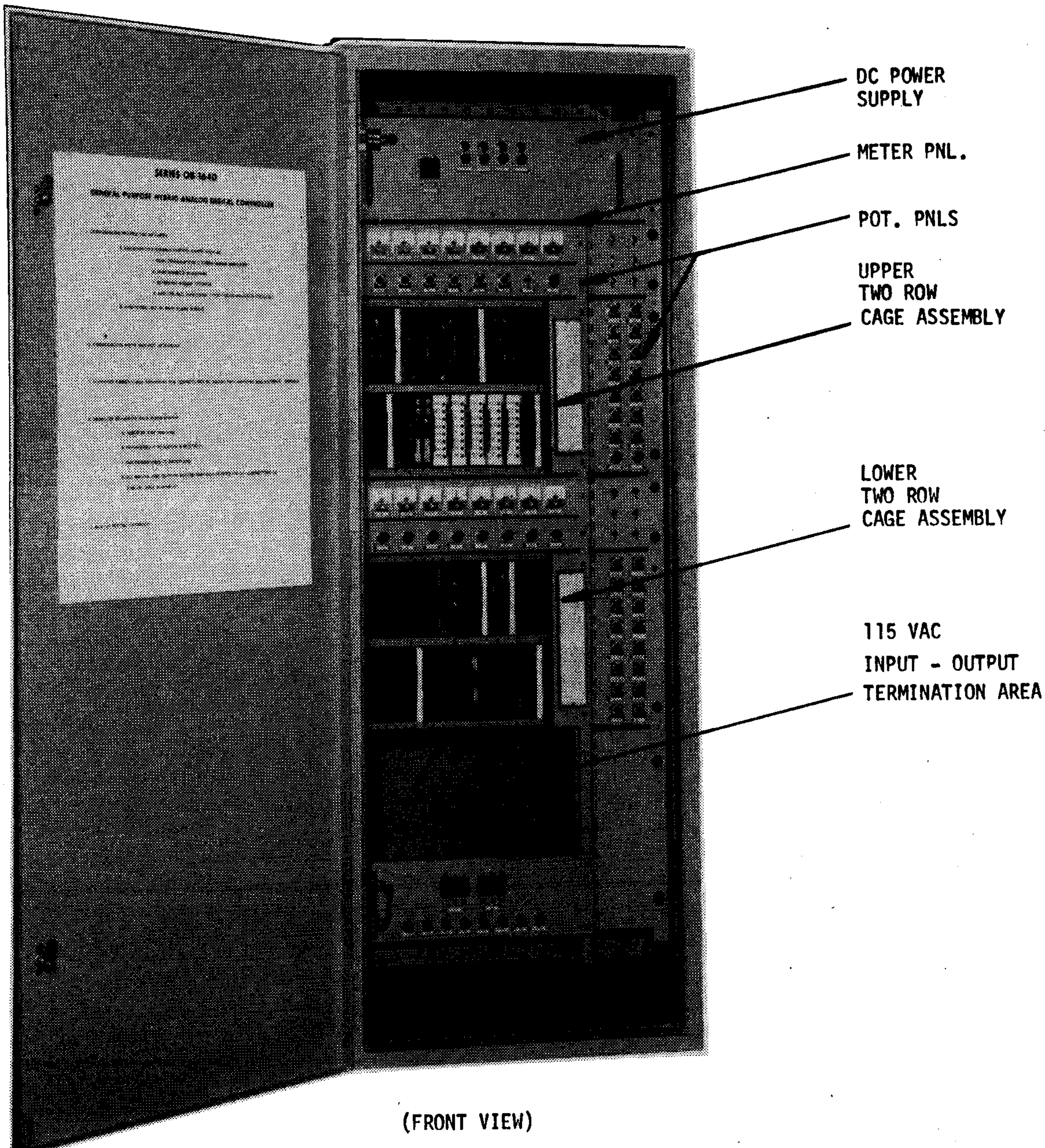
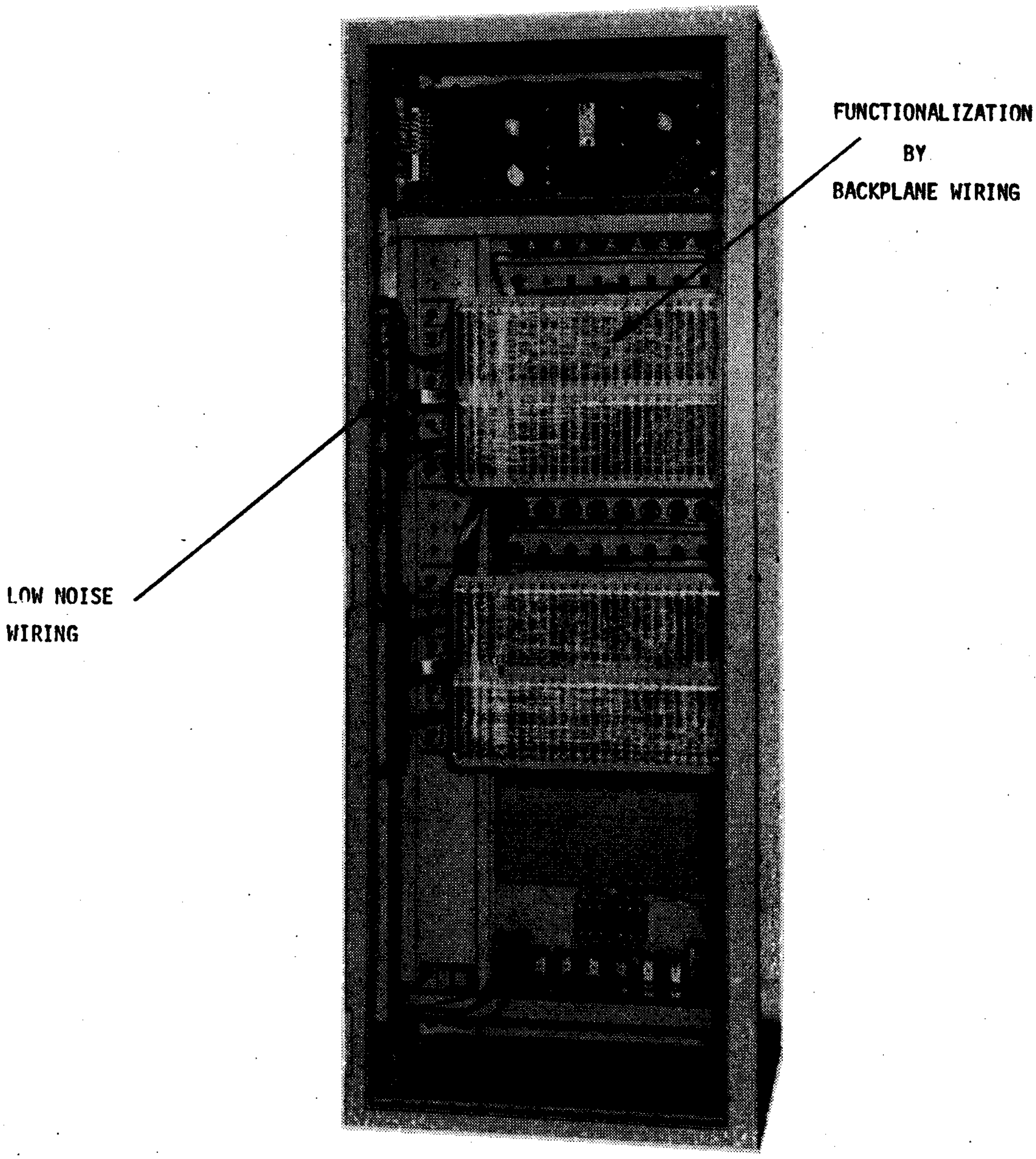
MODEL QB 16

ANALOG-DIGITAL HYBRID CONTROLLER



(FRONT VIEW)

QB 16 HYBRID CONTROLLER



(REAR VIEW)

QB HYBRID CONTROLLER

INDEX

A. GENERAL DESCRIPTION

QB-16 is a hard wired hybrid controller which utilizes a standard line of uncommitted printed circuit cards. QB-16 uses 15 volt HTL digital logic for sequence and switching functions. It can accommodate a limited amount of 115 VAC optically coupled inputs and triac outputs for 115 VAC input - output control functions.

Its major application is on large systems director functions which are normally not duplicated on similar applications. Typical applications are the automatic gauge controls for multi-stand hot and cold rolling mills or the master director for a group of coordinated drives such as the stand drives of a tandem cold rolling mill.

The major hardware components making up a QB-16 Controller are:

1. Nema 1 enclosed structure.
2. DC power supply.
3. Incoming AC circuit breaker.
4. Cabinet fans.
5. Fuse protection for 115 VAC inputs.
6. Two 40 card position cages
7. 5 Row connector panel for common wiring of both cages.
8. Two fixed pot panels (8 - 5K pots ea.).
9. Two fixed meter panels (8 meters ea. 15-0-15V).
10. Two small swinging pot panels (6 - 5K pots ea.).
11. Two large swinging pot panels (1 to 16 pots. ea. - any value).
12. Thru conn wiring channel with provisions for terminating transmitter and receiver boards for inter cabinet wiring.
13. Outrigger connections from back panel to customer low noise analog term blocks.
14. Termination panels for 115V input - output connections (40 input - output boards max.)

External signals involve high and low noise signal levels. Inputs for sequencing purposes and outputs for control functions can be 115 VAC and are separated from low noise analog signals associated with the regulating functions. When logic signals are transmitted and received between QB-16 and other digital logic control (QB-11) transmitter and receiver PC cards are used to condition the signals and provide noise immunity over the transmission line.

B. PC CARD CAGE ASSEMBLY

The basic cage for the QB16 cabinet has positions for up to 40 PC cards, twenty per row, and two basic cages can mount in one cabinet giving a total of 80 PC cards. The basic cards designed for this cage were specifically generated without functionalization. The philosophy of the QB16 approach is that job functionalization is accomplished by means of backplane wiring. In this fashion, the different types of boards required should be kept to a minimum with a corresponding greater usage of the basic boards.

Of particular importance in the QB16 approach is the design flexibility provided by the backplane. Because functionalization is accomplished on the backplane, design changes can also be implemented by associated changes in the wiring. Taken to an extreme, major design changes can be made on a job utilizing the existing cards merely by the generation of the appropriate backplane and wiring.

All connections to the cage are made via edge connectors in card positions 22 to 25. The only exception to this is the PSC bus connection. An external connection to these edge connector positions can be from a meter assembly, from pot assemblies, from external terminal block assemblies or from a second QB16 cabinet. All of these assemblies are pre-wired with ribbon cable connectors into an appropriately sized printed circuit board which plugs into a predesignated position on the backplane. In this manner handwiring is eliminated from the backplane. Any signals brought into the cage via the terminal block, ribbon cable, or pc board assembly should be in the low noise classification to maintain a noise free backplane.

If noisy signals are required in the cage, which may be the case for sequence control, then they should be brought in via logic input cards to which the connections are made by means of a front edge connector. 115V AC from a contact, pushbutton, etc., can be brought in to generate a logic signal in the cage. In a similar fashion, an output board which is also mated to a front edge connector can interface from logic signals to 115V AC for external sequence control.

C. HARDWARE LIMITATIONS

Associated with each QB16 cabinet is a finite amount of hardware. It is the responsibility of the designer to be aware of these limitations because it effects the manner in which the hardware is allocated.

For each two row cage assembly, there is the following available equipment:

1. 8, 15-0-15 Voltmeters - standard

2. 8, 5k ohm potentiometers, single-turn-standard.

3. 16 (or less) selectable ohmage potentiometers, single or multi-turn.

The meters are pre-wired with a common PSC line and 8 wires from the associated meters to fixed terminals on a pre-selected edge connector. The potentiometers are also pre-wired to selected terminals on pre-selected edge connectors with three wires brought to the backplane for each potentiometer. All of these items are associated with the appropriate cage in that they can be interconnected on the backplane by machine wiring.

If the cabinet contains two cage assemblies, then the second cage has its associated meter and potentiometer panels.

Below the cage assemblies is an area that is allocated for high noise input/output lines. In this area there is space allocated for two terminal block panels. Mounted on these panels are printed circuit board assemblies with terminal blocks that are prewired to edge connectors for front mating to input/output boards. Each PC board assembly can contain either one or two terminal blocks with the associated wiring to the edge connectors. Each terminal block and its associated wiring cable connects to only one edge connector. Each panel assembly can contain up to five PC board assemblies for a capacity of 10 I/O cards (20 for a two panel assembly). The incoming and outgoing signals on these lines are high noise 115V AC signals from pushbutton, contactors, switches, etc., or to relays, solenoids, lamps, etc. The prewired harness assemblies are routed through a vertical wire channel on the left front side of the cabinet to the appropriate cages.

Analog inputs are brought into the cages through ribbon cables which are connected to terminal blocks mounted on a vertical strut on the rear of the right side (viewed from the front). These terminal blocks are accessible only from the rear of the cabinet. The ribbon cables are prewired to PC boards which plug into predesignated positions in the cage. For each two row cage assembly, two 12 point terminal blocks are available for bringing analog signals into the cage. The power supply voltages (+24V, +15V and +5V, if used) are brought into these cages through the ribbon cables so that the number of available low noise I/O lines per two row cage is 20 or 21 depending upon the power supplies used. Total low noise I/O capacity for a two cage assembly is 40 or 42 signal lines.

Hardware limitations necessitate the proper allocation of equipment in order to prevent problems from arising when a job is implemented. The design engineer must be aware of these limitations because it requires consideration in the generation of schematics for a job.

D. HARDWARE STRUCTURE

QB16 is hybrid system and as such it will contain a mixture of analog and digital functions. Analog functions can be created which are identical to those existing on committed controller card designs, although it generally take more hardware with the QB16 approach because of the versatility designed into the system. In a similar fashion, digital functions can be created from the basic digital building blocks to provide whatever type of decision making is required. The linear circuit boards contain static switches which can be used for either amplifier resetting or for the selection of signals into summing junctions. These static switches are operated directly by the signals from the logic circuitry.

The basic linear controller boards in this system do not have any defined characteristics by themselves; that is, they are not summing amplifiers nor integrating amplifiers. A functional circuit is generated only when a linear amplifier board is inserted into an edge connector which is wired to provide input and feedback impedances for a high gain operational amplifier. The combination of the board(s) and the backplane wiring generates the functional circuit. Linear circuit flexibility is provided by interconnecting the summing junctions of operational amplifiers to appropriate impedance networks. In so doing, the backplane must be treated in a fashion different from that of a standard variable or fixed regulator backplane.

The basic digital card contains a set of building blocks which when wired on a backplane creates the required digital functions. Various problems associated with the digital functions should be considered in the design. For example, if a memory circuit is created with the digital blocks, then the status of the device after power turn on should be considered. If required, a set or a clear function for power turn on will have to be provided.

The key to proper operation of QB16 is the controlled environment aspect of the structure which is necessary because of the type and level of signals appearing on the backplane. The following signals exist on the backplane: summing junction, logic signals (HTL), linear output and low noise linear inputs. The most critical are the summing junctions and the logic signals and as a result the backplane of QB16 regulator cage is classified as a restricted access, low noise area.

In the digital and analog card repetoire, there are some standard cards which are completely functionalized. These functions are comparators, multiplier/dividers, DACs, etc. In addition, there are some specialized cards which were designed for special purposes. To facilitate setup and test procedures, test and interconnect cards are used.

E. DESIGNING WITH QB16

1. The Starting Point

The basic starting point in designing with QB16 is the implementation of the system into a block diagram format using a standard set of symbols in a fashion analogous to what might be done using an analog computer. The basic boards in this series are used to create single-functioned building blocks, the composite arrangement and interconnection of which generates the desired hardware for a specific function. Some of the basic building blocks in this series are summing amplifiers, integrating amplifiers, comparators, electronic switches, function generators, multiplier/dividers, potentiometers, english logic and input/output interface functions. At times there may be requirements for more specialized functions indigenous to a particular operation or mode of control, but the versatility of the basic building blocks in this system should help reduce the need for these specialized functions.

Once the system has been put into a format using the standard symbols, implementation into hardware can begin assuming that the hardware restrictions have been followed in the block format. For linear circuits, the restrictions involve gains, time constants, etc. For example, in working with a summing amplifier gains of 1 and 10 are easily obtained but not in an unrestricted fashion. On a DCA card there are 3-200k resistors and 2-20k resistors which can be used for inputs and/or feedback resistors. A limitation exists then in using this amplifier as a summer. Similar limitations exist for the other linear boards and the user should be familiar with these limitations before generating the block diagram. Generally, non-standard gains and time constants are set with potentiometers.

The system block diagram can be used to closely approximate the type and quantity of boards, potentiometers and meters required in the system. In addition, aids in troubleshooting and set-up can be designed into the system using the appropriate QB16 cards.

2. Standard Symbols

Figure 1 is a list of some of the symbols which can be used in creating a block diagram.

3. Block Diagram Example

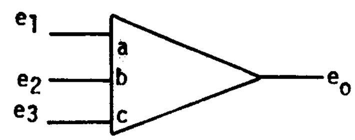
Figure 2 is a block diagram of the linear circuitry of a tension control function. Standard symbols have been used wherever possible.

In Figure 2 separate functional sub-blocks of linear circuits have been grouped together because of their functional relationship and have been enclosed within dashed lines for explanatory purposes only. Implementation into hardware requires the addition of gain and time constant values; and when this has been added, specific boards can be selected and interwired via backplane wiring to create the desired functions.

In referring to sub-block of a schematic, it is implied that a collected set of linear building blocks performs a specific function on a specific signal or signals. For example, in order to create a resettable PI controller two summers, one integrator and two potentiometers are required. The circuit for this is shown in Figure 3 and is functionally complete.

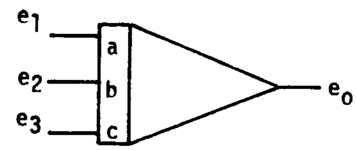
a) Summing Amplifier

$$e_o = -(ae_1 + be_2 + ce_3)$$



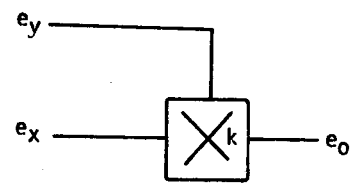
b) Integrating Amplifier

$$e_o = -\left[\frac{1}{a}\int e_1\,dt + \frac{1}{b}\int e_2\,dt + \frac{1}{c}\int e_3\,dt\right]$$



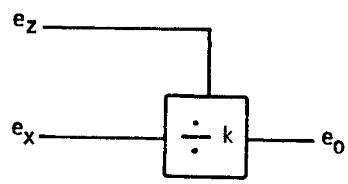
c) Multiplier

$$e_o = Ke_x e_y$$



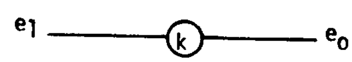
d) Divider

$$e_o = k\frac{e_z}{e_x}$$



e) Potentiometer

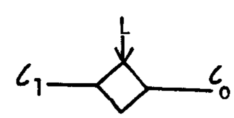
$$e_o = ke_1 \quad 0 \leq k \leq 1$$



f) Electronis Switch

$\ell_o = 0$ when L is a "1"

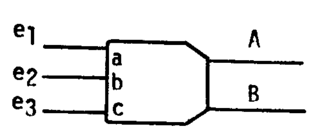
$\ell_o = \ell_1$ when L is a "0"



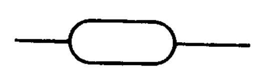
g) Comparator

A = "0" B = "1" if $ae_1 + be_2 + ce_3 > 0$

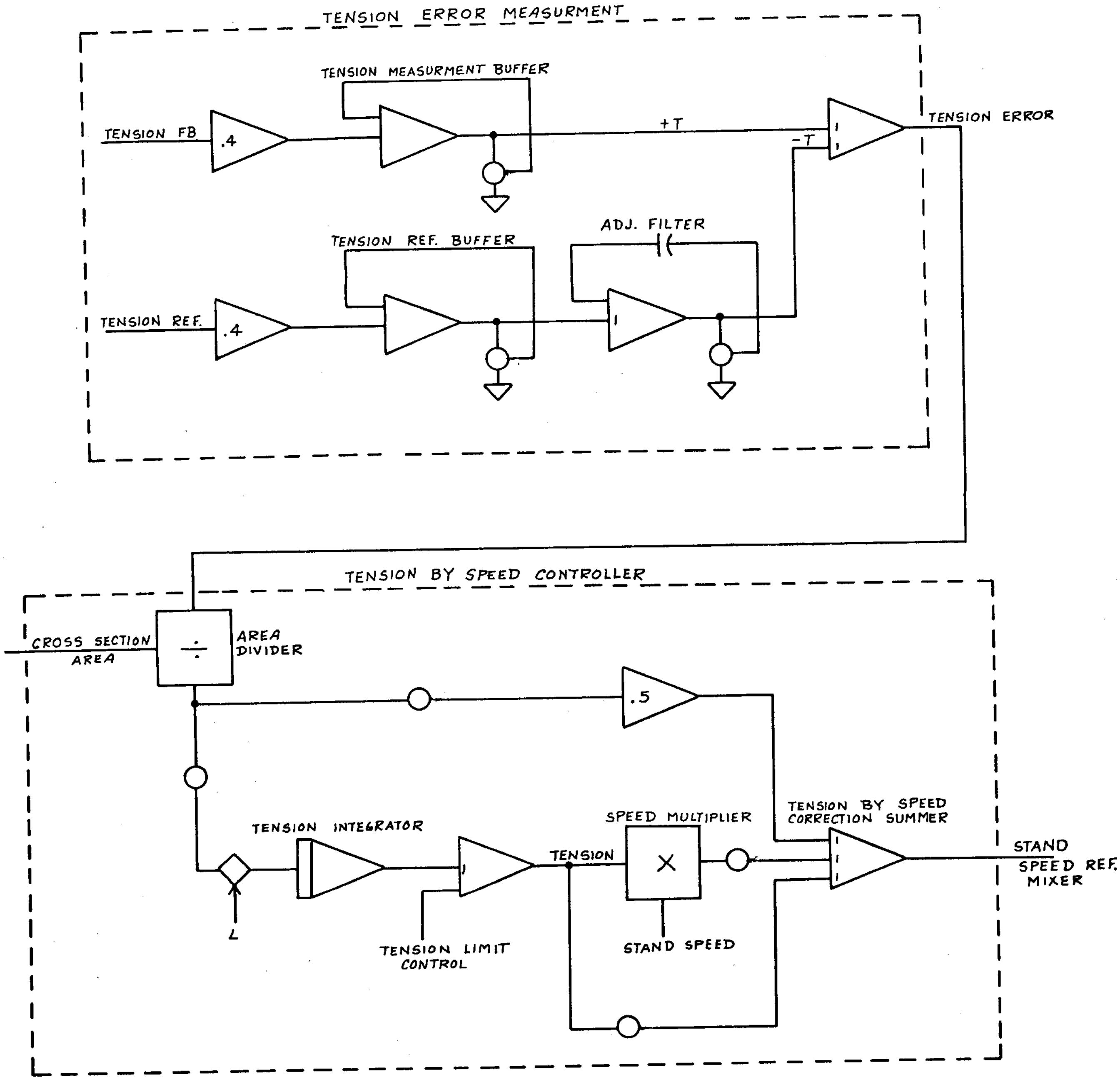
A = "1" B = "0" if $ae_1 + be_2 + ce_3 < 0$



h) Amplifier Limiter

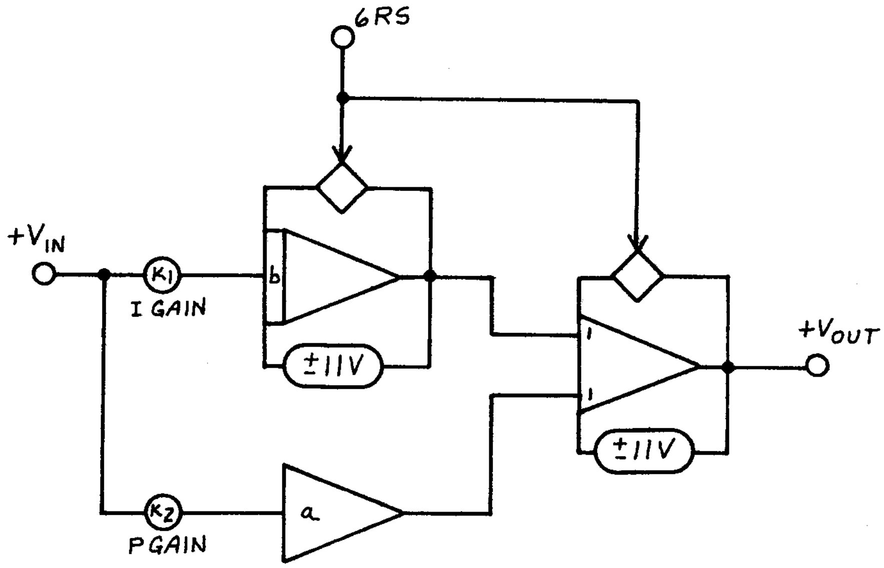


STANDARD ANALOG SYMBOLS
FIGURE 1



FUNCTIONAL BLOCK DIAGRAM

FIGURE 2



$$V_{OUT} = \left(\frac{K_1}{bS} + K_2 a\right) V_{IN}$$

PI CONTROLLER

FIGURE 3

Figure 3 has one input, one output, separate adjustments for the P and I gains and a combined reset for the integrator and the output amplifiers. The output signal, $+V_{out}$, is proportional to and the integral of the input signal. A clearly defined operation has been performed on the input signal. When implementing this circuit into actual hardware it is recommended that, when possible, the various boards used to create the circuitry be in close proximity.

4. Adjustments

In viewing the regulator schematic of Figure 2, several questions can be raised. How are all the adjustable system gains, time constants and limits to be set during installation and/or testing? Is it possible to easily troubleshoot the system in the event of a failure? These questions led to the inclusion in the QB16 series of boards an Interconnect Board and a Test Board. These two boards can be used in a system to simplify both setup and troubleshooting procedures. Their design into a system is relatively simple.

5. Interconnect and Test Boards

The Interconnect Board is used when the system is functional. Its purpose is to route input and output signals between functional sub-blocks by merely providing wire continuity via the copper on the board between pins on opposite sides of the board and to provide monitor points during normal operation for any of the signals being routed by this card. Terminals on the 1 through 30 side have been designated as input terminals; terminals on the 31 through 60 side have been designated as output terminals. Physically opposite terminals are routed through this board; i.e., 3 to 33, 4 to 34, etc. Not all of the terminals on the interconnect board are used for through interconnections. The user should familiarize himself with the Interconnect and Test Board prior to their use.

The test board is generally used to interrupt the signal flow and to allow injection of a test signal (voltage) and to monitor the output of a functional sub-block.

Figure 4 is a simplified schematic showing the external connections of both cards. These boards can be used in either of two ways. First, the interconnect board can be a dead-ended monitor point. Various signals can be routed to this board for monitoring purposes only. It is essentially providing access to selected points on the backplane without having to go around to the back of the cabinet. In addition, if there are unused inputs feeding a linear amplifier, it may be possible to inject a test signal at selected points. If used in this fashion, the associated test points will have to be shown on the schematic so that wiring is routed to these points.

A second way of using these boards is to design the interconnect board into the signal flow path so that when the interconnect board is removed and the test board is inserted, signals can be injected into the normal signal flow path and various points can be monitored.

For example, Figure 3 shows a PI controller with one input, one output and one logic signal. If this sub-block is connected as shown in Figure 5, this sub-block and the associated wiring can be checked. The sub-block is shown connected in the normal mode. Monitor points exist to check all signals associated with this circuit when the circuit is functioning in the normal fashion. If the Interconnect Board is removed and the Test Board inserted in its place, the circuitry would change to that shown in Figure 6. With this arrangement, a test signal can be injected at TP50 (position 5A) and the output can be monitored at TP21 (position 5A). By control of the logic signal (shorting TP26 position 5A to PSC) the operation of the sub-block can be checked. This method can be used for set-up, calibration checks or for troubleshooting.

The question of whether or not this method can be used depends upon the system and if it can be sub-divided into sub-blocks and if the design engineer feels it is required. This is an added feature of the QB16 approach.

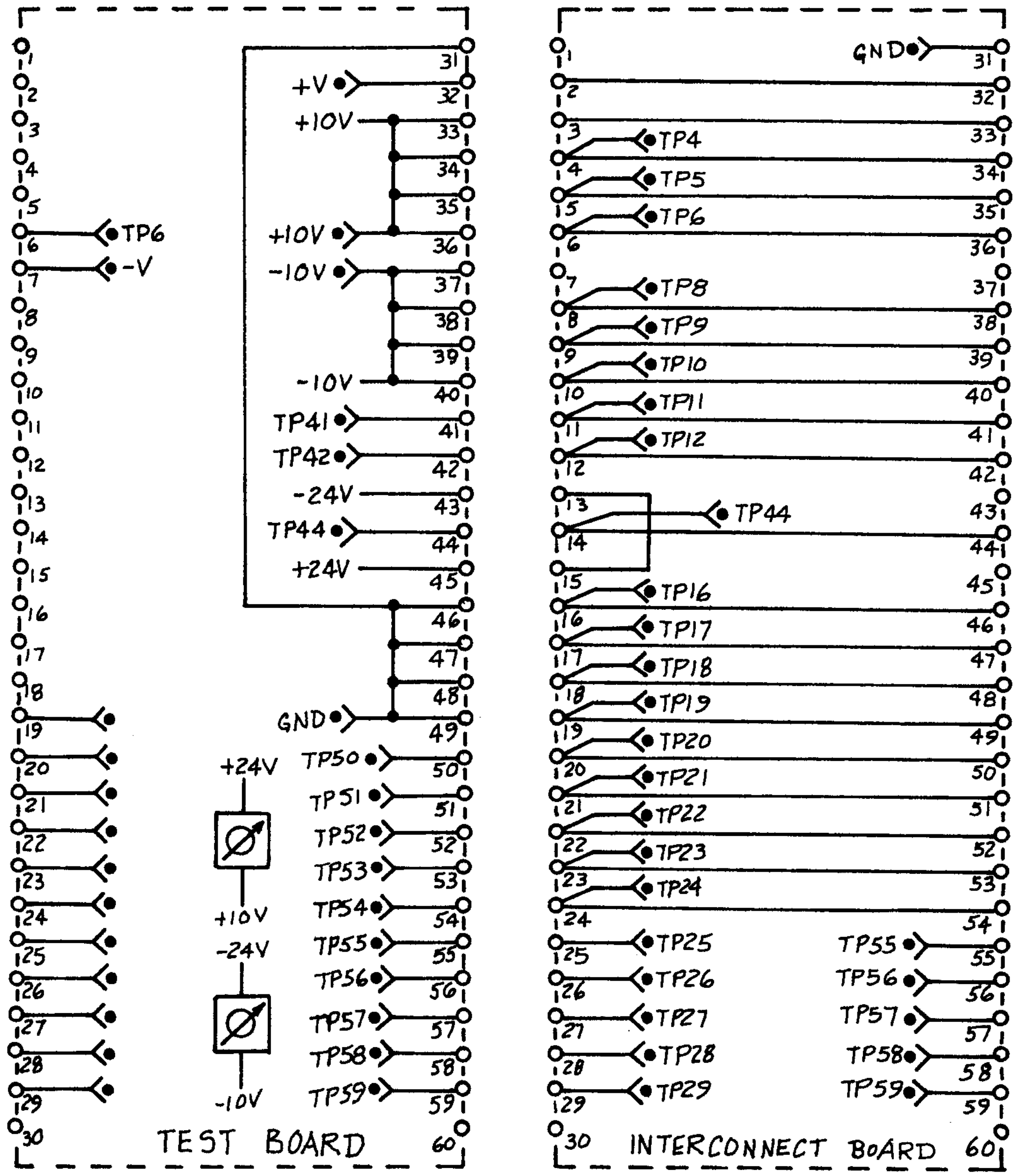
There are some additional points to consider in using these two cards. First, the Test Card does not show up in the normal schematic. If you want to use it be sure it is ordered somewhere. Second, the Interconnect Card can be interlocked to prevent normal operation if it is not in its proper place. Terminals 13 and 15 in conjunction with appropriate logic design can be used for this interlocking feature. Since there is not a one to one terminal correspondence between the two boards, they should be checked to insure that what is required is available. Although terminals 10 and 40 are throught connections on the interconnect board, no access is available on terminal 10 of the test board and terminal 40 of the test board is prewired internally to -10V.

6. Hardware Allocation & Selection

The linear regulator schematic and the associated logic drawings should be looked at from the standpoint of hardware selection and hardware positioning.

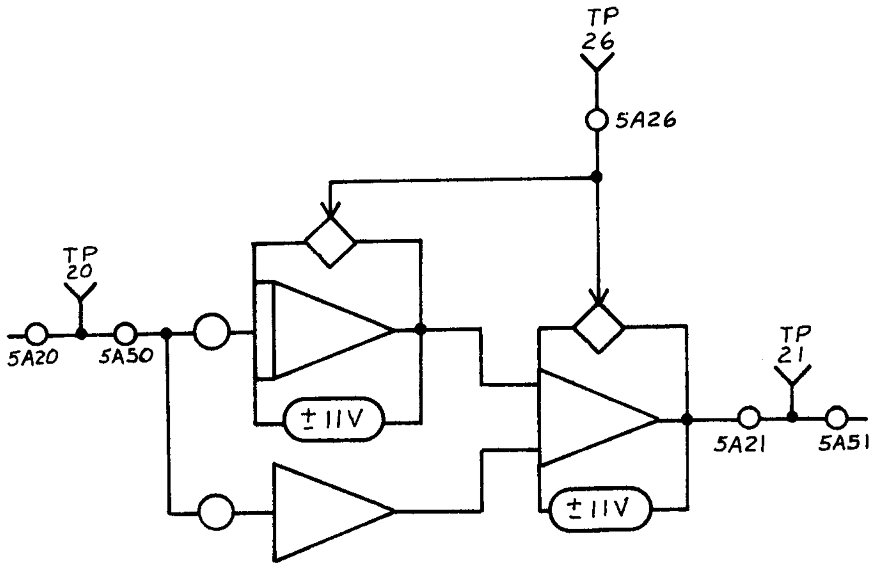
As the logic drawings are worked up it is fairly easy to keep track of the number and types of cards used as the circuitry is implemented. As a general rule it is preferrable to keep the logic circuitry together but this may not always be possible. The number of available signal lines between two cages may necessitate some type of a break in the logic card positioning.

TEST & INTERCONNECT BOARD



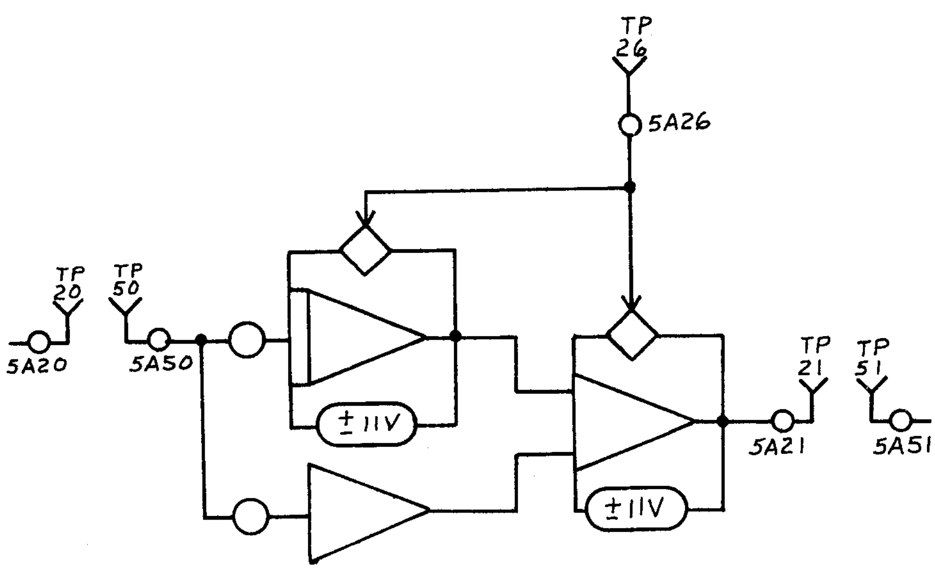
TEST BOARD AND INTERCONNECT BOARD EXTERNAL CONNECTIONS

FIGURE 4



TESTING A SUB-BLOCK

FIGURE 5



TEST BOARD INSERTION

FIGURE 6

In viewing the linear regulator schematic, the number of pots and meters can be determined and compared against what is available in the two row cage. If an excessive quantity of pots is required, some of the linear circuitry may have to be shifted to the second two row cage. If the linear circuitry is sub-divided as in Figure 2, it is relatively easy to determine what can be gained by shifting a particular sub-block to the second cage.

In determining the number of linear boards, a count of two amplifiers per board will yield the number of amplifier boards required; but this count may be altered by the selection of amplifier type. The linear amplifier boards come in two versions: a standard and a precision version. The design engineer should determine where a precision amplifier is required and so indicate this particular requirement on the schematic.

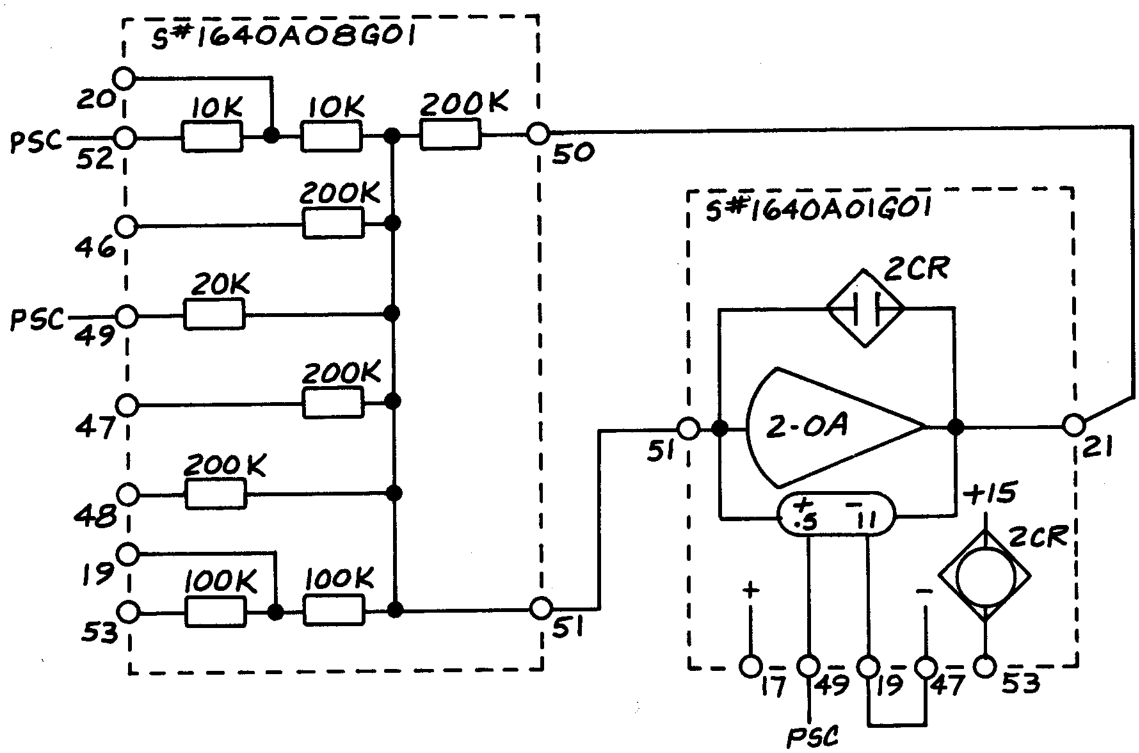
There are a substantial number of fine points that will enter the picture in going from the linear block diagram to schematics detailing the specific circuits. Standard versus precision amplifiers is one of them. Reference voltage is another. There may be requirements for a more precise reference than what is obtainable with the +24 supply, and a decision may necessitate using the Reference Regulator card which provides a highly stable +15V for this purpose. The position and utilization of the Test and Interconnect cards, if it is desired to use them, should be considered. All of these points become a factor in the hardware implementation phase.

F. HARDWARE SCHEMATICS

The linear block diagram(s) of a system have to be translated into actual hardware so that the system can be put together. This necessitates selecting appropriate amplifiers and impedance networks, putting them together on a schematic sheet and connecting them to perform a specific function.

Figures 7 and 8 are representative schematics utilizing two types of boards. These two figures are indicative of the manner in which the schematics can be put together. There is a certain amount of information that needs to be known prior to this work: the relative position of associated boards in a cage, the usage of the appropriate subsections of the linear cards, summing junction impedances, etc.

A substantial amount of detail is required on the schematics. Figure 9 is a schematic from a job utilizing QB16. The various sub-sections of the boards are drawn differently but the detail required on the schematics is shown. Note the detail involved in wiring of the potentiometers, meters and the Test and Interconnect cards.

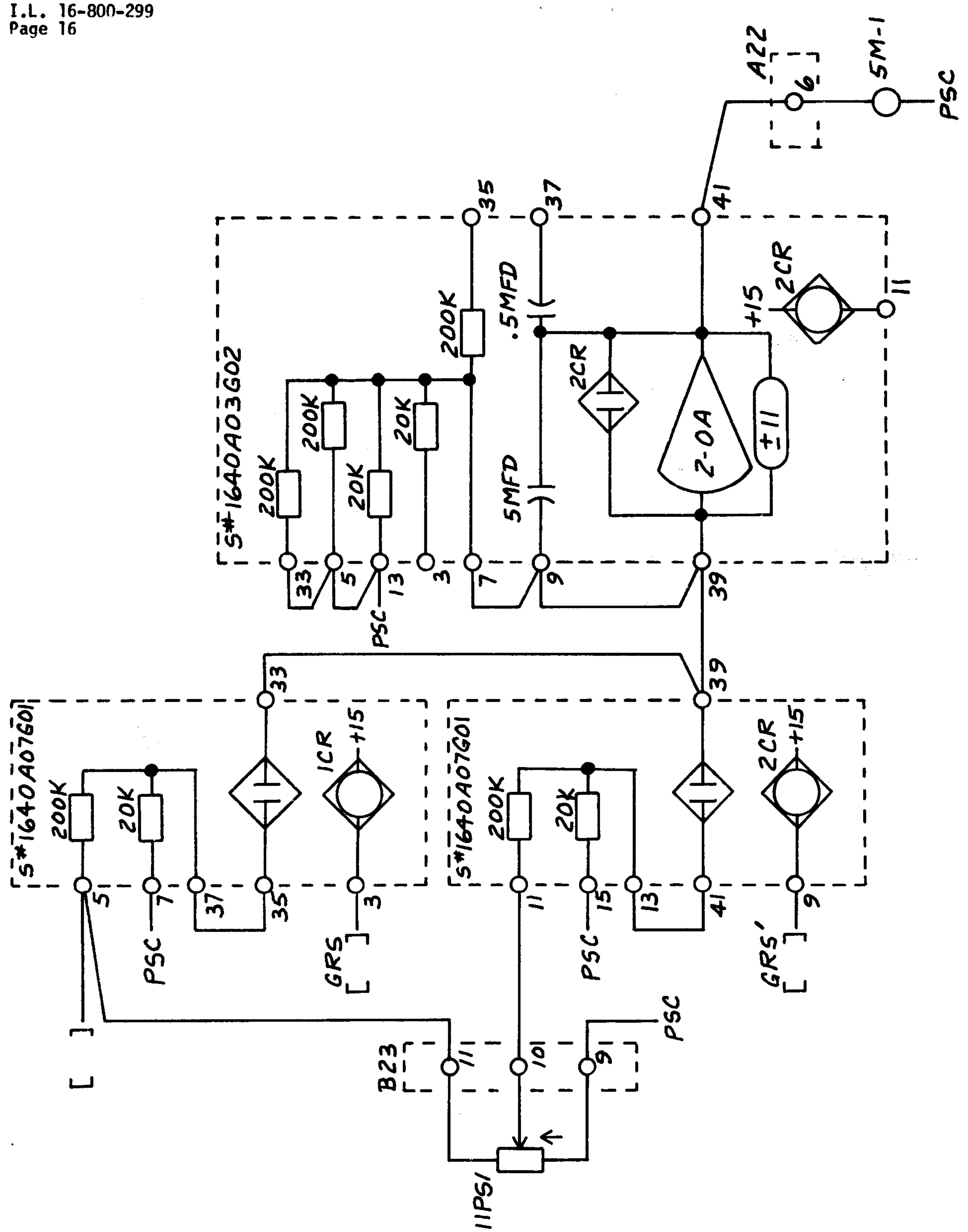


SUMMING AMPLIFIER

GAIN = -1

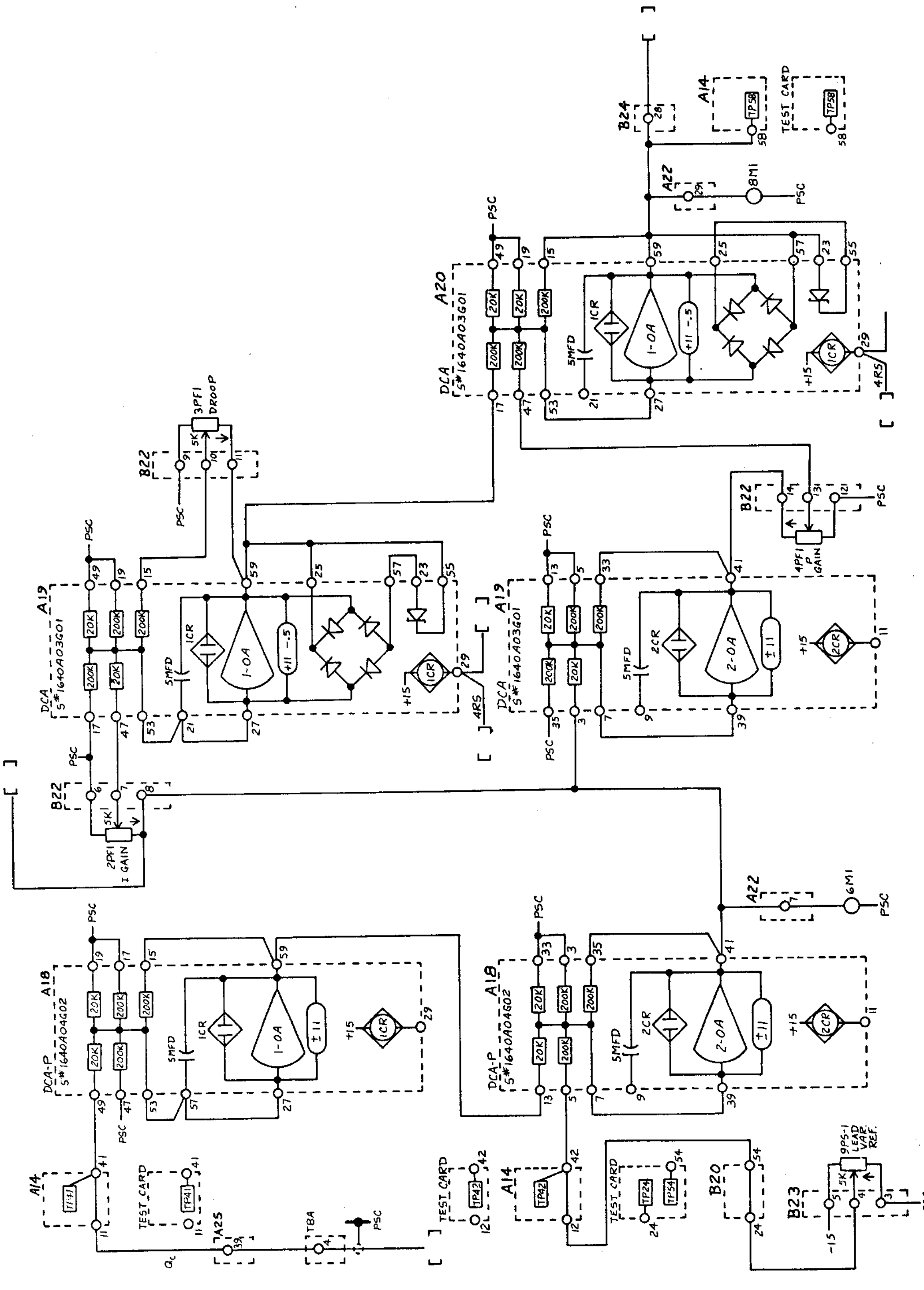
LIMIT = +0.5, -11

FIGURE 7



INTEGRATING AMPLIFIER

FIGURE 8



SCHEMATIC DIAGRAM

FIGURE 9

G. WIRING GUIDELINES

1. Summing Junction Wiring

The backplane wiring in a QB16 cabinet is used to interconnect summing junctions of linear circuit boards; and because of the associated low signal levels, some extra consideration should be given to the wiring and layout when hardware is used to implement a circuit. In addition, the backplane is used to route a multiplicity of logic signals. For these reasons the backplane is classified as a restricted access low noise area.

By interconnecting the summing junction of a linear amplifier on the backplane, greater flexibility is provided in the design of linear circuitry. The summing junction can be extended within limits to more than the basic board for hardware implementation.

Summing junction interconnections involve the following boards:

1. Quad Amplifier
2. Quad Amplifier - Precision
3. Dual Combination Amplifier
4. Dual Combination Amplifier - Precision
5. Passive Network
6. Quad Switch

Various combinations of these boards can be used to implement a function. In the layout of the boards, the prime consideration from a wiring standpoint is to minimize the length of wiring over which the summing junction is routed. Pin compatability between boards has been provided to facilitate this requirement.

The summing junction can be extended to more than two cards if required. The main rules to follow are that when extension takes place the cards should be in adjacent cage positions and the selection of component sets should be such as to minimize lengths of wire for the summing junction wherever possible.

2. PSC Wiring

On all card positions in the QB16 cage, a PSC bus is used to provide a ground return. This bus is connected to pins 1, 31, 30 and 60 of each edge connectors. In using the linear amplifier and the passive network cards, there are many instances in which multiple grounds are used. When these grounds are wired in whatever program used, each edge connector should have a separately identified PSC designation so that the multiple grounds associated with a particular position are wired to either the 1 or the 31 terminal of that respective position. In no circumstances should the grounds be interwired between the edge connector positions.

3. Power Supply Wiring

The various DC currents drawn by the boards in the two row cage should be checked to determine if current levels are compatible with the existing wiring procedures. Amp wiring on the backplane uses #24 wire; the ribbon cable assemblies use #22 wire. The corresponding current ratings are 2 amp and 3 amps. There may be cases where additional DC power supply wires might have to brought in to handle the requirements of special boards.

4. Test and Interconnect Wiring

If these two boards are used for system test and set-up, and if the Test card is to be inserted into an Interconnect card position, the connector must be appropriately wired. +24V must be wired to this position in order to generate the ±10V reference output voltages from the Test Card. In addition, the Test card has two adjustable voltage points designated ±V; but if potentiometers are not appropriately wired, these voltages will not exist. Two pots, single or multi-turn must be allocated to provide these adjustable voltages. The Test card is merely providing means to patch these voltages into the system.

H. PREFERRED CARD LOCATIONS

Input/Output cards should be mounted in the cages starting from position 01 of either Row 1B or Row 2B. Any input or output relay boards that interface with external equipment via the backplane wiring to the terminal blocks at the left rear of the cabinet should be mounted in position 20 of any of the rows. These lines should be of the low energy type (to drive a reed relay) and should go directly from the applicable boards to the terminal blocks via the edge connector-ribbon cable assembly.

I. AMPLIFIER BALANCING

The linear amplifiers in the QB16 series of cards are funtionalized only by appropriate backplane wiring: the input and feedback impedances must be wired to complete an operational circuit. On these appropriate boards, the summing junctions must be connected for desired functionalization from an ideal standpoint; however, as with all practical circuits, these amplifiers have associated errors, and in order to minimize these errors the resistance to PSC as seen by the inverting summing junction should be a specific value.

The noninverting terminal of the operational amplifiers has a fixed resistance to PSC of 8.74k ohms. Thus the resistance to PSC as seen by inverting input of the operational amplifier should be the same value in order to minimize output errors due to the amplifier offset parameters. A paralled combination of three 200k ohm and two 20k ohm resistances yields a resistance of 8.7k ohms. If this combination of resistances is used in the feedback and the inputs circuits, then best drift performance will be obtained. If additional resistors are required, then the appropriate resistors should be tied between the summing junction and PSC.

There may be cases where more resistors are used. The PN/1 card has more combination options; but whatever combination is used, generation of the best available resistance match will generally yield the lowest errors at the output.

J. AMPLIFIER SELECTION

There are precision and stnadard versions of the linear amplifier boards available in the QB series. There are also precision and standard resistance networks available. The designer must determine when a more precise version must be used.

The standard amplifier boards use the 741 operational amplifier as the gain block for the generation of linear circuits. If this amplifier is used with the standard resistance set which includes 3-200k resistors, a multiplicity of gain options is available by connecting these resistances into the circuit. Regardless of which gains are selected, the output error has to be checked to determine suitability.

For a DC amplifier circuit, the output error due to offset is:

$$V_O = \frac{R_f}{R_{eq}} \times V_{OS} + R_f \quad I_{OS}$$

Req: Resistance seen by summing junction.

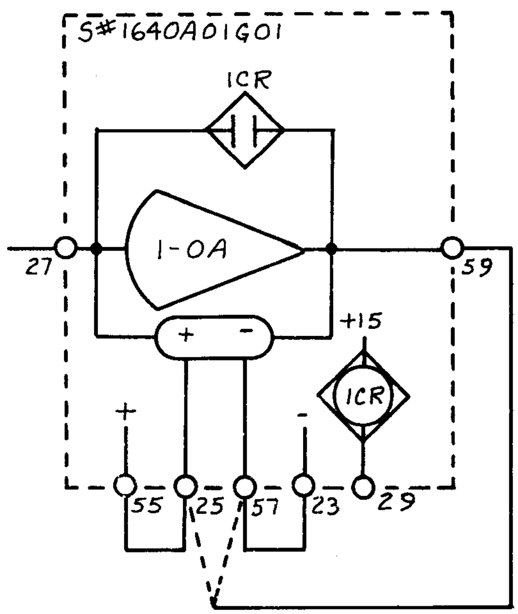
Both summing junctions see matched Req.

V_{OS}: Amplifier Offset Voltage

I_{OS}: Amplifier Offset Current

K. GENERAL INFORMATION - LINEAR

The uncommitted linear amplifiers in this series have an output capability of +11V at 5ma. Some of the amplifiers can be limited to 0.5V in either direction with the remaining limit being 11V. Those amplifiers with a limit option can be left without any limit, or they can have either a symmetrical or an unsymmetrical limit. To obtain a symmetrical limit for the circuitry of Figure 10, wire terminal 55 to terminal 25 and wire terminal 57 to terminal 23. To change to an unsymmetrical limiter add a wire between terminal 59 and terminal 25 (-0.5V, +11V limit) or add a wire between terminal 59 and terminal 57 (+0.5V, -11V limit). The wire from terminal 59 is in addition to the other wires mentioned.



LIMITER WIRING

FIGURE 10

The static switches associated with the linear circuitry boards can be used for resetting amplifiers, for switching signals into summing junctions for for switching points to PSC. The static switches are referenced to PSC which requires that one of the connection points of the switch contact be at a low voltage; i.e., a summing junction or PSC. The remaining terminal of the switch contact is limited to +12V. In the "on" condition, the switch contacts have a typical resistance of 50 ohms. In the "off" condition the switch contacts have a typical impedance of 10^{10} ohms. The static relays must be driven by high threshold logic (+15V). If the input to a static relay is open or a one, the contacts are open. If the input to a static relay is PSC or a zero, the contacts are closed. Logic signals operating static switches can be tied to PSC to activate a static relay. A static relay, when driven by a logic element, requires the logic element to sink 2.4ma of current. This represents a logic load of 2.4. The static relays are all of the form A type. Logic circuitry in conjunction with the static relays can be used to generate other equivalent forms.

On the Quad Comparator card, one of the 21.5k inputs (SF = 1) should be used in a circuit configuration or if not used at least one of the 21.5k inputs should be tied to PSC.

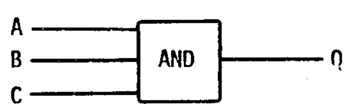
On the Dual Multiplier/Precision drawing S#1640A19 there is shown a method for improving the accuracy of the card. Without the balance pots the accuracy of the unit is 0.5% and if the balance pots (three required) are used the accuracy can be improved to 0.25%. It is recommended that this card be used without any trimming as the improvement is only minimal and exists only if the device is balanced properly.

L. GENERAL INFORMATION - DIGITAL

The general purpose logic board in this series is S#1640A11.

This is an English Logic module containing AND circuits, OR circuits and NOT circuits. The positive logic convention is used in defining the AND, OR and NOT circuits.

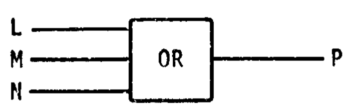
The AND element performs the logic AND function.



The output, Q will be 1 if A and B and C are 1's.

A	B	C	Q
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

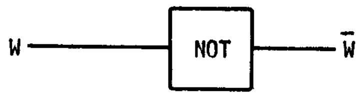
The OR element performs the logic OR function



The output, P, will be a 1 if L or M or N is a 1.

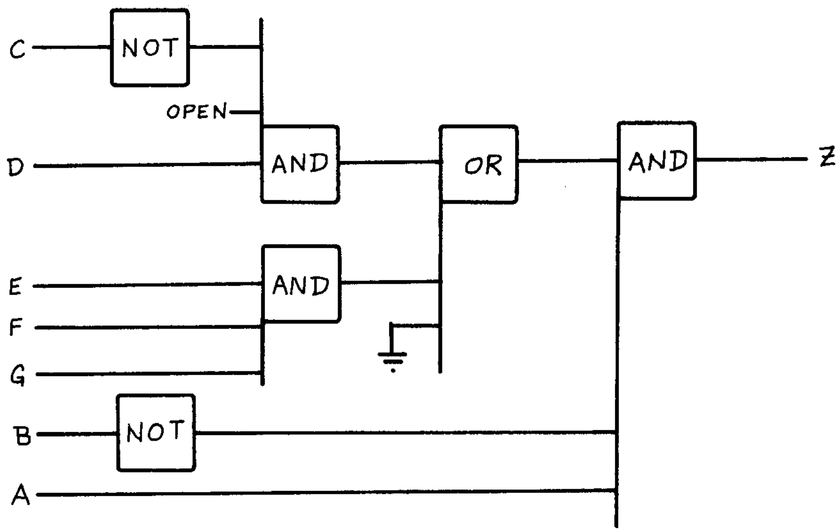
L	M	N	P
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

The NOT element performs the inversion function



W	$\bar{W}$
0	1
1	0

With these elements it is possible to build logic circuits directly from the Boolean expressions. For example, the expression $Z = A \cdot \bar{B} \cdot (\bar{C} \cdot D + E \cdot F \cdot G)$ could be expressed as:

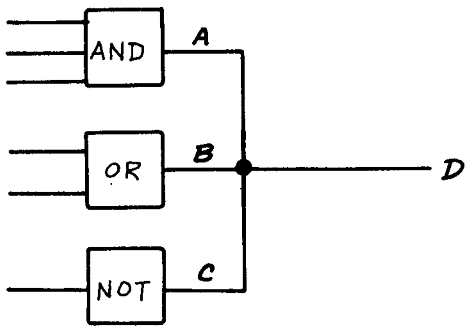


There are usually several ways of writing a Boolean expression and it is desirable to do some manipulating to find the logic expression that results in the minimum number of logic elements or the minimum number of input terminals.

For example the expression $X = AB\bar{C} + ABC + \bar{A}BC + A\bar{B}\bar{C}$ can also be written $X = BC + A\bar{C}$, which will result in a significant hardware savings.

Wired "And"

The outputs of these elements may be tied together to form the logic equivalent of an And output with inputs A, B, and C.



A	B	C	D
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

Each input terminal on this board represents a logic load of 1. Each output terminal can drive 10 logic loads.

Many of the digital boards are specialized functions and the user should check the appropriate drawings to obtain required information. For example, the output Triac card S#1640A41 specifies that each input signal to this card must be capable of driving ten logic loads which is the maximum output capacity of a logic element on the DEA card S#1640A11.

M. PRINTED CIRCUIT BOARDS - INDEX

		Nomenclature	Style No.
1.	Quad Amplifier	QA	1640A01G01
2.	Quad Amplifier-Precision	QA-P	1640A02G01
3.	Dual Combination Amplifier	DCA	1640A03G01
4.	Dual Combination Amplifier-Precision	DCA-P	
	0.1% Resistors		1640A04G01
	1% Resistors		1640A04G02
	Special		1640A04G07
5.	Dual Series Limiter	DSL	1640A05G01
6.	Passive Newtork	PN/1	
	1% Resistors		1640A06G01
	0.1% Resistors		1640A06G02
	Special		1640A06G07
7.	Quad Switch	QS	1640A07G01
8.	Quad Comparator	QC	1640A08G01
9.	English Logic	DEA	1640A11G01
10.	Reversible Binary Counter	RBC	1640A13G01
11.	Digital to Analog Converter	DAC	1640A14H01
12.	Phase Detector, Integrator and Wave Shaper	PDI	1640A15G01
13.	Test Board		1640A16G01
14.	Voltage Controlled Oscillator	VCO	
	0 to 6000 Hz		1640A17G01
	0 to 15000 Hz		1640A17G02
15.	Sine Wave Function Generator	SFG	1640A18G01
16.	Dual Multiplier-Precision	DM-P	1640A19G02
17.	Light Emitting Diodes	LED	1640A20G01
18.	Reference Regulator	RR	1640A21G01
19.	Interconnect Board		1640A22G01
20.	Peak Voltage Detector	PVD	1640A23G01

21. Harmonic Filter	HF/45	1640A24G01
22. Function Generator		1640A25G01
23. Input Board (Static)		1640A40G03
24. Output Board (Static)		1640A41G02
25. Output Relay Board		1640A44G02
26. Long Period Timer		
With Counter		1640A45G03
Without Counter		1640A45G04
27. Uncommitted Passive Network Board		1678A31G01
28. Transmitter		1640A35
29. Receiver		1640A36

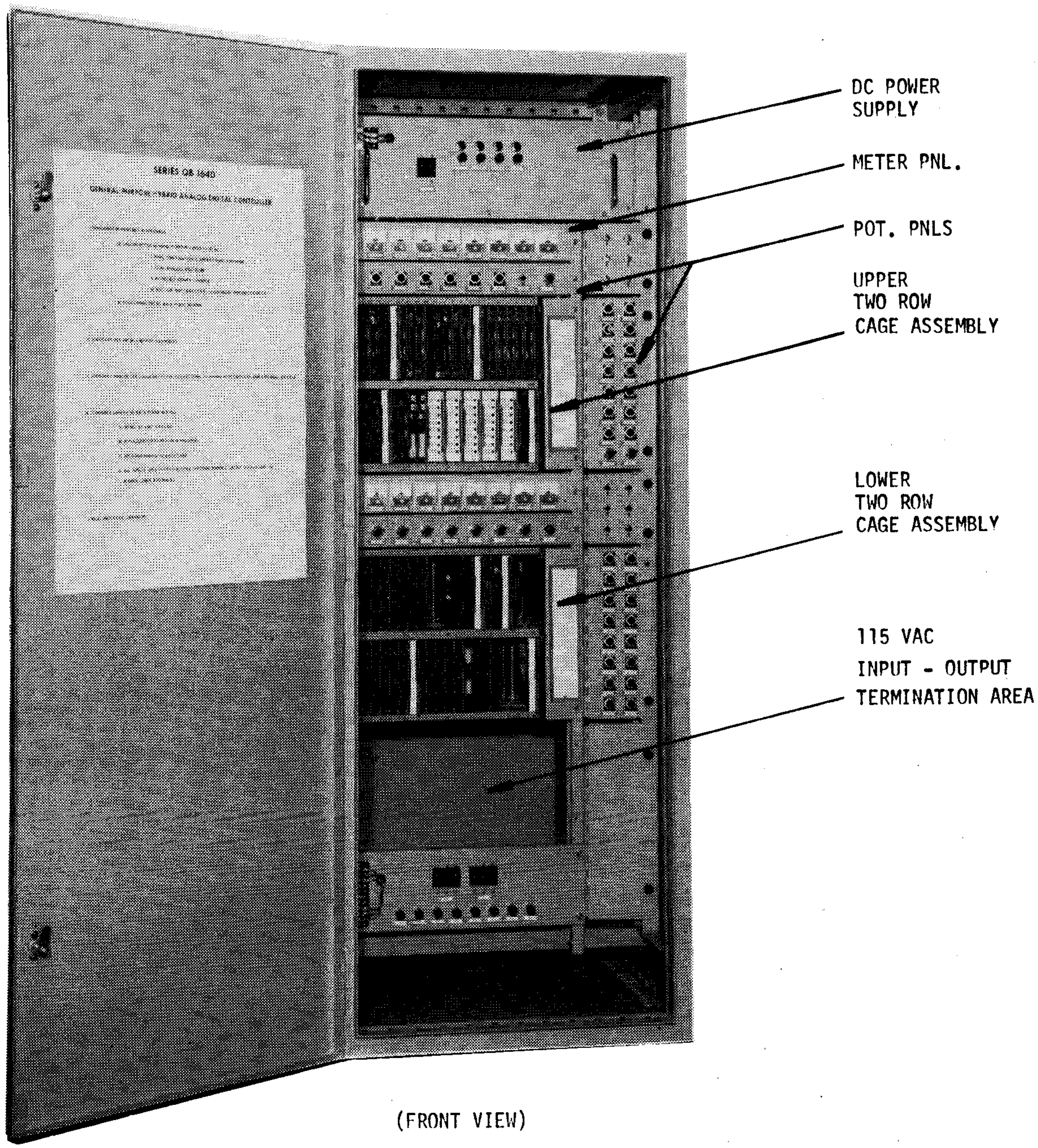
N. PRINTED CIRCUIT BOARDS MAXIMUM DC POWER REQUIREMENTS

STYLE NUMBER	Current Required in ma for DC Supply Voltages					
	+24V	-24V	LP15	LED5	+15	-15
1640A01	48.1	57.1				
1640A02	48.1	57.8				
1640A03	24	28.9				
1640A04	24	28.9				
1640A05	44	44				
1640A06						
1640A07	5	14.4				
1640A08	74.2	51.9				
1640A11			100			
1640A13			260			
1640A14	70	30	100	200		
1640A15	40	40				
1640A16	15	15				
1640A17	40	40	95			
1640A18	20	20			5	5
1640A19	35	35				
1640A20				100	250	
1640A21	100	100				
1640A22	0	0				
1640A23	30	50				
1640A24	40	40				
1640A25	25	25				
1640A40			55			
1640A41			48			
1640A44			311			
1640A45			55			
1640A35					150	420
1640A36					100	

In a QB16 cage assembly, the power requirements should be tabulated to insure that the wire capacity is not exceeded. The backplane wiring is #24 and is rated at 2 amps. The ribbon cable is #22 and is rated at 3 amps. If the totalized currents exceed the wiring capacity, then additional wires on the ribbon cables will have to be used; and correspondingly different wire names will have to be used to feed from the additional input power points to the separated cards being fed from these points.

MODEL QB 16

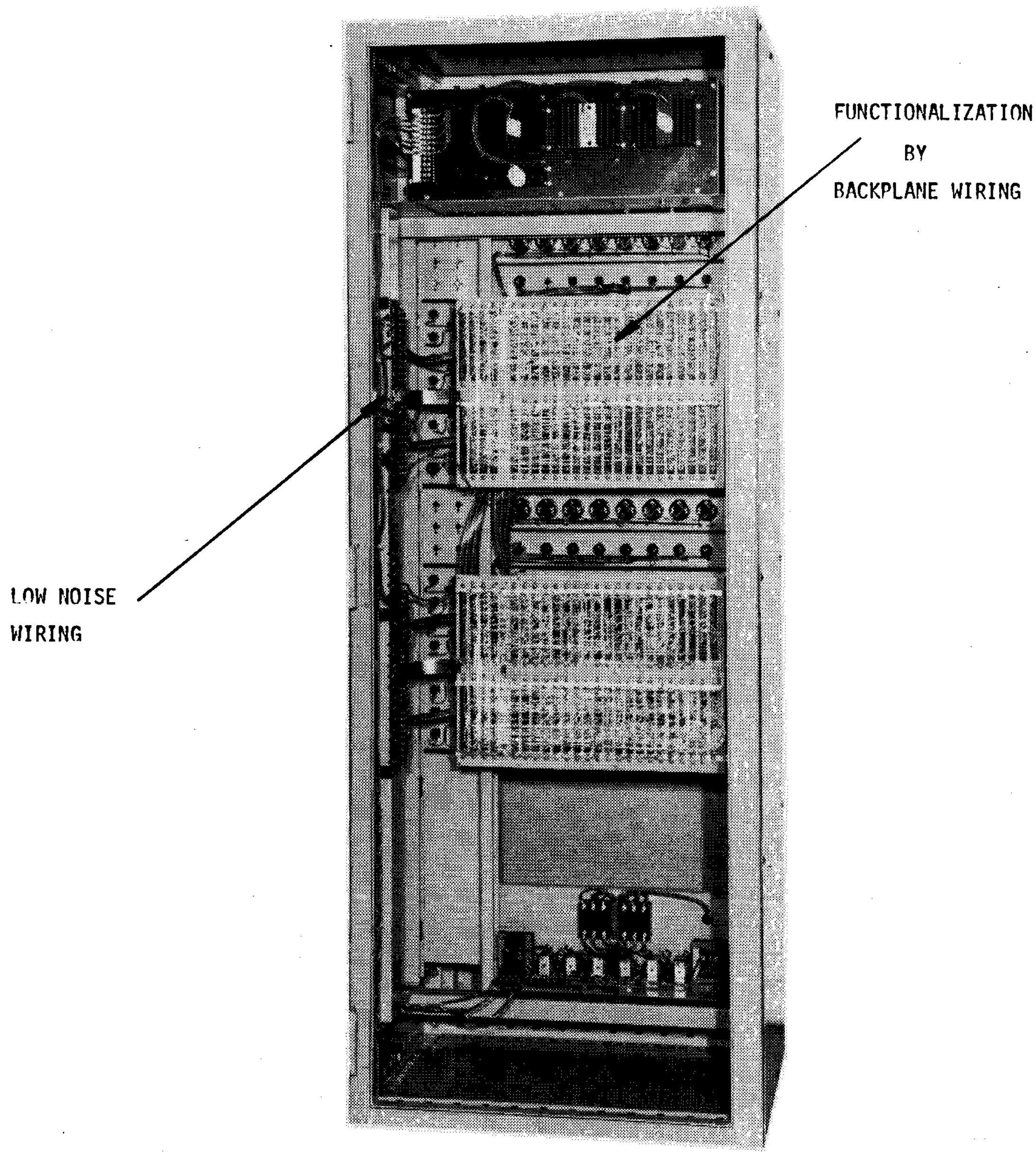
ANALOG-DIGITAL HYBRID CONTROLLER



(FRONT VIEW)

QB 16 HYBRID CONTROLLER

EFFECTIVE MAY, 1976 SUPERSEDES I.L. 16-800-299A



(REAR VIEW)

OB HYBRID CONTROLLER

INDEX

A. GENERAL DESCRIPTION

QB-16 is a hard wired hybrid controller which utilizes a standard line of uncommitted printed circuit cards. QB-16 uses 15 volt HTL digital logic for sequence and switching functions. It can accommodate a limited amount of 115 VAC optically coupled inputs and triac outputs for 115 VAC input - output control functions.

Its major application is on large systems director functions which are normally not duplicated on similar applications. Typical applications are the automatic gauge controls for multi-stand hot and cold rolling mills or the master director for a group of coordinated drives such as the stand drives of a tandem cold rolling mill.

The major hardware components making up a QB-16 Controller are:

MODEL A (PHOTO)	MODEL B
1. Nema 1 enclosed structure.	1. Nema 1 enclosed structure.
2. DC power supply	2. DC power supply.
3. Incoming AC circuit breaker.	3. Incoming AC circuit breaker.
4. Cabinet fans.	4. Cabinet fans.
5. Fuse protection for 115 VAC inputs.	5. Fuse protection for 115 VAC inputs.
6. Two 40 card position cages.	6. One 135 card position cage.
7. 5 Row connector panel for common wiring of both cages.	7. 5 Row connector panel.
8. Two fixed pot panels (8 - 5K pots ea.).	8. Pot PC cards (6 - 5K pots ea.)
9. Two fixed meter panels (8 meters ea. 15-0-15V).	9. Meter PC cards (3 meters).
10. Two small swinging pot panels (6 - 5K pots ea.).	10. Meter PC cards (2 meters, 2 - 10 Pos. Sw's.).
11. Two large swinging pot panels (1 to 16 pots. ea. - any value).	11. Pot PC cards (6 pots - any value).
12. Thru conn wiring channel with provisions for terminating transmitter and receiver boards for inter cabinet wiring.	12. Thru conn wiring channel with provisions for terminating transmitter and receiver boards for inter cabinet wiring.
13. Outrigger connections from back panel to customer low noise analog term blocks.	13. Outrigger connections from back panel to customer low noise analog term blocks.
14. Termination panels for 115V input - output connections (40 input - output boards max.)	14. Termination uprights for 115V input-output connections (26 input-output boards) and a terminations panel for 12 additional I/O boards if required.
15. Term blocks in rear of cabinet for 180 low noise signal lines. PSC Bus is provided next to these blocks for grounding incoming shields.	15. Term blocks in rear of cabinet for 216 low noise signal lines. PSC Bus is provided next to these blocks for grounding incoming shields.

External signals involve high and low noise signal levels. Inputs for sequencing purposes and outputs for control functions can be 115 VAC and are separated from low noise analog signals associated with the regulating functions. When logic signals are transmitted and received between QB-16 and other digital logic control (QB-11) transmitter and receiver PC cards are used to condition the signals and provide noise immunity over the transmission line.

B. PC CARD CAGE ASSEMBLY

The basic cage design for QB16 is such that all circuits plug into the backplane and therefore all variable wiring takes place on the backplane. The basic cards designed for QB16 were specifically generated without functionalization. The philosophy of the QB16 approach is that job functionalization is accomplished by means of backplane wiring. In this fashion, the different types of boards required should be kept to a minimum with a corresponding greater usage of the basic boards.

Of particular importance in the QB16 approach is the design flexibility provided by the backplane. Because functionalization is accomplished on the backplane, design changes can also be implemented by associated changes in the wiring. Taken to an extreme, major design changes can be made on a job utilizing the existing cards merely by the generation of the appropriate backplane and wiring.

If noisy signals are required in the cage, which may be the case for sequence control, then they should be brought in via logic input cards to which the connections are made by means of a front edge connector. 115V AC from a contact, pushbutton, etc., can be brought in to generate a logic signal in the cage. In a similar fashion, an output board which is also mated to a front edge connector can interface from logic signals to 115V AC for external sequence control.

Any signals brought into the cage via the terminal block cable in the rear of the cabinet should be in the low noise classification to maintain a noise free backplane.

C. HARDWARE LIMITATIONS

Assoicated with each QB16 cabinet is a finite amount of hardware. It is the responsibility of the designer to be aware of these limitations because it effects the manner in which the hardware is allocated. The list of major hardware components is included in the general description portion of this I.L.

Model A (Photo)

The meters are pre-wired with a common PSC line and 8 wires from the associated meters to fixed terminals on a pre-selected edge connector. The potentiometers are also pre-wired to selected terminals on pre-selected edge connectors with three wires brought to the backplane for each potentiometer. All of these items are associated with the appropriate cage in that they can be interconnected on the backplane by machine wiring.

Model B

Metering is available either as 3 individual meters with a common PSC line on a plug in PC board or as 2 meters each with a 10 pos selector switch on a plug in PC board

Potentiometers are available with 6 pots to a plug in PC board either as 6, 5K potentiometers or as 6 or less selectable ohmage potentiometers.

The front portion of the cabinet is an area that is allocated for high noise input/output lines. In this area there is space allocated for terminal blocks that are prewired to edge connectors for front mating to input/output boards. Each terminal block and its associated wiring cable connects to only one edge connector. The incoming and outgoing signals on these lines are high noise 115V AC signals from pushbutton, contactors, switches, wtc., or to relays, solenoids, lamps, etc. The prewired cable assemblies are routed through wire channels to the appropriate cages.

Analog inputs are brought into the cages through cables which are connected to terminal blocks mounted on a vertical strut on the rear of the right side (viewed from the front). These terminals blocks are accessible only from the rear of the cabinet. The cables are prewired and plug into predesignated positions in the cage. A PSC Bus is located on the customer side of the terminal blocks. The shields from incoming low noise wiring should be connected at this Bus.

Hardware limitations necessitate the proper allocation of equipment in order to prevent problems from arising when a job is implemented. The design engineer must be aware of these limitations because it requires consideration in the generation of schematics for a job.

D. HARDWARE STRUCTURE

QB16 is hybrid system and as such it will contain a mixture of analog and digital functions. Analog functions can be created which are identical to those existing on committed controller card designs, although it generally takes more hardware with the QB16 approach because of the versatility designed into the system. In a similar fashion, digital functions can be created from the basic digital building blocks to provide whatever type of decision making is required. The linear circuit boards contain static switches which can be used for either amplifier resetting or for the selection of signals into summing junctions. These static switches are operated directly by the signals from the logic circuitry.

The basic linear controller boards in this system do not have any defined characteristics by themselves; that is, they are not summing amplifiers nor integrating amplifiers. A functional circuit is generated only when a linear amplifier board is inserted into an edge connector which is wired to provide input and feedback impedances for a high gain operational amplifier. The combination of the board(s) and the backplane wiring generates the functional circuit. Linear circuit flexibility is provided by interconnecting the summing junctions of operational amplifiers to appropriate impedance networks. In so doing, the backplane must be treated in a fashion different from that of a standard variable or fixed regulator backplane.

The basic digital card contains a set of building blocks which when wired on a backplane creates the required digital functions. Various problems associated with the digital functions should be considered in the design. For example, if a memory circuit is created with the digital blocks, then the status of the device after power turn on should be considered. If required, a reset or a clear function for power turn on will have to be provided.

The key to proper operation of QB16 is the controlled environmnet aspect of the structure which is necessary because of the type and level of signals appearing on the backplane. The following signals exist on the backplane: summing junction, logic signals (HTL), linear output and low noise linear inputs. The most critical are the summing junctions and the logic signals and as a result the backplande of QB16 regulator cage is classified as a restricted access, low noise area.

In the digital and analog card repetoire, there are some standard cards which are completely functionalized. These functions are comparators, multiplier/dividers, DACs, etc. In addition, there are some specialized cards which were designed for special purposes. To facilitate setup and test procedures, test and interconnect cards are used.

E. DESIGNING WITH QB16

1. The Starting Point

The basic starting point in designing with QB16 is the implementation of the system into a block diagram format using a standard set of symbols in a fashion analogous to what might be done using an analog computer. The basic boards in this series are used to create single-functioned building blocks, the composite arrangement and interconnection of which generates the desired hardware for a specific function. Some of the basic building blocks in this series are summing amplifiers, integrating amplifiers, comparators, electronic switches, function generators, multiplier/dividers, potentiometers, english logic and input/output interface functions. At times there may be requirements for more specialized functions indigenous to a particular operation or mode of control, but the versatility of the basic building blocks in this system should help reduce the need for these specialized functions.

Once the system has been put into a format using the standard symbols, implementation into hardware can begin assuming that the hardware restrictions have been followed in the block format. For linear circuits, the restrictions involve gains, time constants, etc. For example, in working with a summing amplifier gains of 1 and 10 are easily obtained but not in an unrestricted fashion. On a DCA card there are 3-200k resistors and 2-20k resistors which can be used for inputs and/or feedback resistors. A limitation exists then in using this amplifier as a summer. Similar limitations exist for the other linear boards and the user should be familiar with these limitations before generating the block diagram. Generally, non-standard gains and time constants are set with potentiometers.

The system block diagram can be used to closely approximate the type and quantity of boards, potentiometers and meters required in the system. In addition, aids in troubleshooting and set-up can be designed into the system using the appropriate QB16 cards.

2. Standard Symbols

Figure 1 is a list of some of the symbols which can be used in creating a block diagram.

3. Block Diagram Example

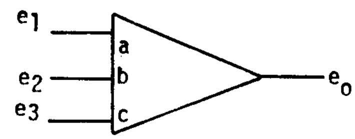
Figure 2 is a block diagram of the linear circuitry of a tension control function. Standard symbols have been used wherever possible.

In Figure 2 separate functional sub-blocks of linear circuits have been grouped together because of their functional relationship and have been enclosed within dashed lines for explanatory purposes only. Implementation into hardware requires the addition of gain and time constant values; and when this has been added, specific boards can be selected and interwired via backplane wiring to create the desired functions.

In referring to sub-block of a schematic, it is implied that a collected set of linear building blocks performs a specific function on a specific signal or signals. For example, in order to create a resettable PI controller two summers, one integrator and two potentiometers are required. The circuit for this is shown in Figure 3 and is functionally complete.

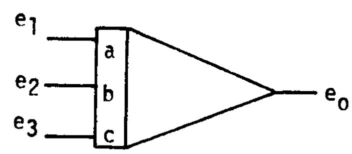
a) Summing Amplifier

$$e_o = -(ae_1 + be_2 + ce_3)$$



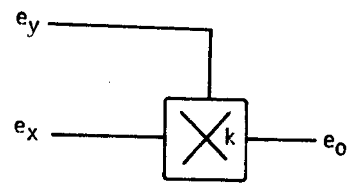
b) Integrating Amplifier

$$e_o = -\left[\frac{1}{a}\int e_1\,dt + \frac{1}{b}\int e_2\,dt + \frac{1}{c}\int e_3\,dt\right]$$



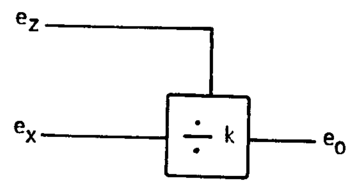
c) Multiplier

$$e_o = Ke_x e_y$$



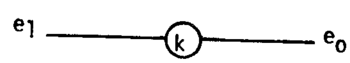
d) Divider

$$e_o = k\,\frac{e_z}{e_x}$$



e) Potentiometer

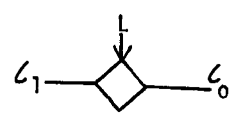
$$e_o = ke_1 \quad 0 \leq k \leq 1$$



f) Electronis Switch

$\ell_o = 0$ when L is a "1"

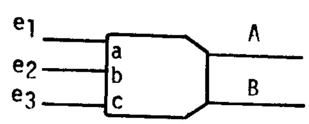
$\ell_o = \ell_1$ when L is a "0"



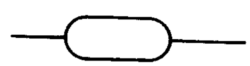
g) Comparator

A = "0" B = "1" if $ae_1 + be_2 + ce_3 > 0$

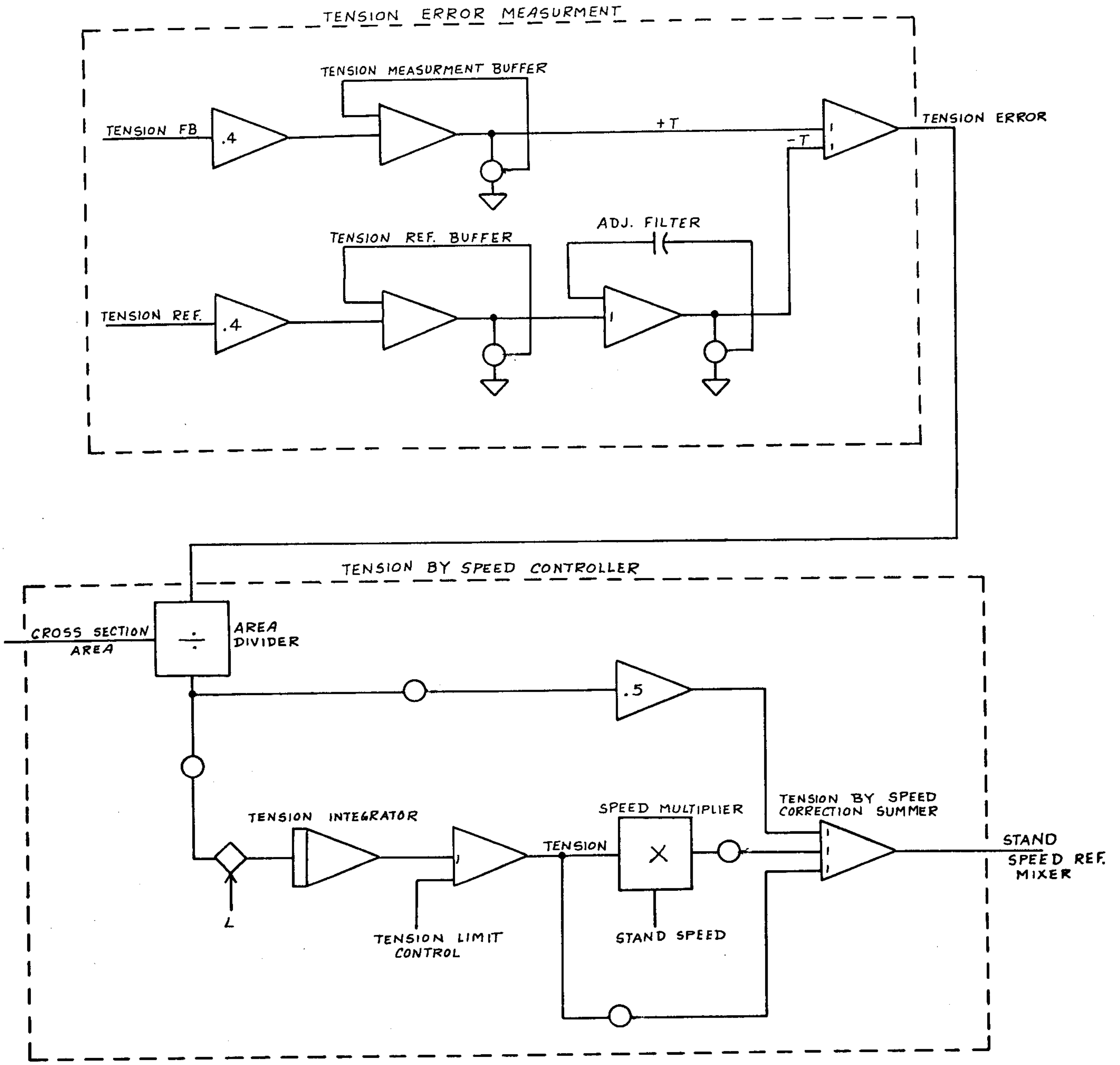
A = "1" B = "0" if $ae_1 + be_2 + ce_3 < 0$



h) Amplifier Limiter

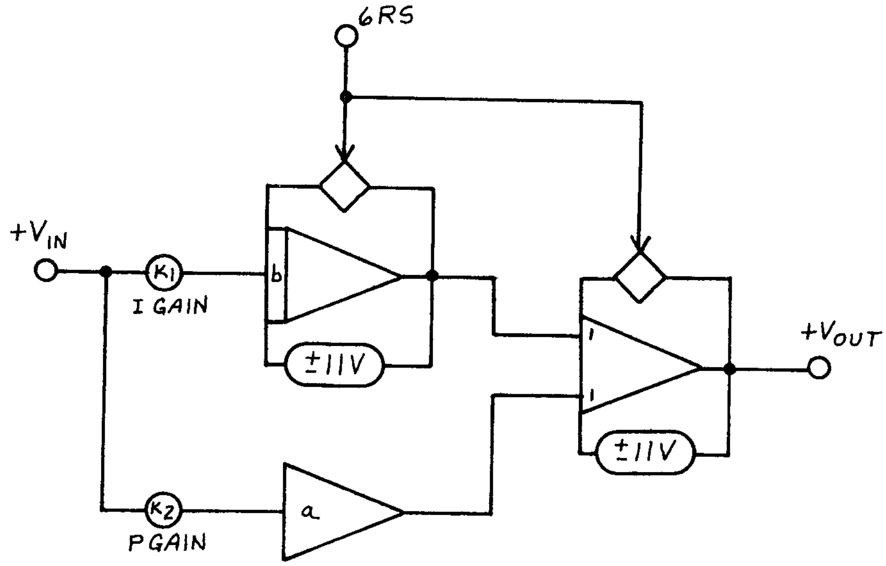


STANDARD ANALOG SYMBOLS
FIGURE 1



FUNCTIONAL BLOCK DIAGRAM

FIGURE 2



$$V_{OUT} = \left(\frac{K_1}{bS} + K_2 a\right) V_{IN}$$

PI CONTROLLER

FIGURE 3

Figure 3 has one input, one output, separate adjustments for the P and I gains and a combined reset for the integrator and the output amplifiers. The output signal, $+V_{out}$, is proportional to and the integral of the input signal. A clearly defined operation has been performed on the input signal. When implementing this circuit into actual hardware it is recommended that, when possible, the various boards used to create the circuitry be in close proximity.

4. Adjustments

In viewing the regulator schematic of Figure 2, several questions can be raised. How are all the adjustable system gains, time constants and limits to be set during installation and/or testing? Is it possible to easily troubleshoot the system in the event of a failure? These questions led to the inclusion in the QB16 series of boards an Interconnect Board and a Test Board. These two boards can be used in a system to simplify both setup and troubleshooting procedures. Their design into a system is relatively simple.

5. Interconnect and Test Boards

The Interconnect Board is used when the system is functional. Its purpose is to route input and output signals between functional sub-blocks by merely providing wire continuity via the copper on the board between pins on opposite sides of the board and to provide monitor points during normal operation for any of the signals being routed by this card. Terminals on the 1 through 30 side have been designated as input terminals; terminals on the 31 through 60 side have been designated as output terminals. Physically opposite terminals are routed through this board; i.e., 3 to 33, 4 to 34, etc. Not all of the terminals on the interconnect board are used for through interconnections. The user should familiarize himself with the Interconnect and Test Board prior to their use.

The test board is generally used to interrupt the signal flow and to allow injection of a test signal (voltage) and to monitor the output of a functional sub-block.

Figure 4 is a simplified schematic showing the external connections of both cards. These boards can be used in either of two ways. First, the interconnect board can be a dead-ended monitor point. Various signals can be routed to this board for monitoring purposes only. It is essentially providing access to selected points on the backplane without having to go around to the back of the cabinet. In addition, if there are unused inputs feeding a linear amplifier, it may be possible to inject a test signal at selected points. If used in this fashion, the associated test points will have to be shown on the schematic so that wiring is routed to these points.

A second way of using these boards is to design the interconnect board into the signal flow path so that when the interconnect board is removed and the test board is inserted, signals can be injected into the normal signal flow path and various points can be monitored.

For example, Figure 3 shows a PI controller with one input, one output and one logic signal. If this sub-block is connected as shown in Figure 5, this sub-block and the associated wiring can be checked. The sub-block is shown connected in the normal mode. Monitor points exist to check all signals associated with this circuit when the circuit is functioning in the normal fashion. If the Interconnect Board is removed and the Test Board inserted in its place, the circuitry would change to that shown in Figure 6. With this arrangement, a test signal can be injected at TP50 (position 5A) and the output can be monitored at TP21 (position 5A). By control of the logic signal (shorting TP26 position 5A to PSC) the operation of the sub-block can be checked. This method can be used for set-up, calibration checks or for troubleshooting.

The question of whether or not this method can be used depends upon the system and if it can be sub-divided into sub-blocks and if the design engineer feels it is required. This is an added feature of the QB16 approach.

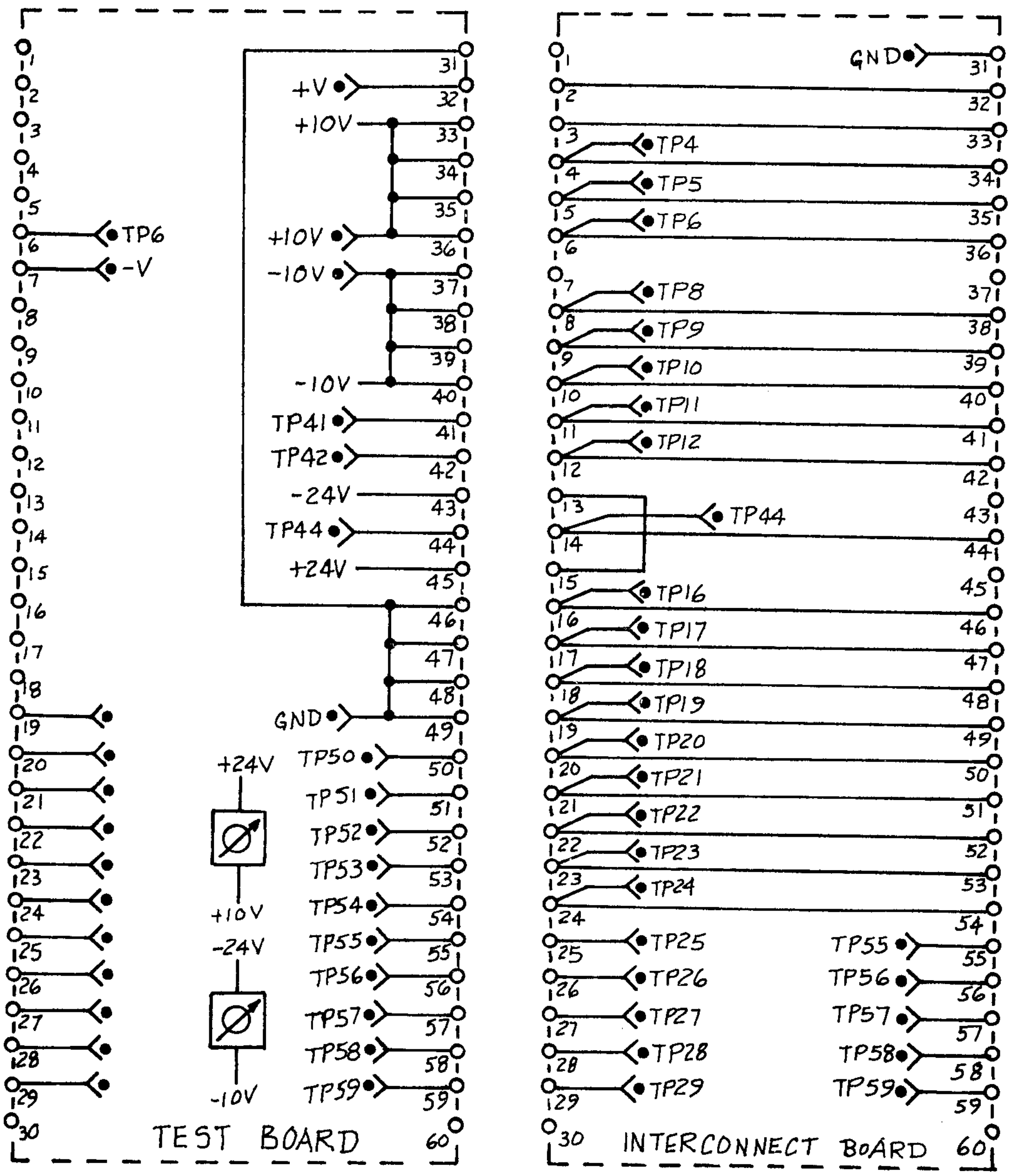
There are some additional points to consider in using these two cards. First, the Test Card does not show up in the normal schematic. If you want to use it be sure it is ordered somewhere. Second, the Interconnect Card can be interlocked to prevent normal operation if it is not in its proper place. Terminals 13 and 15 in conjunction with appropriate logic design can be used for this interlocking feature. Since there is not a one to one terminal correspondence between the two boards, they should be checked to insure that what is required is available. Although terminals 10 and 40 are throught connections on the interconnect board, no access is available on terminal 10 of the test board and terminal 40 of the test board is prewired internally to -10V.

6. Hardware Allocation & Selection

The linear regulator schematic and the associated logic drawings should be looked at from the standpoint of hardware selection and hardware positioning.

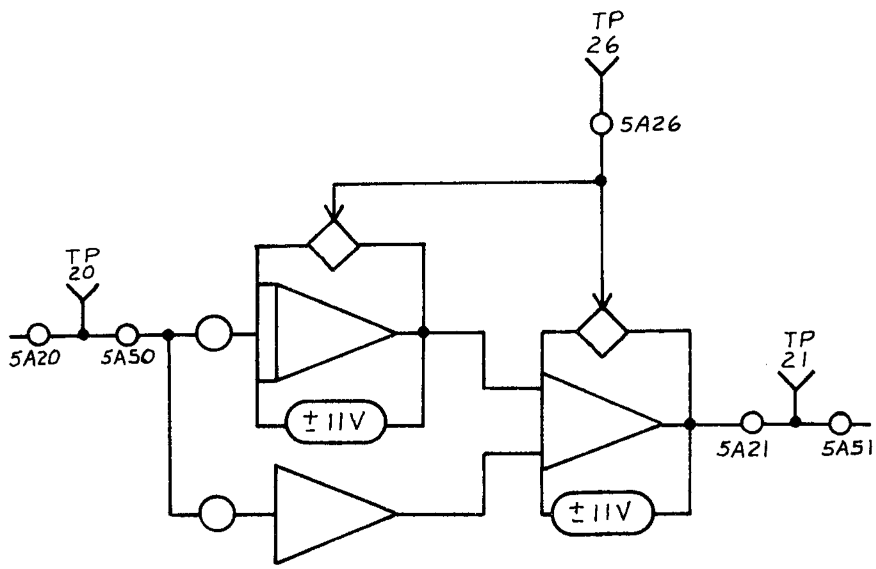
As the logic drawings are worked up it is fairly easy to keep track of the number and types of cards used as the circuitry is implemented. As a general rule it is preferrable to keep the logic circuitry together but this may not always be possible. The number of available signal lines between two cages may necessitate some type of a break in the logic card positioning.

TEST & INTERCONNECT BOARD



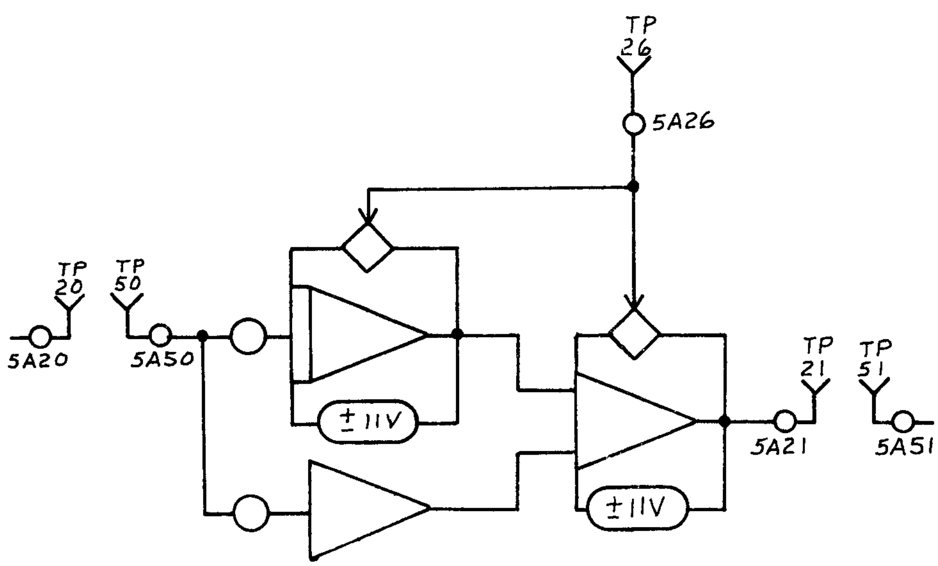
TEST BOARD AND INTERCONNECT BOARD EXTERNAL CONNECTIONS

FIGURE 4



TESTING A SUB-BLOCK

FIGURE 5



TEST BOARD INSERTION

FIGURE 6

In viewing the linear regulator schematic, the number of pots and meters can be determined and compared against what is available in the two row cage. If an excessive quantity of pots is required, some of the linear circuitry may have to be shifted to the second two row cage. If the linear circuitry is sub-divided as in Figure 2, it is relatively easy to determine what can be gained by shifting a particular sub-block to the second cage.

In determining the number of linear boards, a count of two amplifiers per board will yield the number of amplifier boards required; but this count may be altered by the selection of amplifier type. The linear amplifier boards come in two versions: a standard and a precision version. The design engineer should determine where a precision amplifier is required and so indicate this particular requirement on the schematic.

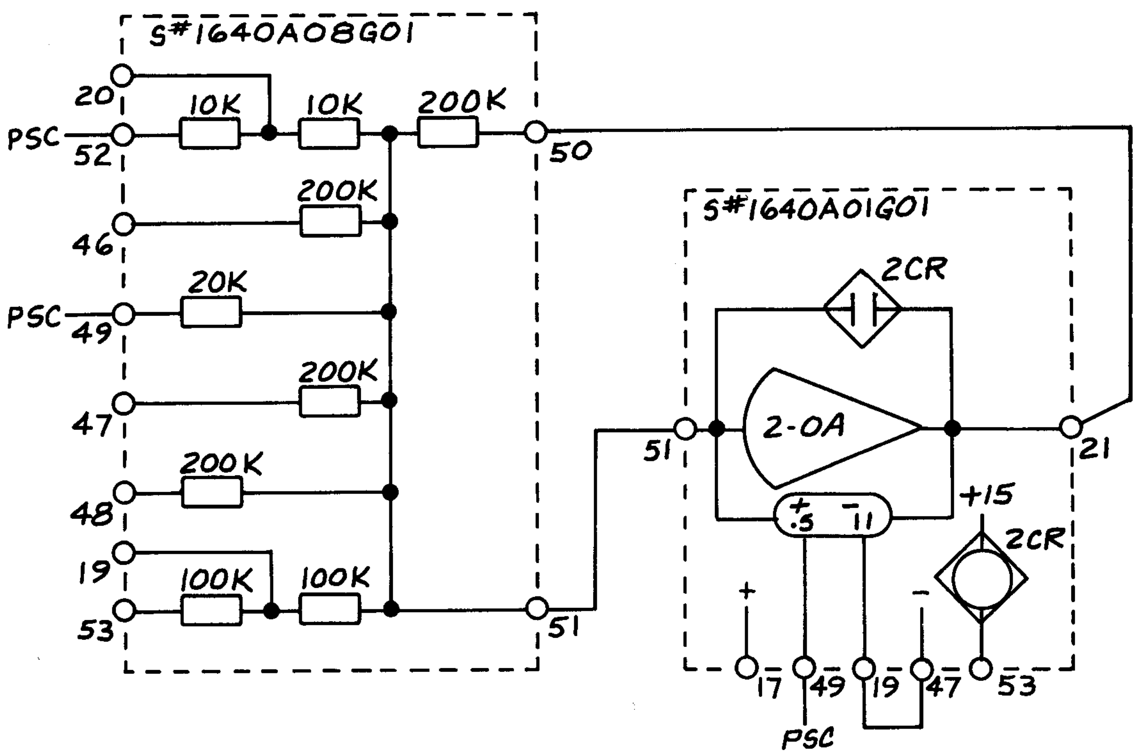
There are a substantial number of fine points that will enter the picture in going from the linear block diagram to schematics detailing the specific circuits. Standard versus precision amplifiers is one of them. Reference voltage is another. There may be requirements for a more precise reference than what is obtainable with the +24 supply, and a decision may necessitate using the Reference Regulator card which provides a highly stable +15V for this purpose. The position and utilization of the Test and Interconnect cards, if it is desired to use them, should be considered. All of these points become a factor in the hardware implementation phase.

F. HARDWARE SCHEMATICS

The linear block diagram(s) of a system have to be translated into actual hardware so that the system can be put together. This necessitates selecting appropriate amplifiers and impedance networks, putting them together on a schematic sheet and connecting them to perform a specific function.

Figures 7 and 8 are representative schematics utilizing two types of boards. These two figures are indicative of the manner in which the schematics can be put together. There is a certain amount of information that needs to be known prior to this work: the relative position of associated boards in a cage, the usage of the appropriate subsections of the linear cards, summing junction impedances, etc.

A substantial amount of detail is required on the schematics. Figure 9 is a schematic from a job utilizing QB16. The various sub-sections of the boards are drawn differently but the detail required on the schematics is shown. Note the detail involved in wiring of the potentiometers, meters and the Test and Interconnect cards.

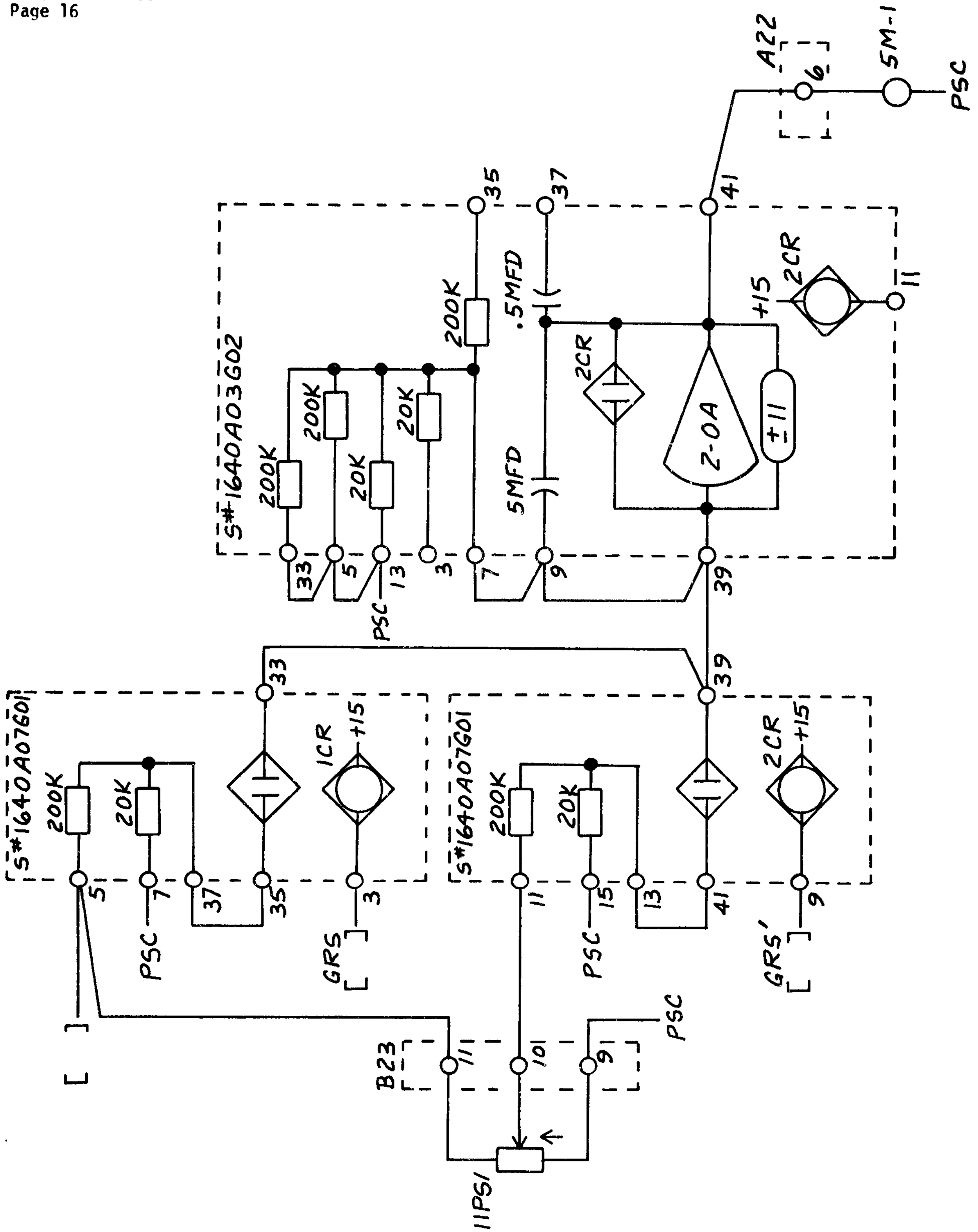


SUMMING AMPLIFIER

GAIN = -1

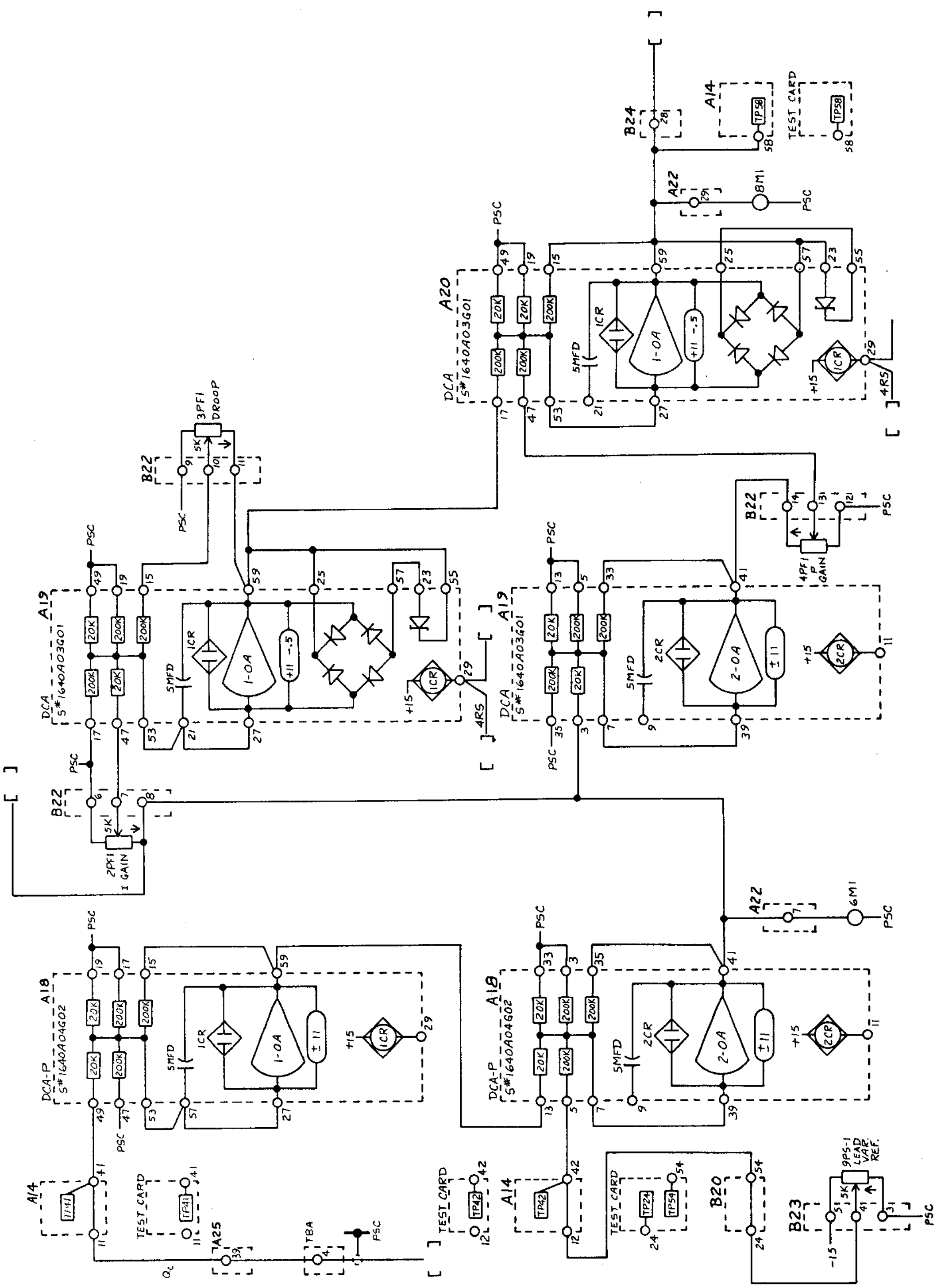
LIMIT = +0.5, -11

FIGURE 7



INTEGRATING AMPLIFIER

FIGURE 8



SCHEMATIC DIAGRAM

FIGURE 9

G. WIRING GUIDELINES

1. Summing Junction Wiring

The backplane wiring in a QB16 cabinet is used to interconnect summing junctions of linear circuit boards; and because of the associated low signal levels, some extra consideration should be given to the wiring and layout when hardware is used to implement a circuit. In addition, the backplane is used to route a multiplicity of logic signals. For these reasons the backplane is classified as a restricted access low noise area.

By interconnecting the summing junction of a linear amplifier on the backplane, greater flexibility is provided in the design of linear circuitry. The summing junction can be extended within limits to more than the basic board for hardware implementation.

Summing junction interconnections involve the following boards:

1. Quad Amplifier
2. Quad Amplifier - Precision
3. Dual Combination Amplifier
4. Dual Combination Amplifier - Precision
5. Passive Network
6. Quad Switch

Various combinations of these boards can be used to implement a function. In the layout of the boards, the prime consideration from a wiring standpoint is to minimize the length of wiring over which the summing junction is routed. Pin compatability between boards has been provided to facilitate this requirement.

The summing junction can be extended to more than two cards if required. The main rules to follow are that when extension takes place the cards should be in adjacent cage positions and the selection of component sets should be such as to minimize lengths of wire for the summing junction wherever possible.

2. PSC Wiring

On all card positions in the QB16 cage, a PSC bus is used to provide a ground return. This bus is connected to pins 1, 31, 30 and 60 of each edge connectors. In using the linear amplifier and the passive network cards, there are many instances in which multiple grounds are used. When these grounds are wired in whatever program used, each edge connector should have a separately identified PSC designation so that the multiple grounds associated with a particular position are wired to either the 1 or the 31 terminal of that respective position. In no circumstances should the grounds be interwired between the edge connector positions.

3. Power Supply Wiring

The various DC currents drawn by the boards in the two row cage should be checked to determine if current levels are compatible with the existing wiring procedures. Amp wiring on the backplane uses #24 wire; the ribbon cable assemblies use #22 wire. The corresponding current ratings are 2 amp and 3 amps. There may be cases where additional DC power supply wires might have to brought in to handle the requirements of special boards.

4. Test and Interconnect Wiring

If these two boards are used for system test and set-up, and if the Test card is to be inserted into an Interconnect card position, the connector must be appropriately wired. +24V must be wired to this position in order to generate the ±10V reference output voltages from the Test Card. In addition, the Test card has two adjustable voltage points designated ±V; but if potentiometers are not appropriately wired, these voltages will not exist. Two pots, single or multi-turn must be allocated to provide these adjustable voltages. The Test card is merely providing means to patch these voltages into the system.

H. PREFERRED CARD LOCATIONS

Input/Output cards should be mounted in the cages starting from position 01 of either Row 1B or Row 2B. Any input or output relay boards that interface with external equipment via the backplane wiring to the terminal blocks at the left rear of the cabinet should be mounted in position 20 of any of the rows. These lines should be of the low energy type (to drive a reed relay) and should go directly from the applicable boards to the terminal blocks via the edge connector-ribbon cable assembly.

I. AMPLIFIER BALANCING

The linear amplifiers in the QB16 series of cards are funtionalized only by appropriate backplane wiring: the input and feedback impedances must be wired to complete an operational circuit. On these appropriate boards, the summing junctions must be connected for desired functionalization from an ideal standpoint; however, as with all practical circuits, these amplifiers have associated errors, and in order to minimize these errors the resistance to PSC as seen by the inverting summing junction should be a specific value.

The noninverting terminal of the operational amplifiers has a fixed resistance to PSC of 8.74k ohms. Thus the resistance to PSC as seen by inverting input of the operational amplifier should be the same value in order to minimize output errors due to the amplifier offset parameters. A paralled combination of three 200k ohm and two 20k ohm resistances yields a resistance of 8.7k ohms. If this combination of resistances is used in the feedback and the inputs circuits, then best drift performance will be obtained. If additional resistors are required, then the appropriate resistors should be tied between the summing junction and PSC.

There may be cases where more resistors are used. The PN/1 card has more combination options; but whatever combination is used, generation of the best available resistance match will generally yield the lowest errors at the output.

J. AMPLIFIER SELECTION

There are precision and stnadard versions of the linear amplifier boards available in the QB series. There are also precision and standard resistance networks available. The designer must determine when a more precise version must be used.

The standard amplifier boards use the 741 operational amplifier as the gain block for the generation of linear circuits. If this amplifier is used with the standard resistance set which includes 3-200k resistors, a multiplicity of gain options is available by connecting these resistances into the circuit. Regardless of which gains are selected, the output error has to be checked to determine suitability.

For a DC amplifier circuit, the output error due to offset is:

$$V_O = \frac{R_f}{R_{eq}} \times V_{os} + R_f \; I_{os}$$

Req: Resistance seen by summing junction.

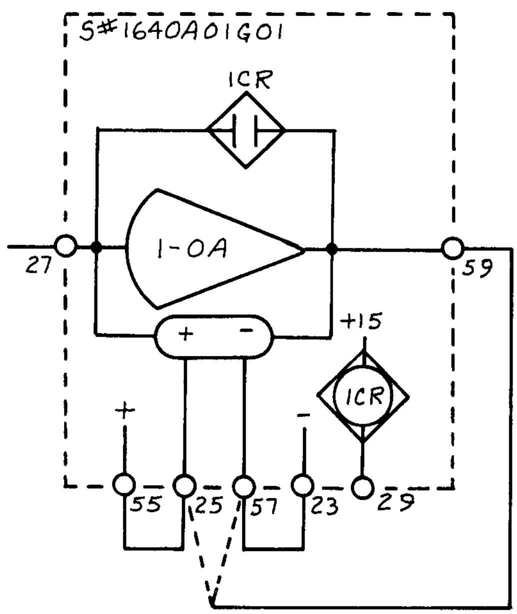
Both summing junctions see matched Req.

V_{os}: Amplifier Offset Voltage

I_{os}: Amplifier Offset Current

K. GENERAL INFORMATION - LINEAR

The uncommitted linear amplifiers in this series have an output capability of +11V at 5ma. Some of the amplifiers can be limited to 0.5V in either direction with the remaining limit being 11V. Those amplifiers with a limit option can be left without any limit, or they can have either a symmetrical or an unsymmetrical limit. To obtain a symmetrical limit for the circuitry of Figure 10, wire terminal 55 to terminal 25 and wire terminal 57 to terminal 23. To change to an unsymmetrical limiter add a wire between terminal 59 and terminal 25 (-0.5V, +11V limit) or add a wire between terminal 59 and terminal 57 (+0.5V, -11V limit). The wire from terminal 59 is in addition to the other wires mentioned.



LIMITER WIRING

FIGURE 10

The static switches associated with the linear circuitry boards can be used for resetting amplifiers, for switching signals into summing junctions for for switching points to PSC. The static switches are referenced to PSC which requires that one of the connection points of the switch contact be at a low voltage; i.e., a summing junction or PSC. The remaining terminal of the switch contact is limited to +12V. In the "on" condition, the switch contacts have a typical resistance of 50 ohms. In the "off" condition the switch contacts have a typical impedance of 10^{10} ohms. The static relays must be driven by high threshold logic (+15V). If the input to a static relay is open or a one, the contacts are open. If the input to a static relay is PSC or a zero, the contacts are closed. Logic signals operating static switches can be tied to PSC to activate a static relay. A static relay, when driven by a logic element, requires the logic element to sink 2.4ma of current. This represents a logic load of 2.4. The static relays are all of the form A type. Logic circuitry in conjunction with the static relays can be used to generate other equivalent forms.

On the Quad Comparator card, one of the 21.5k inputs (SF = 1) should be used in a circuit configuration or if not used at least one of the 21.5k inputs should be tied to PSC.

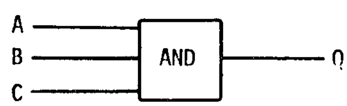
On the Dual Multiplier/Precision drawing S#1640A19 there is shown a method for improving the accuracy of the card. Without the balance pots the accuracy of the unit is 0.5% and if the balance pots (three required) are used the accuracy can be improved to 0.25%. It is recommended that this card be used without any trimming as the improvement is only miminal and exists only if the device is balanced properly.

L. GENERAL INFORMATION - DIGITAL

The general purpose logic board in this series is S#1640A11.

This is an English Logic module containing AND circuits, OR circuits and NOT circuits. The positive logic convention is used in defining the AND, OR and NOT circuits.

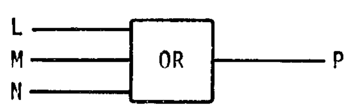
The AND element performs the logic AND function.



The output, Q will be 1 if A and B and C are 1's.

A	B	C	Q
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

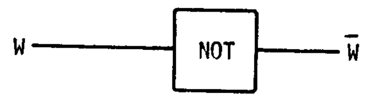
The OR element performs the logic OR function



The output, P, will be a 1 if L or M or N is a 1.

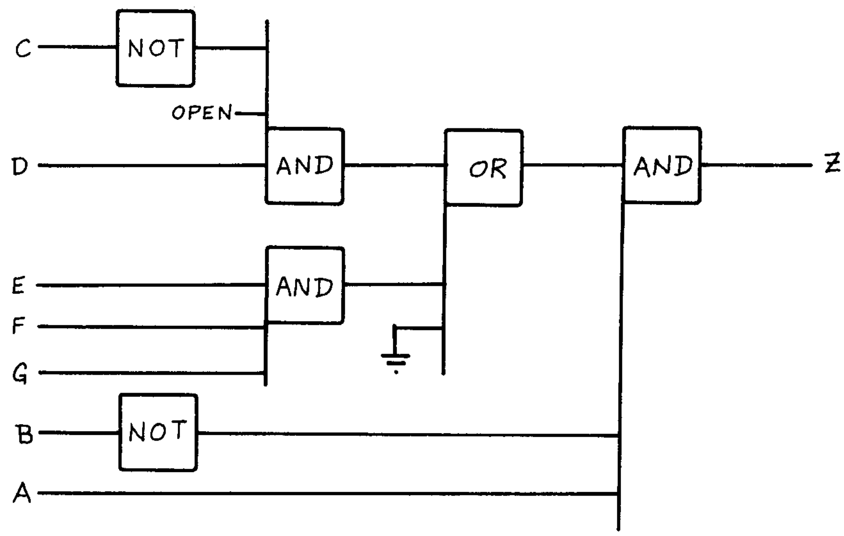
L	M	N	P
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

The NOT element performs the inversion function



W	$\bar{W}$
0	1
1	0

With these elements it is possible to build logic circuits directly from the Boolean expressions. For example, the expression $Z = A \cdot \bar{B} \cdot (\bar{C} \cdot D \;+\; E \cdot F \cdot G)$ could be expressed as:

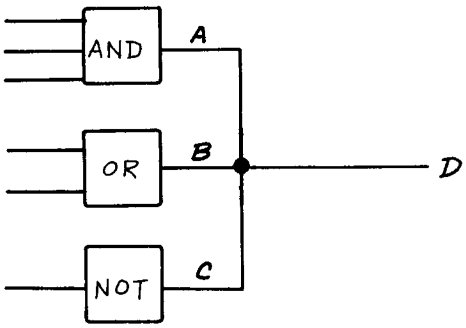


There are usually several ways of writing a Boolean expression and it is desirable to do some manipulating to find the logic expression that results in the minimum number of logic elements or the minimum number of input terminals.

For example the expression $X = AB\bar{C} + ABC + \bar{A}BC + A\bar{B}\bar{C}$ can also be written $X = BC + A\bar{C}$, which will result in a significant hardware savings.

Wired "And"

The outputs of these elements may be tied together to form the logic equivalent of an And output with inputs A, B, and C.



A	B	C	D
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

Each input terminal on this board represents a logic load of 1. Each output terminal can drive 10 logic loads.

Many of the digital boards are specialized functions and the user should check the appropriate drawings to obtain required information. For example, the output Triac card S#1640A41 specifies that each input signal to this card must be capable of driving ten logic loads which is the maximum output capacity of a logic element on the DEA card S#1640A11.

M. PRINTED CIRCUIT BOARDS - INDEX

		Nomenclature	Style No.
1.	Quad Amplifier	QA	1640A01G01
2.	Quad Amplifier-Precision	QA-P	1640A02G01
3.	Dual Combination Amplifier	DCA	1640A03G01
4.	Dual Combination Amplifier-Precision	DCA-P	
	0.1% Resistors		1640A04G01
	1% Resistors		1640A04G02
	Special		1640A04G07
5.	Dual Series Limiter	DSL	1640A05G01
6.	Passive Newtork	PN/1	
	1% Resistors		1640A06G01
	0.1% Resistors		1640A06G02
	Special		1640A06G07
7.	Quad Switch	QS	1640A07G01
8.	Quad Comparator	QC	1640A08G01
9.	English Logic	DEA	1640A11G01
10.	Reversible Binary Counter	RBC	1640A13G01
11.	Digital to Analog Converter	DAC	1640A14H01
12.	Phase Detector, Integrator and Wave Shaper	PDI	1640A15G01
13.	Test Board		1640A16G01
14.	Voltage Controlled Oscillator	VCO	
	0 to 6000 Hz		1640A17G01
	0 to 15000 Hz		1640A17G02
15.	Sine Wave Function Generator	SFG	1640A18G01
16.	Dual Multiplier-Precision	DM-P	1640A19G02
17.	Light Emitting Diodes	LED	1640A20G01
18.	Reference Regulator	RR	1640A21G01
19.	Interconnect Board		1640A22G01
20.	Peak Voltage Detector	PVD	1640A23G01

Printed Circuit Bd. Index Cont'd.	Nomenclature	Style No.
21. Harmonic Filter	HF/45	1640A24G01
22. Function Generator		1640A25G01
23. Input Board (Static)		1640A40G03
24. Input Board (Static)		1640A29G03
25. Output Board (Static)		1640A41G02
26. Output Relay Board		1640A44G02
27. Long Period Timer		
With Counter		1640A45G03
Without Counter		1640A45G04
28. Uncommitted Passive Network Board		1678A31G01
29. Transmitter		1640A35G02
30. Receiver		1640A36G02

N. PRINTED CIRCUIT BOARDS MAXIMUM DC POWER REQUIREMENTS

STYLE NUMBER	Current Required in ma for DC Supply Voltages +24V	-24V	LP15	LED5	+15	-15
1640A01	48.1	57.1				
1640A02	48.1	57.8				
1640A03	24	28.9				
1640A04	24	28.9				
1640A05	44	44				
1640A06						
1640A07	5	14.4				
1640A08	74.2	51.9				
1640A11			100			
1640A13			260			
1640A14	70	30	100	200		
1640A15	40	40				
1640A16	15	15				
1640A17	40	40	95			
1640A18	20	20			5	5
1640A19	35	35				
1640A20				100	250	
1640A21	100	100				
1640A22	0	0				
1640A23	30	50				
1640A24	40	40				
1640A25	25	25				
1640A29			100			
1640A40			55			
1640A41			48			
1640A44			311			
1640A45			55			
1640A35					150	420
1640A36					100	

In a QB16 cage assembly, the power requirements should be tabulated to insure that the wire capacity is not exceeded. The backplane wiring is #24 and is rated at 2 amps. The ribbon cable is #22 and is rated at 3 amps. If the totalized currents exceed the wiring capacity, then additional wires on the ribbon cables will have to be used; and correspondingly different wire names will have to be used to feed from the additional input power points to the separated cards being fed from these points.