢ and for #30 wire is 45¢.

Both applicable to standard module discount agreements.

Wiring Verification:
At no extra charge to the customer the wire wrapped panel will be verified. The only restriction being that the size of the panel be limited to 4 connector blocks high by 10 connector blocks wide. No price reduction will be allowed for elimination of the verification service.

Customer Receives:
The customer receives one copy each of the Name Sort, Pin Sort, To-From and Z level list. Additional copies will be provided at a cost of $10.00 each. The card deck and Gardner-Denver deck are the property of the customer and will be shipped to him upon completion of the job.

PRICE LIST AND NUMERICAL INDEX

		Price	Page
M707	Teletype Transmitter	175.00	88
M730	Bus Interface	185.00	94
M731	Bus Interface	185.00	94
M732	Bus Interface	185.00	96
M733	Bus Interface	190.00	96
M734	I/O Bus Input Multiplexer	110.00	98
M735	I/O Bus Transfer Register	140.00	100
M736	Priority Interrupt Module	130.00	105
M901	Flexprint Cable Connector	16.00	112
M903	Flexprint Connector	12.50	113
M904	Coaxial Cable Connector	14.00	114
M906	Cable Terminator	20.00	115
M907	Diode Clamp Connector	16.00	116
M908	Ribbon Connector	18.00	117
W018	Cable Connector	9.00	300
W021	Cable Connector	4.00	300
W022	Cable Connector	5.00	300
W023	Cable Connector	4.00	300
W028	Cable Connector	5.00	300
W512	Positive Level Converter	25.00	118
W603	Positive Level Amplifier	23.00	119
W970	Blank Module/36-pins	4.00	294
W971	Blank Module/Double Height/72-pins	8.00	294
W972	Blank Module/Copper-clad/36-pins	4.00	295
W973	Blank Module/Double Height/72-pins	6.00	295
W974	Blank Module/36-pins	9.00	294
W975	Blank Module/72-pins	18.00	294
W980	Module Extender	14.00	292
W982	Module Extender	18.00	293
W990	Blank Module/18-pins	2.50	294
W991	Blank Module/36-pins	5.00	294
W992	Blank Module/Copper-clad/18-pins	2.00	295
W993	Blank Module/Double Height/36-pins	4.00	295
W998	Blank Module/Perforated Board	4.50	294
W999	Blank Module/Perforated Board	9.00	294
913	Patchcords	18.00	286
914	Power Jumper	4.00	287
915	Patchcords	33.00	286
917	Daisy Chain	50.00	288
932	Bus Strip	0.60	289
933	Bus Strip	1.00	289
934	Wire-wrapping Wire	50.00	289
935	Wire-wrapping Wire	60.00	290
936	Conductor Ribbon Cable	0.60	290
1907	Cover	9.00	282

ALPHABETICAL INDEX

MODULES

Describes 60 M Series high-speed TTL integrated logic modules, 57 compatible K Series low-speed noise-immune logic modules, and fifteen A Series analog/digital modules.

HARDWARE

Comprises over 100 separate hardware and accessory items including power supplies, connector blocks, mounting panels, blank modules, and connector cards.

APPLICATIONS

Contains thirty-five applications notes and dozens of useful design notes that make this Handbook one of the most informative digital electronics handbooks available.

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