
AMPLIFIER
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AUX
REMOTE
REMOTE UNIT
FILTER
HIGH CUTOFF, KHz
LOW CUTOFF, KHz
OUTPUTS
AMP
FILTER
PROCESSING
SQUARER
POLARITY
ON
POS
OFF
NEG
DISCRIMINATOR
THRESHOLD
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Operating and Service Manual

662C-4 Nerve Traffic Analysis System

THE UNIVERSITY OF IOWA

Bioengineering
Carver College of Medicine

662C-4 Nerve Traffic Analysis System

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Operating and Service Manual

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This device is intended for non-human use only.

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Table of Contents

General Description and Specifications

General Description

The 662C-4 Nerve Traffic Analysis System is designed to monitor and quantify nerve spike activity. It is a modular system and may be configured to each users needs. The following modules are available;

This general description is organized by system modules.

Amplifier Module

The amplifier has two sections: The electrically isolated preamplifier, housed in a small remote box, and the variable-gain amplifier. The electrically isolated preamplifier is a precision, low bias current, low-noise, wide-band device. The total gain through this circuit is 1000. An "Input" switch allows the use of the "live" signal through the electrically isolated preamplifier ("Remote"), or a tape-recorded or other signal source ("Aux").

The gain of the variable-gain amplifier is controlled by a "Gain" thumbpot on the front panel over the range of 0 to 99.9. Note that from the "Remote" (isolated) input, total gain is 0 to 99,900 (the total gain through the isolated portion of the circuit is 1000); From the "Aux" input, the gain range is 0 to 99.9. From the amplifier, the signal is routed to the front panel, and if installed, the optional back panel, "Amp Output" jack(s) and to the first present of the following modules: Bandpass Filter; Signal Processor & Integrator; or Window Discriminator.

Filter Module

This is a band-pass filter with adjustable low and high cutoff frequencies. The response of the filter is flat within the passband (a "Butterworth" type filter).

The low cutoff may be set to 0.1, 0.3, 0.5, 0.7, 1, 1.5, 2 or 3 Kilohertz, and the high cutoff to 0.7, 0.85, 1, 1.5, 2, 3, 5 or 10 Kilohertz. The output of the Bandpass Filter Module goes to the front panel, and if installed, the optional back panel, "Filter Out" connector(s), the "Source" switch in the Audio Amplifier Module, described later, and to the first present of the following modules: Signal Processor & Integrator; or Window Discriminator.

Signal Processor & Integrator Module

The Signal Processor section increases the signal-to-noise ratio by removing low-level noise. This is accomplished by a "discriminator", which allows only that portion of the input signal that exceeds the level set by the front-panel "Discriminator Threshold" control to get through. The total effect of the discriminator circuit may be seen on an oscilloscope connected to the "Discr. Monitor" output connector.

A "Polarity" switch determines if the negative or positive portion of the signal is to be passed on to the Window Discriminator Module to be analyzed.

This section also includes a "squaring" circuit, which produces the mathematical square of the input signal. This also has the effect of reducing unwanted noise on a signal by minimizing the lower level portions and emphasizing the desired "spikes". The "Squarer" may be switched in or out as desired by the front-panel "Squaring" switch. The effect of the Discriminator and Squarer together may be seen on the front panel, and if installed, optional back panel, "Proc. Out" connector(s).

The integrator section directly integrates the full-wave rectified signal, without regard to the Signal Processor. It is designed to give some idea of the activity on the input even without spikes that are easily detected by a window discriminator. The output full scale is 1 volt, and may be offset negatively (zero-suppressed) to enable observation of small changes on top of large signals. The range of the offset corresponds to the full-scale output, 0 to 1 volt.

Window Discriminator Module

The "Window Discriminator" is a pulse height analysis circuit, with two threshold controls to determine the levels at which spikes are detected. The outputs of this module are delivered to the Counter and/or RatemeterModules, described below, if installed.

If a spike is above the low threshold, but below the high threshold, a pulse will be delivered to output "A". If a spike is above the high threshold a pulse will be delivered to output "B". This function is noted in the small box on the front panel labeled "Modes". Note that for any input spike that exceeds the low threshold one and only one output pulse will be present.

The "Cursor Out" jacks provide D.C. voltages that correspond to the settings of the "Threshold" controls. These signals may be superimposed on the amplified nerve traffic signal on a multi-channel oscilloscope to produce a display of the input signals and the levels at which spike detection occurs.

A "Trigger Source" switch routes the output pulse from window A or B to the front panel, and if installed, the optional back panel, "Trigger Out" jack(s). This signal may be used to trigger a "bucket brigade" device or a digital storage oscilloscope so that the spike that was just detected by the window may be observed. Note that the pulse from this connector occurs after the spike that has been detected has dropped below the low threshold. The trigger output pulses are 50 microseconds long and 15 volts in amplitude.

A front-panel indicator light labeled "L>H" is provided to warn of threshold overlap (that is, the low threshold being set more clockwise than the high threshold), an illegal condition.

Counter Module

The Window Discriminator Module is required to use this module.

There are two counters, A and B. Counter A counts pulses from window output A, and Counter B counts pulses from window B (see the Window Discriminator Module section above). The output of each counter is presented as an analog voltage resulting in a "staircase" of about 1 volt full scale. The number of steps in the staircase is determined by the "Counts F.S." switch ("F.S." is an abbreviation for "Full Scale"). If "10" is selected, 10 pulses from the window discriminator will produce one complete cycle of the output staircase. The operation is similar for "100" and "1000."

"External Reset" may be used to reset the counter to zero before the normal full-scale output is reached. A 5 to 15 volt pulse is required to cause a reset. A typical application might be to use a precise timer to reset the counter at regular intervals so that the output would be a histogram-type display of the pulse rate.

Ratemeter Module

The Window Discriminator Module is required to use this module.

As with the Counter Module (above), there are two ratemeters, one for each window output. The output voltage from each ratemeter is proportional to the input frequency with a scale factor of 0.1V per KHz, and may be offset in the negative direction (zero suppressed) so that small changes in a high frequency signal may be observed. The offset control is calibrated 0 to 10 KHz.

The period of time over which the input frequency is averaged may be set to 0.05, 0.1, 0.5 or 1 second by the "Time Constant" switches.

Audio Module

The audio power amplifier supplies up to 7 watts of audio to an external speaker through the front panel, and if installed, the optional rear panel, "External Speaker" jack(s), or a reduced level to the built-in speaker. When an external speaker is connected, the internal speaker is automatically disconnected.

The audio signal source may be selected from the Bandpass Filter Module or Signal Processor (if installed) outputs with the "Source" switch. If neither of those modules are installed, the signal source is simply the input signal.

A "Volume" control adjusts the amplitude of the audio output.

Specifications

1. Variable Gain Amplifier with isolated preamplifier
    A. Amplifier Gain 0-99,900
    B. Amplifier Isolation 8000 volts Isolation Test Voltage
    C. Remote Amplifier Input Impedance 1 Megohm

2. Bandpass Filter
    A. High pass cutoff frequencies 0.3, 0.5, 0.7, 1, 2, 3 KHz.
    B. Low pass cutoff frequencies of 0.7, 1, 2, 3, 5, 10 KHz.

3. Signal Processor and Integrator
    A. Discriminator, 0-±10 Volt precision "dead space"
    B. Signal Squarer produces mathematical square of input
    C. Integrates signal without regard to discriminator
    D. Output polarity, selectable

4. Window Discriminator
    A. Low Cursor 0-10 Volts
    B. High Cursor 0-10 Volts
    C. Out A = between high and low cursors
    D. Out B = above high cursor

5. Counters
    A. Two counters available, for Window Out A and Window Out B
    B. Full Scale Count of 10, 100 or 1000, user selectable

6. Ratemeters
    A. Two ratemeters available, for Window Out A and Window Out B
    B. Time constant selectable from 0.05, 0.1, 0.5, or 1 second
    C. Output 0.1 Volt/KHz.
    D. Offset 0-10Khz

7. Audio
    A. Power output 7 watts into 8 ohms
    B. Two jacks for external speakers
    C. Internal speaker

Power	100,120,200,220,230, or 240 volts A.C. 47-63 Hertz at 50 VA max.
Environment temp.	0-55 degrees Celsius

NOTICE This device is intended for non-human use only!

Chassis

General Description

The 662C-4 Nerve Traffic Analysis System is housed in a tabletop enclosure a tilt stand, in a two-tone gray color. Optional rack-mount brackets allow mounting in a standard 19-inch equipment rack. Dimensions are 7"H X 16.9"W X 12.7"D (17.8cm X 42.9cm X 32.3cm). Net weight is approximately 20 lbs. (9 KG).

A back-panel power switch controls all A.C. power to the unit. The "Power" indicator on the Audio Module illuminates when internal D.C. power is present. The 662C-4 Nerve Traffic Analysis System requires 105 to 125 volts A.C., 47 to 63 Hertz at 1/2 amp maximum.

For a complete description of each module, including operating instructions, circuit descriptions, calibration procedures, parts lists, schematics, and board layouts, please turn to the particular module sections later in this manual.

Notice

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Operating Instructions

Before connecting the 662C-4 Nerve Traffic Analysis System to a source of 100, 120, 220 or 240 volt 47-63 Hz electrical power, refer to Appendix A to check, and if necessary, correct, the input power configuration. When changing primary operating voltages, it will be necessary to also change the fuse size and/or type. Again, refer to Appendix A and the Fuse Size Chart, below, for instructions on these procedures.

When first operating the 662C-4 Nerve Traffic Analysis System, turn the line power to the unit on by depressing the top half the rocker-type power switch on the power entry module on the back panel of the chassis, which will set it to the "1" (or "on") position. The "Power" lamp on the front panel of the unit will illuminate, indicating presence of normal operating voltages.

To turn the unit **off**, depress the **bottom** half of the rocker-type power switch on the power entry module on the back panel. This sets it to the "0" (or "off") position. The "Power" lamp on the front panel will extinguish.

If the power indicator does not illuminate, check the fuse by the following procedure.

Fuse Replacement

To replace the fuse, disconnect the power cord from the connector on the power entry module and open the cover by prying with a small blade screwdriver or similar tool inserted into the notch adjacent to the power cord connector. Replace fuse only with MDL 0.5A fuse or equivalent.

Fuse Size Chart

Voltage	Fuse Size
100-130	0.5 A, 250V
220-240	0.25 A, 250V

Connect the line cord to the IEC connector on the Power Entry Module on the back panel, and to a source of 100, 120, 220 or 240 volts 47-63 Hz as appropriate.

Amplifier Module

Operating Instructions

The amplifier has two sections that we must be concerned with: The electrically isolated pre-amplifier in the small remote box, and the variable-gain amplifier.

The electrically isolated preamplifier is a precision, low bias current, low-noise, wide-band device. The total gain through this circuit is 1000.

The "Input" switch allows the use of the "live" signal through the electrically isolated pre-amplifier ("Remote"), or a tape-recorded or other signal source ("Aux").

The gain of the variable-gain amplifier is controlled by the "Gain" thumbpot on the front panel over the range of 0 to 99.9. Note that from the "Remote" (isolated) input, total gain is 0 to 99,900 (The total gain through the isolated portion of the circuit is 1000); From the "Aux" input, the gain range is 0 to 99.9.

From the amplifier, the signal is routed to the front and rear panel "Amp Out" jacks and to the Filter Module.

Circuit Description

U1 is the input buffer amplifier, and is a very high quality, low noise, low bias current integrated op- amplifier. It is in a gain of 100 non-inverting configuration. Power is supplied from the isolated power from U10, the isolation amplifier.

The output of U1 is AC coupled into the isolation amplifier. The isolation amplifier is a Burr-Brown 3656, a transformer coupled design featuring wide bandwidth and low noise. The isolation amplifier has a gain of 10, for a total gain through the circuit to this point of 1000.

From the isolation amplifier, the signal goes through a follower amplifier, in U10. Following U10 is a selection switch to allow input from the "Aux" connector, typically for use with a tape recorded signal, or from the isolation amplifier ("Remote Unit").

The variable gain stage, U11-A, is AC coupled, and has variable gain set by the feedback resistor, a digital "thumbpot" potentiometer whose maximum value is 99.9K ohm. With a nominal 2K-ohm input resistor, this gives a gain range of 0.05 to 49.9 in this stage. A non-inverting amplifier U11-B has gain of 2 giving a total gain of 0.1 X 1000 to 99.9 X 1000 for the "Remote" input. For the "Aux" input, the gain range is 0.1 to 99.9). The gain is trimmable with R14.

Note that the gain is well distributed and each stage is shielded from the next to insure stability. Power supply lines are highly filtered for noise reduction.

From the variable gain amplifier, the signal is routed to the front and rear panel "Amp Out" jacks and to the bandpass Filter Module.

Calibration Instructions

Calibration of the 662C Nerve Traffic Analyzer requires the following test equipment:

1. A sine-wave signal generator whose amplitude and frequency can be accurately controlled;
2. A digital multimeter of known accuracy;
3. A laboratory oscilloscope;
4. A frequency counter.

Calibration should not be attempted without proper test equipment.

Refer to the appropriate component locator drawings elsewhere in this manual to locate the adjustments in the following steps.

DVM and scope common leads are to be connected to the chassis for all measurements.

Preliminary set-up

A. Set the front panel "Gain" control for "01.0" (gain of 1000).

B. Turn the front panel "Squarer" switch "off".

C. Set the "Discriminator Threshold" control fully counter-clockwise.

D. Construct a precision 1000:1 attenuator consisting of one each 1.00Meg 1% and 1.00K 1% Resistors. Use this to attenuate the output of the sine wave Signal generator from 1.00 V. AC to 1.00 mV. AC. Connect this 1 mV signal to the inputs on the remote box. Provide a signal return by connecting signal generator ground to the copper plate.

E. Set the signal generator for a frequency of 2 KHz. and verify that the output voltage is 1.00 V. RMS with the DVM.

Amplifier Gain

A. Connect the DVM to the "Amp out" jack on the front panel.

B. Adjust R14, "Gain Trim" on board 3 (accessible at the top of the module as viewed from the front with the module out of the case) for 1.00 V. RMS on the DVM.

Parts List

Pre-Amplifier

Resistors

(Ohms, 10% tolerance, 1/4 watt unless otherwise noted)

R1	100k/1%	R4	1.0k
R2	1.00k/1%	R5	1.0M
R3	1.0M	R6	1.0M

Capacitors

(Mfd, 50 Volt Ceramic unless otherwise noted)

C1	0.47	C3	50pF
C2	0.47	C4	1.0

Semiconductors

U1	AD645

Connectors

J1	Mini Binding Post Red	J4	Pin Jack Black
J2	Mini Binding Post Black	P1	Lemo PAGM05GLAC65G
J3	Pin Jack red		

Miscellaneous

1	Circuit Board 2BIO-662-1011
1	Enclosure Pomona 2417
S1	DPDT min toggles

Iso-Amplifier

Resistors

(Ohms, 10% tolerance, 1/4 watt unless otherwise noted)

R10	270k	R15	1.74k/1%
R11	2.7M	R16	100k thumbpot
R12	301k/1%	R17	10.0k/1%
R13	2.7M	R18	10.0k/1%
R14	500 vert. Trimpot	R19	220

Capacitors

(Mfd, 50 Volt Ceramic unless otherwise noted)

C10	0.01	C16	10uF 30V tantalum
C11	0.47	C17	0.47
C12	0.47	C18	1.0
C13	0.47	C19	1.0
C14	0.47	C20	120uF 30V tantalum
C15	10 uF 30V tantalum	C21	120uF 30V tantalum

Semiconductors

U10	3656 Burr-Brown	U11	TL081

Switches

S10	DPDT On-On min. toggle

Connectors

J10	Lemo PLGM056LLG
J11	BNC

Miscellaneous

1	Circuit Board 2BIO-662-1040
1	Chrome dress nur

Filter Module

Operating Instructions

The Filter section is a band-pass filter with adjustable low and high cutoff frequencies. The response of the filter is flat within the passband (a "Butterworth" type filter)

The low cutoff may be set to 0.1, 0.3, 0.5, 0.7, 1, 1.5, 2 or 3 kilohertz, and the high cutoff to 0.7, 0.85, 1, 1.5, 2, 3, 5 or 10 kilohertz. Note that it is possible to have the high and low cutoff frequencies overlap, which will eliminate the signal.

The output of the filter goes to the "Filter Out" connectors on the front and rear panels, and to the "Source" switch in the Audio Amplifier section, described later

Circuit Description

The filters, are built on a single modules. Each is a Butterworth filter, with switch selectable cutoff frequencies. U1b is the low-pass and U1a the high-pass.

The "Source" switch is used to select either the filtered or processed signal for audio amplification. The output of the filter goes to the "Filter Out" connector on the front and rear panels.

Parts List

Resistors

(Ohms, 10% tolerance, 1/4 watt unless otherwise noted)

R1	Not used	R24	17.4k/1%
R2	Jumper	R25	64.9k/1%
R3	Not used	R26	14.3k/1%
R4	113k/1%	R27	53.6k/1%
R5	226k/1%	R28	10.7k/1%
R6	68.1k/1%	R29	40.2k/1%
R7	137k/1%	R30	7.15k/1%
R8	48.7k/1%	R31	26.7k/1%
R9	97.6k/1%	R32	4.75k/1%
R10	34.0k/1%	R33	17.8k/1%
R11	68.1k/1%	R34	2.87k/1%
R12	24.3k/1%	R35	10.7k/1%
R13	51.1k/1%	R36	1.43k/1%
R14	16.9k/1%	R37	5.36k/1%
R15	34.0k/1%	R38	20.5k/1%
R16	11.3k/1%	R39	76.8k/15
R17	22.6k/1%		
R18	340k/1%		
R19	681k/1%		

Capacitors

(Mfd, 50 Volt Ceramic unless otherwise noted)

C1	0.0033/33V poly	C4	0.1
C2	0.0033/33V poly	C7	0.0033 /33V poly
C3	0.1	C8	0.1 /33V poly

Semiconductors

U1	TL082

Switches

S1	Grayhill 71ADF30-2-1AJN	S2	Grayhill 71ADF30-2-1AJN

Miscellaneous

1	Circuit Board 2BIO-020-0311
2	Knobs alco KS500A-1/8

Signal Processor and Integrator Module

Operating Instructions

The signal processing section increases the signal-to-noise ratio by removing low-level noise. This is accomplished by a "Discriminator", which allows only that portion of the input signal that exceeds the level set by the front panel "Discriminator Threshold" control to get through. The total effect of the discriminator circuit may be seen on an oscilloscope connected to the "Discr. Monitor" output connector.

This section also includes a "Squaring" circuit, which produces the mathematical square of the input signal. This also has the effect of reducing unwanted noise on a signal by minimizing the lower level portions and emphasizing the desired "spikes". The "Squarer" may be switched on or off as desired by the front-panel "Squarer" switch. The effect of the Discriminator and Squarer together may be seen on the "Proc. Out" connectors on the front and rear panels.

The Integrator directly integrates the filtered, full-wave rectified signal without regard to the Window Discriminator. It is designed to give some idea of the activity on the input, even without spikes that are easily detected by the window. The output full scale is 1.0 volt, and may be offset negatively (zero-suppressed) to enable observation of small changes on top of large signals. The range of the offset corresponds to the full-scale output, 0 to 10 volts.

Circuit Description

The signal processing section increases the signal-to-noise ratio by removing low-level noise.

U101-A and -B, U102-A and -B, and U103-A and -B form the discriminator, a precision "dead-space" circuit. This operates so that only that portion of the input signal that exceeds the "Discriminator Threshold" level gets through. U104 and U105-A select either the positive or negative half of the signal for further processing, but the total effect of the discriminator circuit may be seen on an Oscilloscope on the "Discriminator Monitor" output connector.

U105-B is a variable-gain amplifier for the purpose of changing the scale factor of the squarer, U106, an analog devices AD532KD monolithic multifunction device. The squarer may be switched in or out of the circuit with S101, U107 and U108-A. U108-B merely inverts the signal so that the proper polarity is presented to the window and integrator.

The Integrator directly integrates the filtered, full-wave rectified signal, without regard to the Window Discriminator. It is designed to give some idea of the activity on the input even without spikes that are easily detected by the window. The output full scale is 10.0 volt, and may be offset negatively (zero-suppressed) to enable observation of small changes on top of large signals. The range of the offset corresponds to the full-scale output, 0 to 10 volt

Calibration

Squarer Offset

A. Remove the input signal from the remote box and short the two inputs together.

B. Connect the DVM to the "Processed Signal Out" jack.

C. Turn the "Squarer" switch "on".

D. Adjust R110, "SQR Offset," for 0.0 mV DC at this connector.

Squarer Gain

Note R108, the Squarer Gain adjustment for the squaring module, can be set to any desired gain from 1 to 10, although the normal setting is for 1.00 V. out of the squarer for 1.00 V. in.

A. Reconnect the signal generator (through the attenuator) to the inputs.

B. Turn the "Squarer" switch off.

C. Set the signal generator amplitude so that the peak-to-peak amplitude at the"processed Signal out" connector as observed on the oscilloscope is 1.00 volts.

D. Turn the squarer "on".

E. Adjust R108 so that the peak-to-peak signal is 1.00 volts (note that there is no negative-going signal at this point with the squarer either on or off).

Processor Threshold

A. Connect the DVM to the clockwise terminal of R141, the "Discriminator Threshold" control on the front panel.

B. Adjust R105, "Trheshold Cal" for 4.0 volts D.C. indicated on the DVM

Integral Offset and Balance

A. Connect the DVM to the clockwise terminal of the Integral Offset control on the front panel. Adjust R124, Offset cal for 10.00 V. DC.

B. Set the Integral offset control fully counter-clockwise.

C. Disconnect the signal generator and short the inputs to the pre-amp. (These two steps prevent any pulses from being generated by the window.)

D. Adjust R122 "Integrator Balance on the 662C-4 board for 0 mV. DC at "Integrator out."

Parts List

Resistors

(Ohms, 10% tolerance, 1/4 watt unless otherwise noted)

R101	316B104 resistor network	R115	Na
R102	316B104 resistor network	R116	100k/1%
R103	316B104 resistor network	R117	100k/1%
R104	314A103 resistor network	R118	100k/1%
R105	5k vert. Trim	R119	49.9k/1%
R106	24.9k/1%	R120	100k/1%
R107	10k10T pot	R121	Na
R108	10k vert. Trim	R122	10k vert.trim
R109	1.10k/1%	R123	4.53k/1%
R110	20k vert. Trim	R124	2k vert. Trim
R111	10k10T pot	R125	Na
R112	40.2k/1%	R126	100
R113	1.00M/1%	R127	100
R114	40.2k/1%	R128	Na

Capacitors

(Mfd, 50 Volt Ceramic unless otherwise noted)

C101	1.0/poly	C115	0.1/50V
C102	0.47/poly	C116	0.1/50V
C103	0.047/poly	C117	0.1/50V
C104	0.047/poly	C118	0.1/50V
C105	10pF/SM	C119	0.1/50V
C106	10pF/SM	C120	0.1/50V
C107	10pF/SM	C121	0.1/50V
C108	0.1/50V	C122	0.1/50V
C109	0.1/50V	C123	0.1/50V
C110	0.1/50V	C124	100pF/1kV
C111	0.1/50V	C125	100pF/1kV
C112	0.1/50V	C126	0.1/50V
C113	0.1/50V	C127	0.1/50V
C114	0.1/50V		

Semiconductors

U101	TL082	U107	Na
U102	TL082	U108	TL082
U103	Tl082	U109	DG201
U104	DG201	U110	TL082
U105	TL082	U111	TL082
U106	AD632	U112	TL081
D101	1N4148	D104	1N4148

D102	1N4148	D105	1N4148
D103	1N4148	D106	1N4148

Switches

S101	SPDT min. toggle	SS103	Rotary 1P11T
S102	SPDT min. toggle		

Miscellaneous

3	BNC connectors
1	Knobs alco KS500A-1/8
2	10T Dials

Window Discriminator

Operating Instructions

The "Window" is a pulse height analysis circuit, with two threshold controls to determine the levels at which spikes are detected. If a spike is above the low threshold, but below the high threshold, a pulse will be delivered to output "A". If a spike is above the high threshold a pulse will be delivered to output "B". This function is noted in the small box on the front panel labeled "Modes". Note that for any input spike that exceeds the low threshold one and only one output pulse will be present.

The "Polarity" switch determines if the negative or positive portion of the signal is to be analyzed. (This switch actually controls a gating circuit in the signal processor section, but the effect is seen in the window section as well as at the "Proc. Out" connectors.)

The "Cursor Out" jacks present D.C. voltages that correspond to the settings of the "Threshold" controls. These signals may be superimposed on the "Proc. Out" signal on a multi-channel oscilloscope to produce a display of the processed input signals and the levels at which spike detection occurs.

The "Trigger Source" switch routes the output pulse from window A or B to the front and rear panel "Trigger Out" jacks. This signal may be used to trigger a "bucket brigade" device or a digital storage oscilloscope so that the spike that was just detected by the window may be observed. Note that the pulse from this connector occurs after the spike that has been detected has dropped below the low threshold. The trigger output pulses are 50 microseconds long and 15 volts in amplitude.

A front-panel indicator light labeled "L>H" is provided to warn of threshold overlap (that is, the low threshold being set more clockwise than the high threshold), an illegal condition.

Circuit Description

U201-A and -B are buffer amplifiers for the high and low threshold potentiometers respectively. U202 is the high threshold comparator, U203 the low threshold comparator and U204 is a comparator that will light the front panel "L>H" light in case of cursor overlap.

As the signal crosses the low threshold in the positive direction, the output of U203 goes negative, (This has no effect on any of the following circuitry). If the signal crosses the high threshold, the output of U202 goes positive, setting flip-flop U206-A.

When the signal again crosses the low threshold, this time in the negative direction, both one-shots, U205-A and -B are fired, and flip-flops U206-A and -B are clocked, shifting the previous contents of U206-A into U206-B, and clearing U206-A. The outputs of U206-B are gated with the one-shot outputs to give Output pulses to either "Window A" or "Window B" outputs as required. The gating of U207 will inhibit the output pulse for "A" if U206-B is set, and enable output "B". If U206-B is not set, output "A" is enabled, and "B" disabled. Hence, output "B" corresponds to nerve spikes that are above the high cursor, and output "A" corresponds to those that are "in the window," that is, the spike is between the low and high cursors in amplitude.

S201 selects the source window for the trigger output pulse. This pulse is intended to trigger devices such as a "bucket brigade" to capture the whole pulse that caused the trigger.

Calibration Instructions

Cursors

A. Turn the "Low" threshold control fully clockwise.

B. Connect the DVM to the "Cursor Low Out" jack

C. Adjust R200, "Cursor Cal," on the 662C-4 board for 10.0 V. DC out.

Window Pulse Width

A. Set the signal generator for a frequency of 1.00 KHz using the frequency counter as a standard and connect to the input jacks on the remote box through the attenuator (see amplifier calibration).

B. Set the "Trigger Source" switch to "A."

C. Set the "Low Cutoff" switch to 0.3 KHz.

D. Set the "High Cutoff" switch to 10 KHz.

E. Turn the "Low" threshold control to the 9 o'clock position.

F. Turn the "High" threshold control fully clockwise.

G. Monitor the "Trig Out" jack with the oscilloscope and verify that pulses of 15V amplitude and a width of 50 μSec. appear. If they do not, adjust the gain and threshold controls to produce output pulses.

H. Connect the oscilloscope probe to U205 pin 6.

I. Adjust R210, "P Width." for a positive pulse width of 100 microseconds

Parts List

Resistors

(Ohms, 10% tolerance, 1/4 watt unless otherwise noted)

R200	5k vert. Trim	R209	10k
R201	10k	R210	20k vert. Trim
R202	1.0M	R211	100
R203	10k	R212	100
R204	10k	R213	100
R205	1.0M	R214	100
R206	1.0M	R215	1.0M
R207	75.0k/1%	R216	10k pot
R208	100k	R217	10k pot

Capacitors

(Mfd, 50 Volt Ceramic unless otherwise noted)

C200	100pF/1kV	C210	0.1/.50V
C201	100pF/1kV	C211	0.1/.50V
C202	0.001/33V	C212	0.1/.50V
C203	470pF/SM	C213	0.1/.50V
C204	0.01.50V	C214	0.1/.50V
C205	0.01/50V	C215	0.1/.50V
C206	200pF/1kV	C216	0.1/.50V
C207	0.1/50V	C217	0.1/.50V
C208	0.001/50V	C218	0.1/.50V
C209	0.001/50V	C219	0.1/.50V

Semiconductors

U201	TL082	U205	MC4538B
U202	LM311	U206	MC14013B
U203	LM311	U207	MC4081B
U204	LM311	U208	MC14049B

Switches

S201	SPDT On-On min. toggle

Connectors

J201	BNC	J203	BNC
J202	BNC		

Miscellaneous

1	LED HLMP-3600	1	Red Lens
1	Chrome dress nur	2	Knobs, Alco KS500A

Counters Module

Operating Instructions

Requires the presence of the Window Module for the counters to function. There are two counters A and B. Counter A counts pulses from window output A, and B counts pulses from window B (see the window section). The output of each counter is presented as an analog voltage resulting in a "staircase" of about 1 volt full scale. The number of steps in the staircase is determined by the "Counts f.s." switch ("f.s." is an abbreviation for "full Scale"). If "10" is selected, 9 pulses from the window discriminator will produce full scale, and the tenth pulse will cause the output to return to zero. The operation is similar for "100" and "1000."

"External reset" may be used to reset the counter to zero before normal full-scale output is reached. A typical use for this might be to connect a precise timer to the input to reset at regular intervals so that the output would be a histogram-type display of the pulse rate. A 5 to 15 volt pulse is required to cause a reset.

Circuit Description

Counter A

This is basically a decade counter created in software running on U302, a PIC 16C65 microprocessor. The count length may be set to 1, 2 or 3 decades by the front panel "Counts f.s." switch ("f.s." is an abbreviation for "full scale"). The output of the counter is converted to an analog voltage by U301, a digital to analog converter, resulting in a staircase of about 1 volt full scale. The number of steps in the staircase is determined by the "Counts f.s." switch. If "10" is selected, 9 pulses from the window discriminator will produce full scale, and the tenth pulse will cause the output to return to zero. The operation is similar for "100" and "1000."

U303-A and B buffer the output of the DAC.

External reset may be used to truncate the output before normal full-scale output is reached. A typical use for this might be to connect a precise timer to the input to reset at regular intervals So that the output would be a histogram-type display of the pulse rate.

Counter B

This section is identical to counter A described above.

Parts List

Resistors

(Ohms, 10% tolerance, 1/4 watt unless otherwise noted)

R302	3920/1%	R312	100k
R303	1.00k/1%	R313	100k
R304	1.00k/1%	R314	Na
R305	3920/1%	R315	10k
R306	100	R316	10k
R307	100	R317	10k
R308	10k	R318	10k
R309	10k	R19	10
R310	10k		

Capacitors

(Mfd, 50 Volt Ceramic unless otherwise noted)

C301	10uF/30V tantalum	C307	0.1/50V
C302	10uF/30V tantalum	C308	0.1/50V
C303	0.1/50V	C309	0.1/.50V
C304	0.1/50V	C310	0.1/.50V
C305	0.1/50V	C311	0.1/.50V
C306	0.1/50V	C312	0.1/.50V

Semiconductors

U301	AD7237	U304	MC4013B
U302	PIC16C65A	U305	MC4050B
U303	TL082	U306	MC14013B
Q301	UA78L05		

Switches

S301	Rotary 1P 11T	S302	Rotary 1P 11T

Connectors

J301	BNC	J303	BNC
J302	BNC	J304	BNC

Miscellaneous

CR1	Crystal 4.00MHz
2	Knobs, Alco KS500A

Ratemeter Module

Operating Instructions

As with the counters, the ratemeters require the presence of the Window module for the Ratemeters to function. There are two Ratemeters, one for each window output. The output voltage from each Ratemeter is proportional to the input frequency with a scale factor of 0.1V per KHz, and may be offset in the negative direction (zero suppressed) so that small changes on top of a high frequency signal may be observed. The offset control is calibrated 0 to 10 KHz.

The period of time over which the input frequency is averaged may be set to 0.05, 0.1, 0.5 or 1 second by the "Time Constant" switches.

Circuit Description

Ratemeter A

This is basically a pulse averaging circuit. U401 is a multiple analog switch which selects the proper integrating capacitor on U402, a "leaky" integrator, as the time constant is changed by the front panel switch, S401.

The window discriminator pulses turn on the lower-most switch for precisely 0.1 ms each time a pulse is detected, integrating a reference voltage generated by R404-R406 and U403-A. The output of this integrator is a voltage representing the average input voltage over a period of time determined by the capacitor selected. Since the input is a constant voltage turned on for precisely 0.1 ms for each input pulse, the output voltage is proportional to the input frequency.

The output is attenuated and buffered to give a 0.1V per KHz output, and may be offset in the negative direction (zero suppressed) so that small changes on top of a high frequency signal may be observed. The offset control is calibrated 0 to 10 KHz.

Ratemeter B

This section is identical to Ratemeter A described above.

Calibration Instructions

Offsets

A. Connect the DVM to the clockwise terminal of any of the two "Offset" controls on the front panel.

B. Adjust R414 "Rate Offset" for 10.0 volts DC indicated.

Balance

A. Set the "Low Threshold" fully clockwise.

B. Disconnect the signal generator and short the inputs to the pre-amp. (These two steps prevent any pulses from being generated by the window.)

C. Set the "Ratemeter A offset" and "Ratemeter B offset" controls fully Counter-clockwise.

D. Adjust R409, "A bal," for 0 mV DC at "Ratemeter A out."

E. Adjust R428, "B bal," for 0 mV DC at "Ratemeter B out."

Ratemeter A calibration

A. Set the window discriminator "High Threshold" control just enough clockwise from the "Low Threshold" control so the "L>H" lamp is extinguished.

B. Set the "Trig Source" switch to "A" and verify that there are pulses being generated. If there are not, readjust the threshold controls until pulses are present.

C. Set the "Ratemeter A time constant" switch to 0.5.

D. Connect the DVM to the "Ratemeter A out" jack

E. Adjust R405, "A cal," for 0.100 V. DC out with a 1KHz signal at the input

Ratemeter B calibration

A. Set the window discriminator "high threshold" control just enough clockwise from the "Low Threshold" control so the "L>H" lamp is extinguished.

B. Set the "Trig Source" switch to "B" and verify that there are pulses being generated. If there are not, readjust the threshold controls until pulses are present.

C. Set the "Ratemeter B time constant" switch to 0.5.

D. Connect the DVM to the "Ratemeter B out" jack.

E. Adjust R420, "B cal," for 0.100 V DC out.

Parts List

Resistors

(Ohms, 10% tolerance, 1/4 watt unless otherwise noted)

R401	10k	R416	10k
R402	10k	R417	10k
R403	10k	R418	10k
R404	4.02k/1%	R419	Na
R405	5k vert. Trim	R420	5k vert. Trim
R406	9.09k/1%	R421	1.00M/1%
R407	1.00M/1%	R422	1.00M/1%
R408	1.00M/1%	R423	100k/1%
R409	10k vert. Trim	R424	100k/1%
R410	100k/1%	R425	10.0k/1%
R411	100k/1%	R426	10k 10T pot
R412	10.0k/1%	R427`	10k 10T pot
R413	Na	R428	10k
R414	1k vert. Trim	R429	100
R415	2.26k/1%	R430	100

Capacitors

(Mfd, 50 Volt Ceramic unless otherwise noted)

C401	1.0/poly	C411	0.1/50V
C402	0.47/poly	C412	0.1/50V
C403	0.047/33V	C413	0.1/.50V
C404	0.047/33V	C414	0.1/.50V
C405	1.0/poly	C415	0.1/.50V
C406	0.47/poly	C416	0.1/.50V
C407	0.047/33V	C417	100pF/1kV
C408	0.047/33V	C418	100pF/1kV
C409	0.1/50V	C419	0.1/50V
C410	0.1/50V	C420	0.1/50V

Semiconductors

U401	DG201	U405	TL081
U402	TL081	U406	TL082
U403	TL082	U407	TL082
U404	DG201		

Switches

S401	Rotary 1P 11T	SS02	Rotary 1P 11T

Connectors

J401	BNC
J402	BNC

Miscellaneous

2	10T Dial
2	Knobs, Alco KS500A

Audio Module

Operating Instructions

The audio power amplifier supplies about 7 watts of audio to the built-in speaker, or to an external speaker through the front and rear panel "external speaker" jacks. When an external speaker is connected, the internal speaker is automatically disconnected.

The audio signal source may be selected from the filter or discriminator outputs with the "Source" switch.

"Volume" adjusts the amplitude of the audio output.

Circuit Description

U501 is a monolithic audio power amplifier. It supplies about 7 watts of audio to the built-in speaker, or to an external speaker through J501 and J502. When an external speaker is connected, the internal speaker is automatically disconnected. The audio source is selectable and volume is adjustable from the front panel.

This amplifier has its own power supply to prevent loading of the main supply by the high current demands of the power amplifer.

Parts List

Resistors

(Ohms, 10% tolerance, 1/4 watt unless otherwise noted)

R501	220	R504	22 1 watt
R502	2.2	R505	100k
R503	1	R506	10k pot

Capacitors

(Mfd, 50 Volt Ceramic unless otherwise noted)

C501	470	C504	1000
C502	10	C505	470
C503	0.1/50V		

Semiconductors

U501	LM383T

Switches

S501	SPDT min. toggle

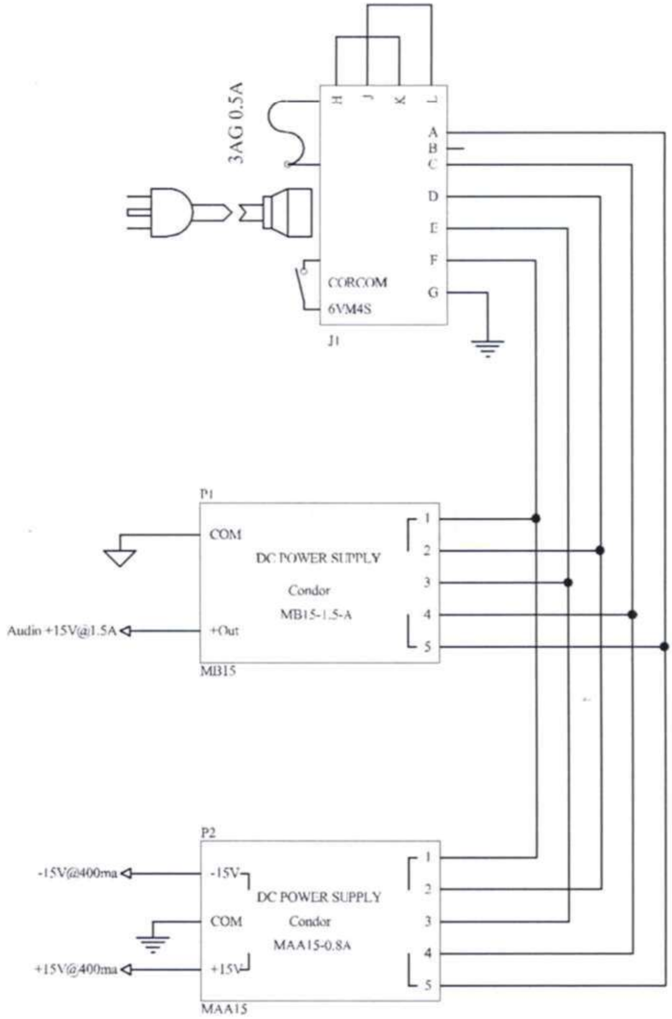
Connectors

J301	Phone Jack tini

Miscellaneous

1	Speaker 8 ohm
1	Knobs, Alco KS500A

Drawings



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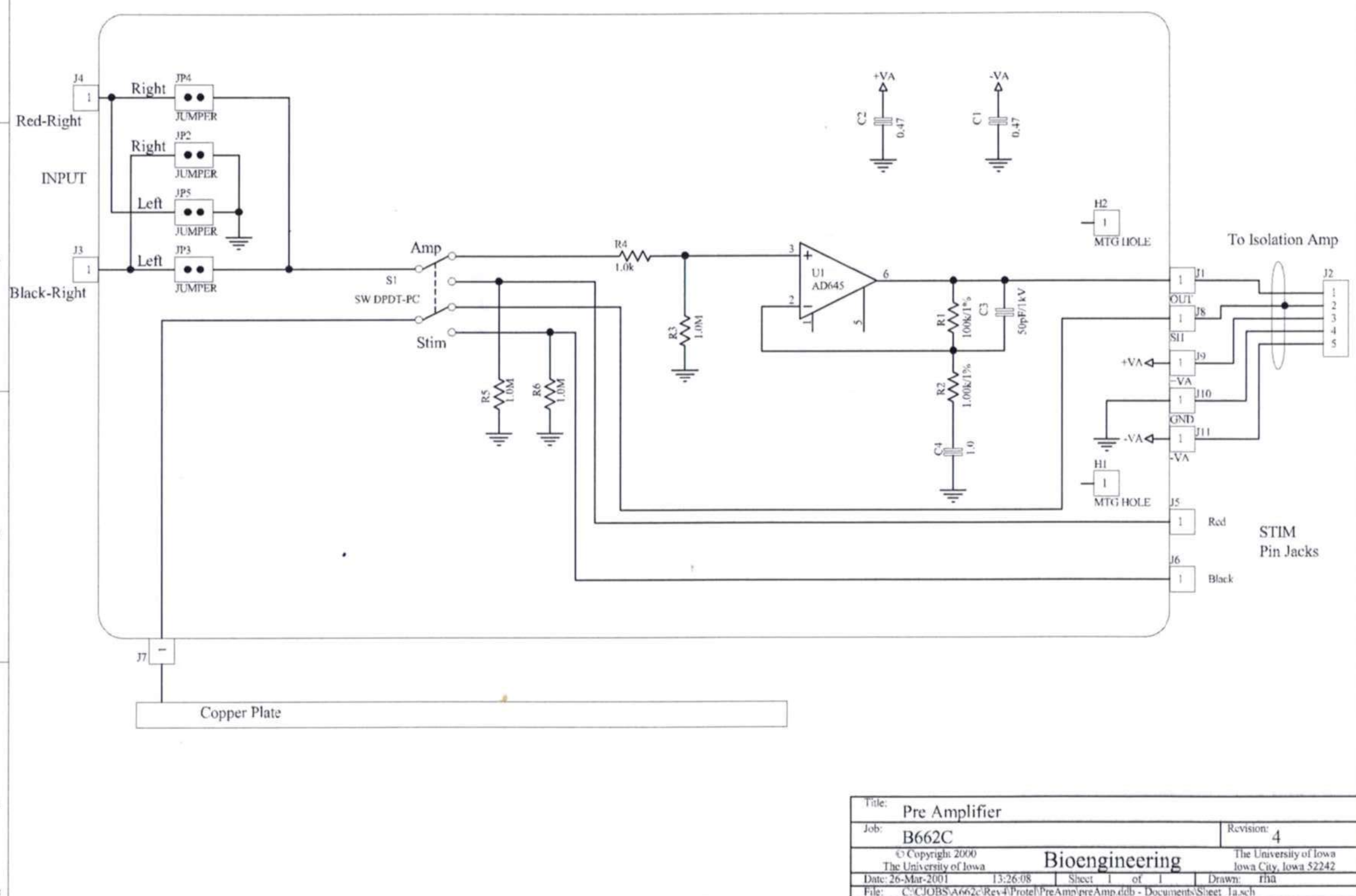
J4
Red-Right
INPUT
J3
Black-Right
Right
Right
Left
Left
JP4
JP2
JP5
JP3
JUMPER
Amp
Stim
S1
SW DPDT-PC
R4
1.0k
R3
1.0M
R5
1.0M
R6
1.0M
U1
AD645
+VA
-VA
C2
C1
0.47
R1
100k/1%
C3
50pF/1kV
R2
1.00k/1%
C4
1.0
H2
H1
MTG HOLE
To Isolation Amp
J1
OUT
J8
SI1
J9
J10
GND
J11
J2
J5
Red
J6
Black
STIM
Pin Jacks
J7
Copper Plate
Title: Pre Amplifier
Job: B662C
Revision: 4
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Sheet 1 of 1
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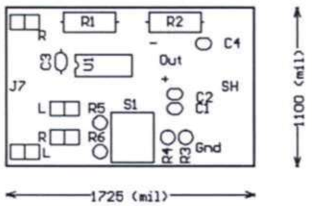
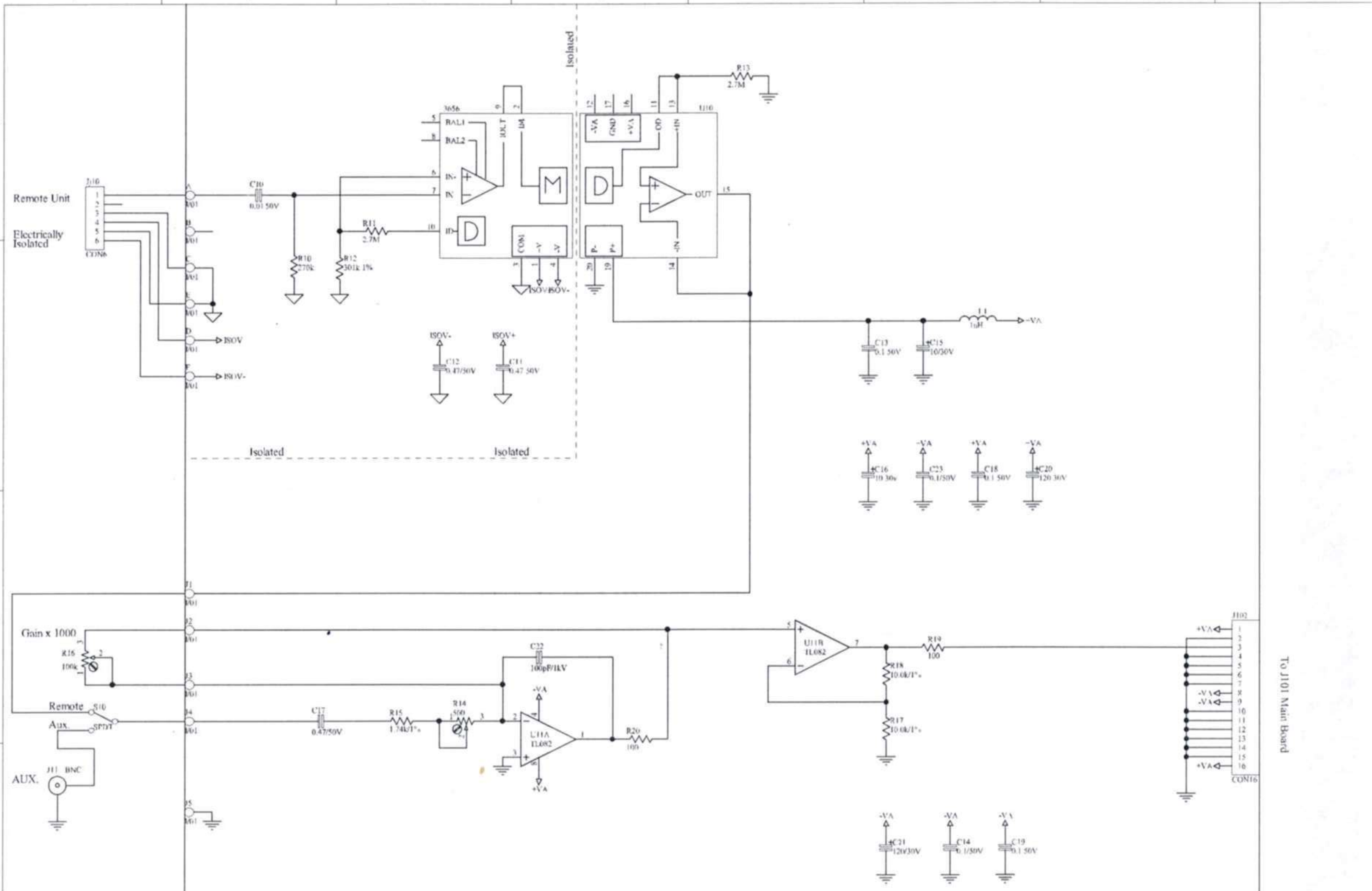
SilkScreen



Pre-Amplifier Circuit Board Layout



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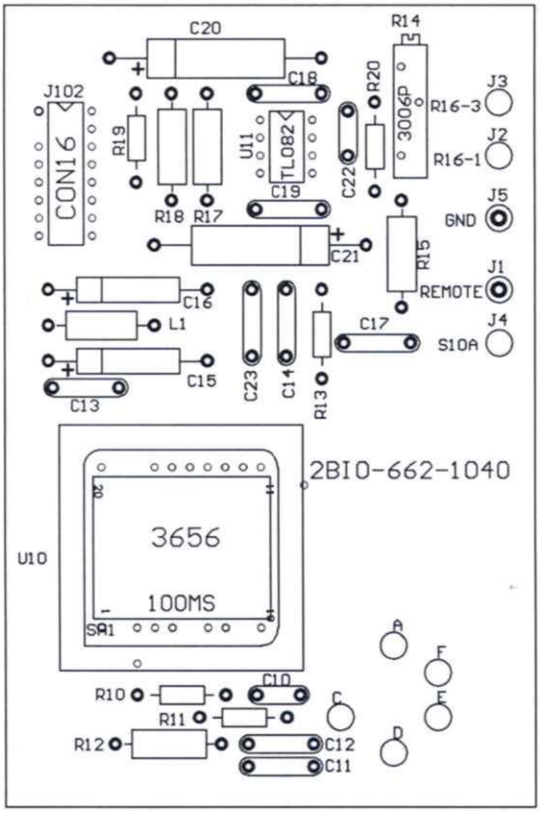
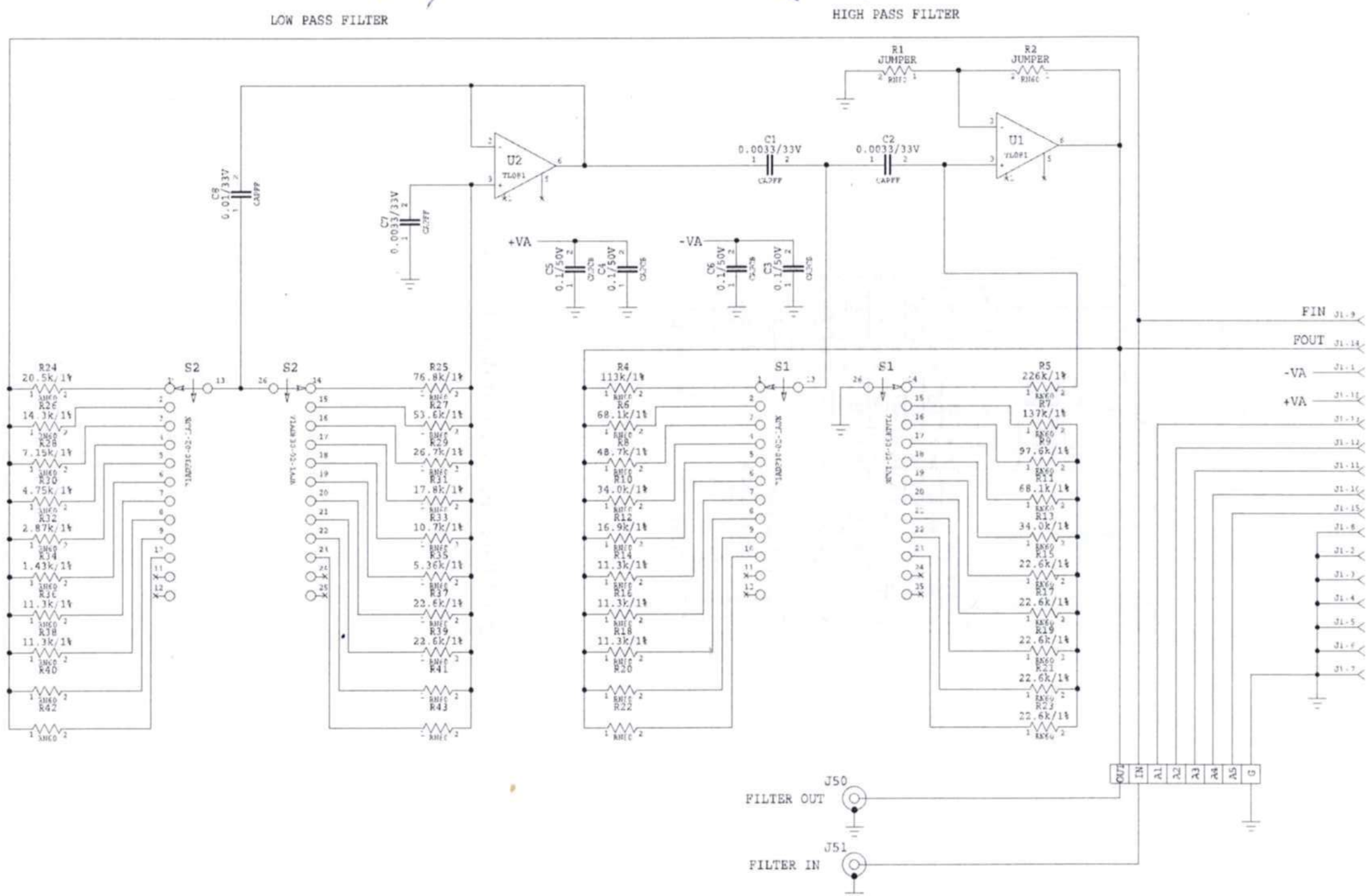


Isolation Amplifier Circuit Board Layout



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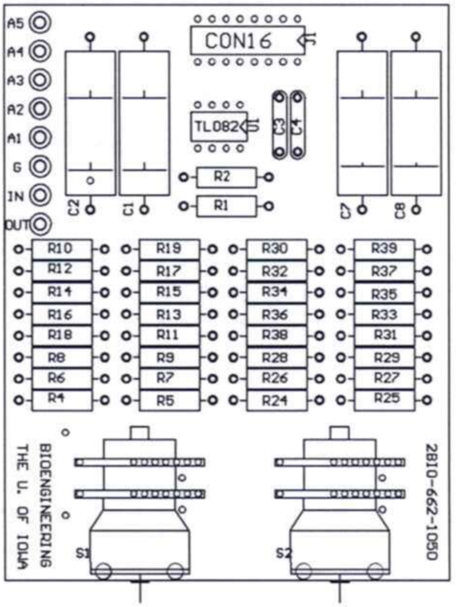
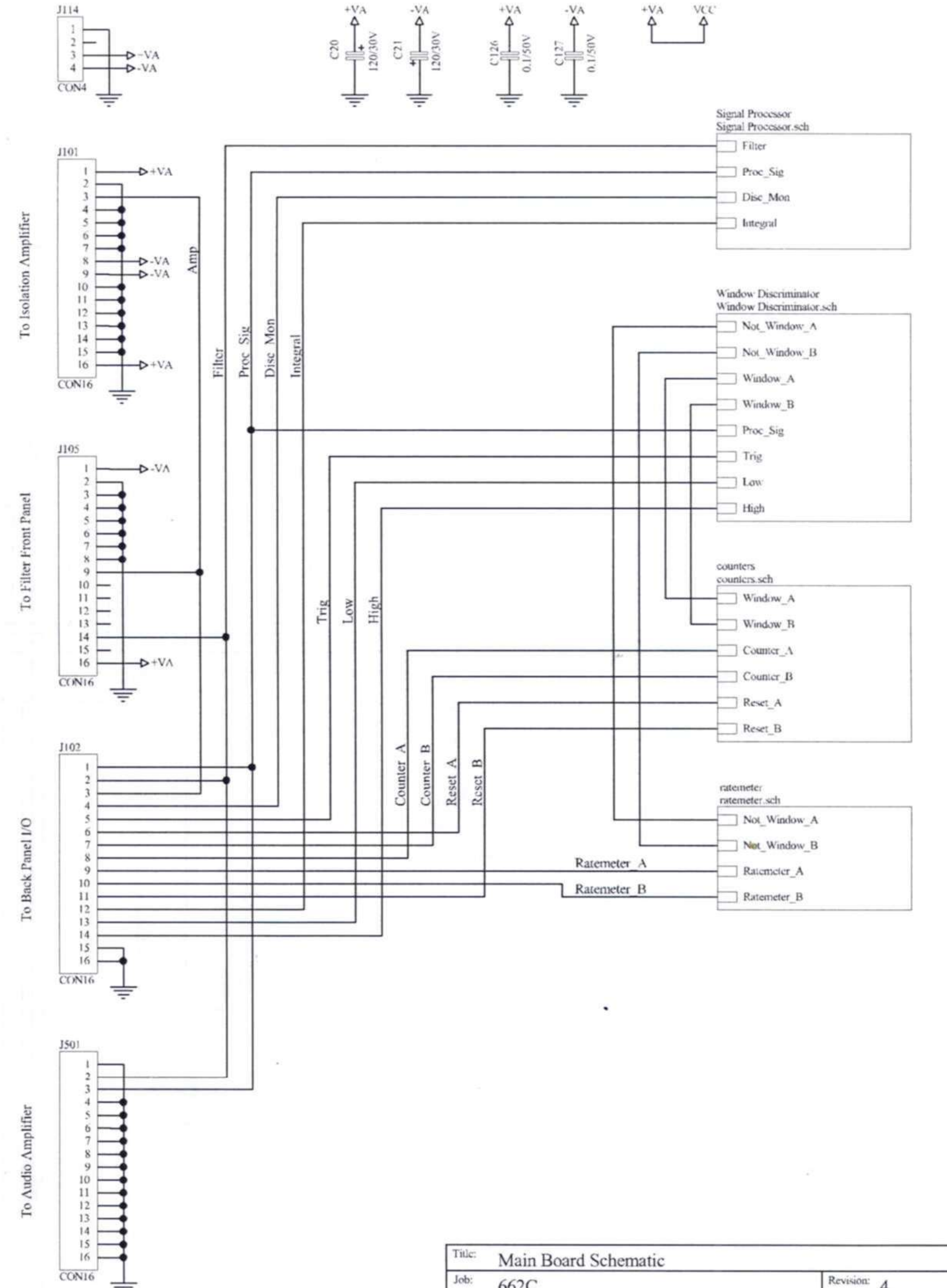
SILKSCREEN



Band Pass Filter Circuit Board Layout



Title: Main Board Schematic

Job: 662C

Revision: 4

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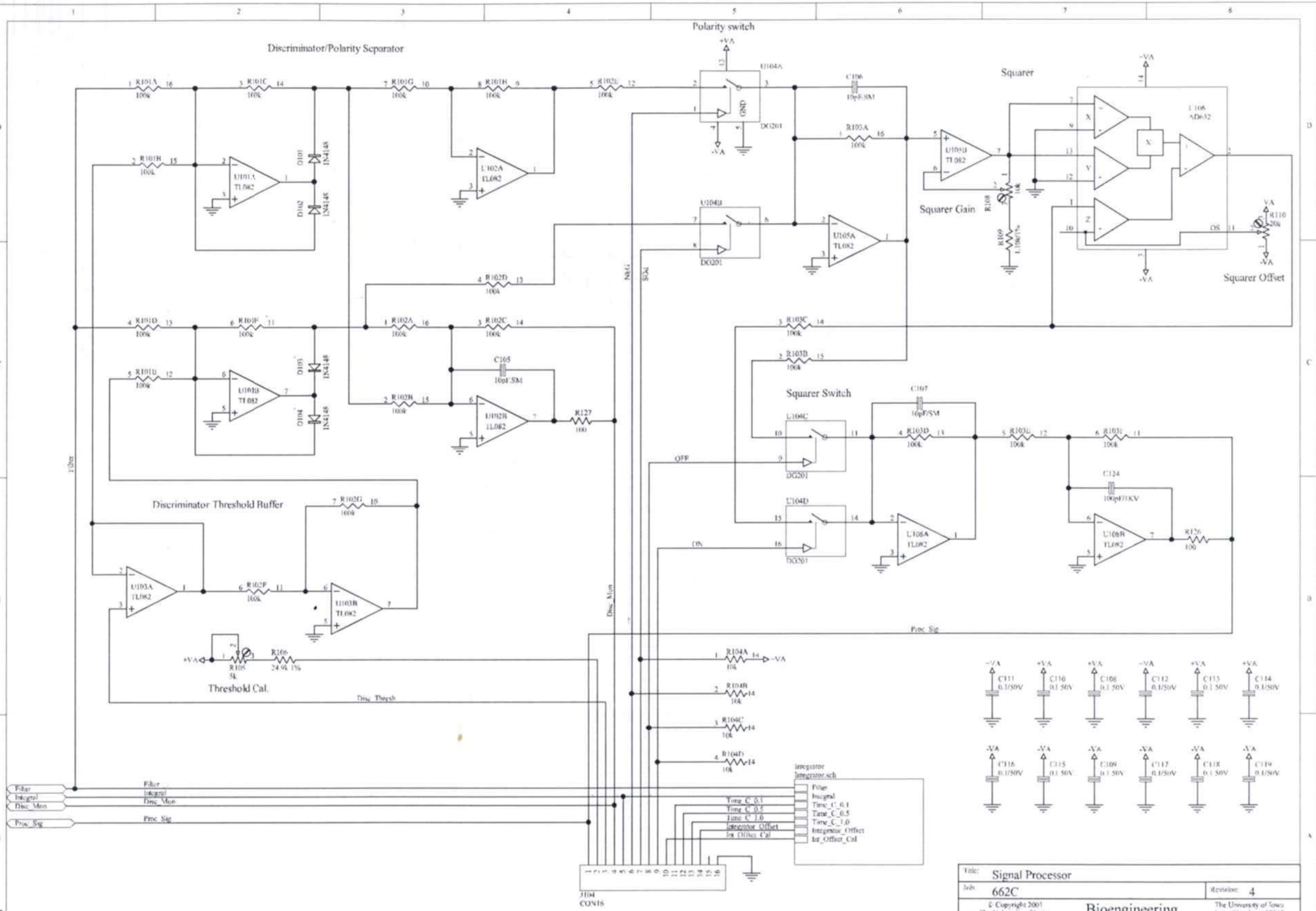
Discriminator/Polarity Separator
Polarity switch
Squarer
Squarer Gain
Squarer Offset
Squarer Switch
Discriminator Threshold Buffer
Threshold Cal.
U101A TL082
U101B TL082
U102A TL082
U102B TL082
U103A TL082
U103B TL082
U104A
U104B
U104C
U104D
DG201
U105A TL082
U105B TL082
U106 AD632
U108A TL082
U108B TL082
D101 1N4148
D102 1N4148
D103 1N4148
D104 1N4148
C105 10pF/SM
C106 10pF/SM
C107 10pF/SM
C124 100pF/1KV
R108 10k
R109 1.10k/1%
R110 20k
R105 5k
R106 24.9k 1%
R127 100
R126 100
NEG
POS
OFF
ON
Filter
Integral
Disc_Mon
Proc_Sig
Disc_Thresh
Integrator
Integrator.sch
Time_C_0.1
Time_C_0.5
Time_C_1.0
Integrator_Offset
Int_Offset_Cal
J104
CON16
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Job: 662C
Revision: 4
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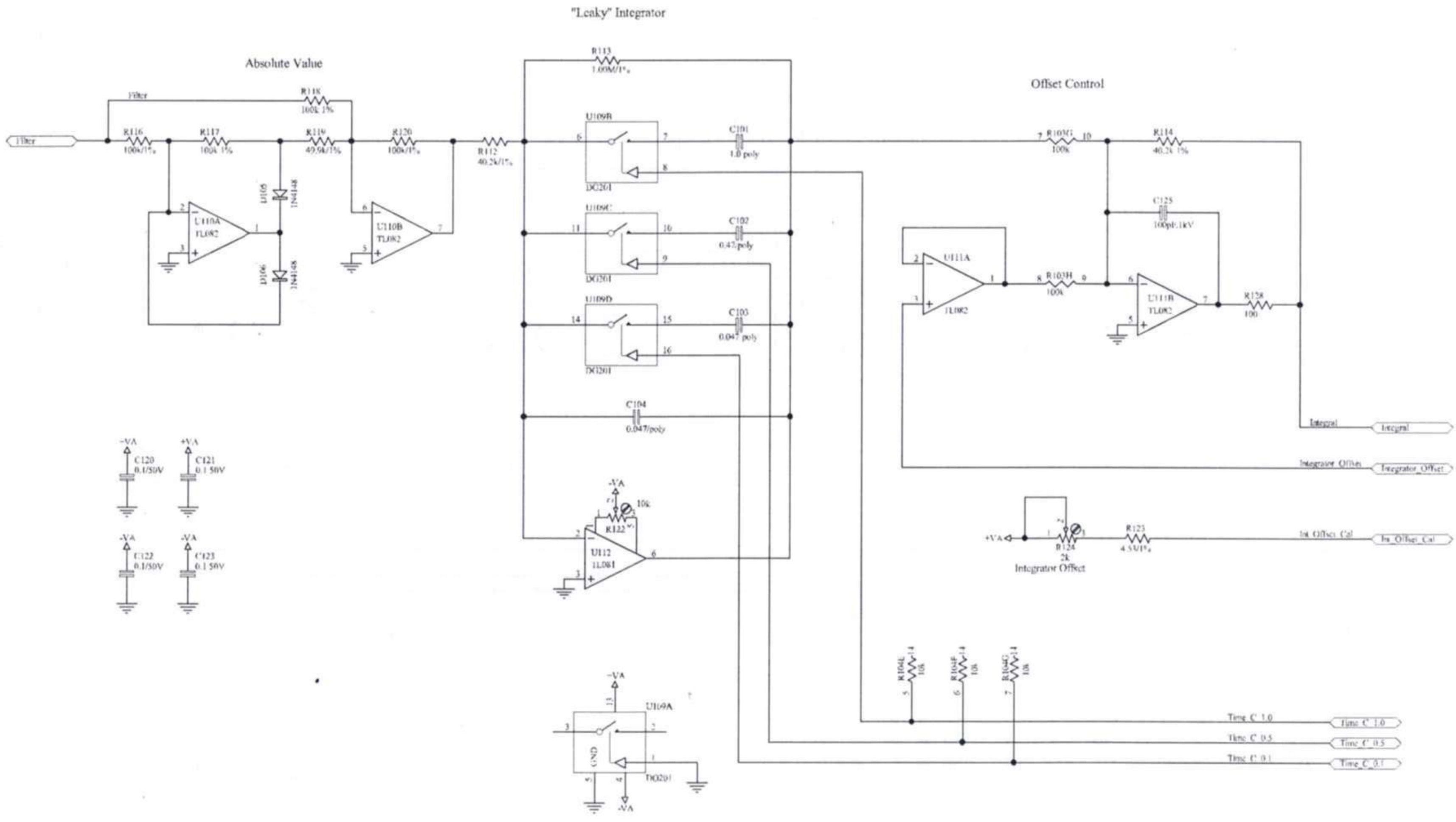

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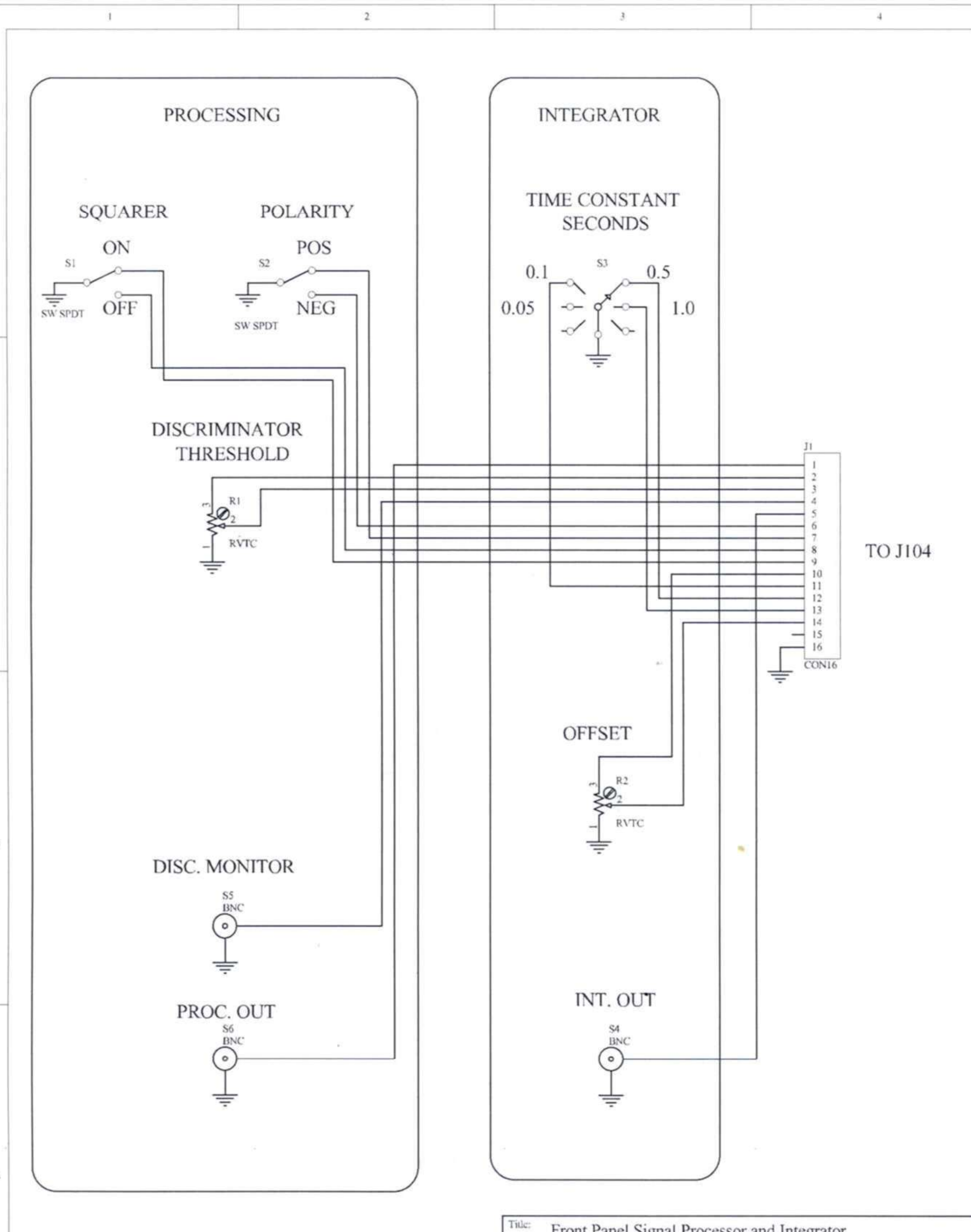

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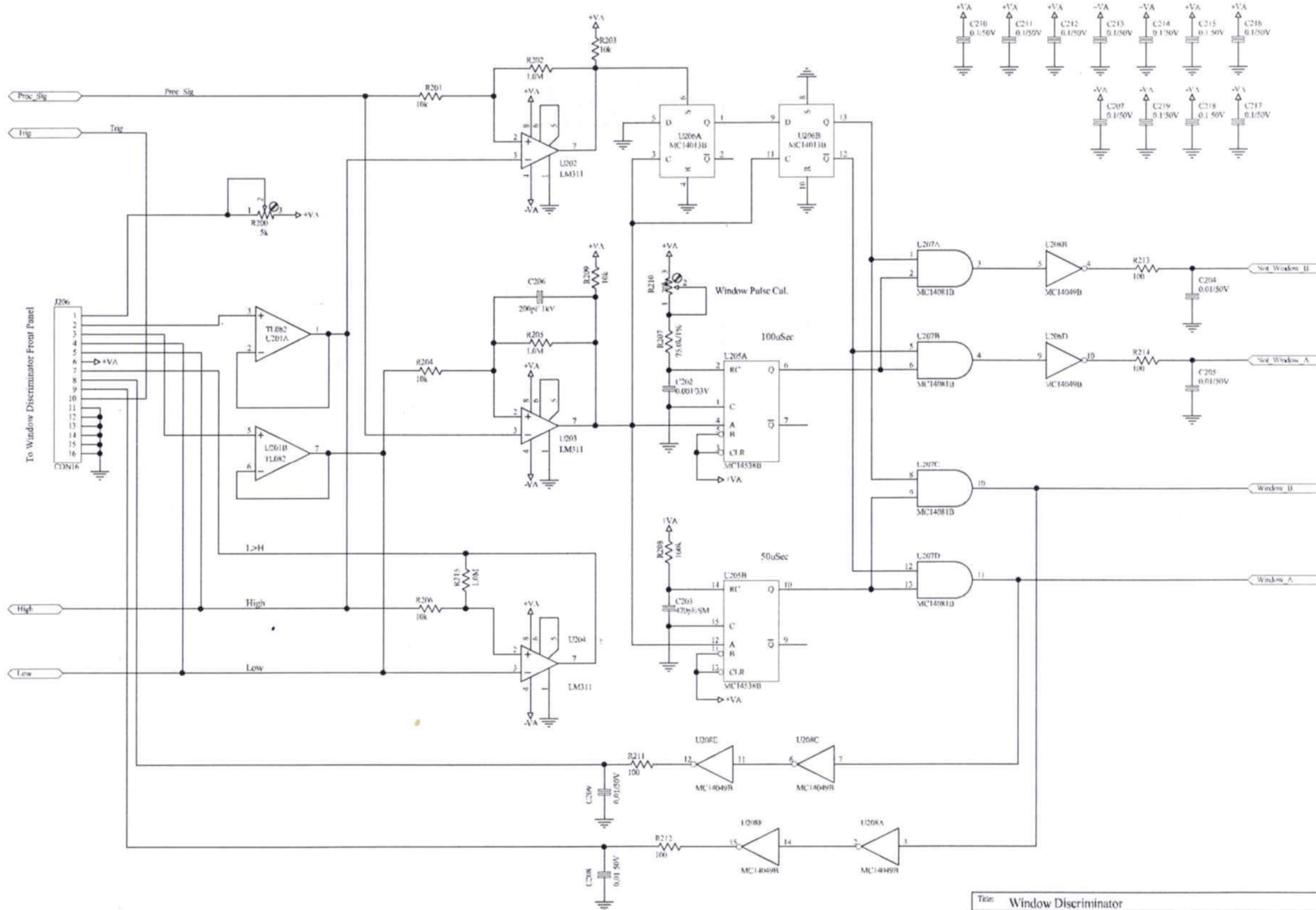

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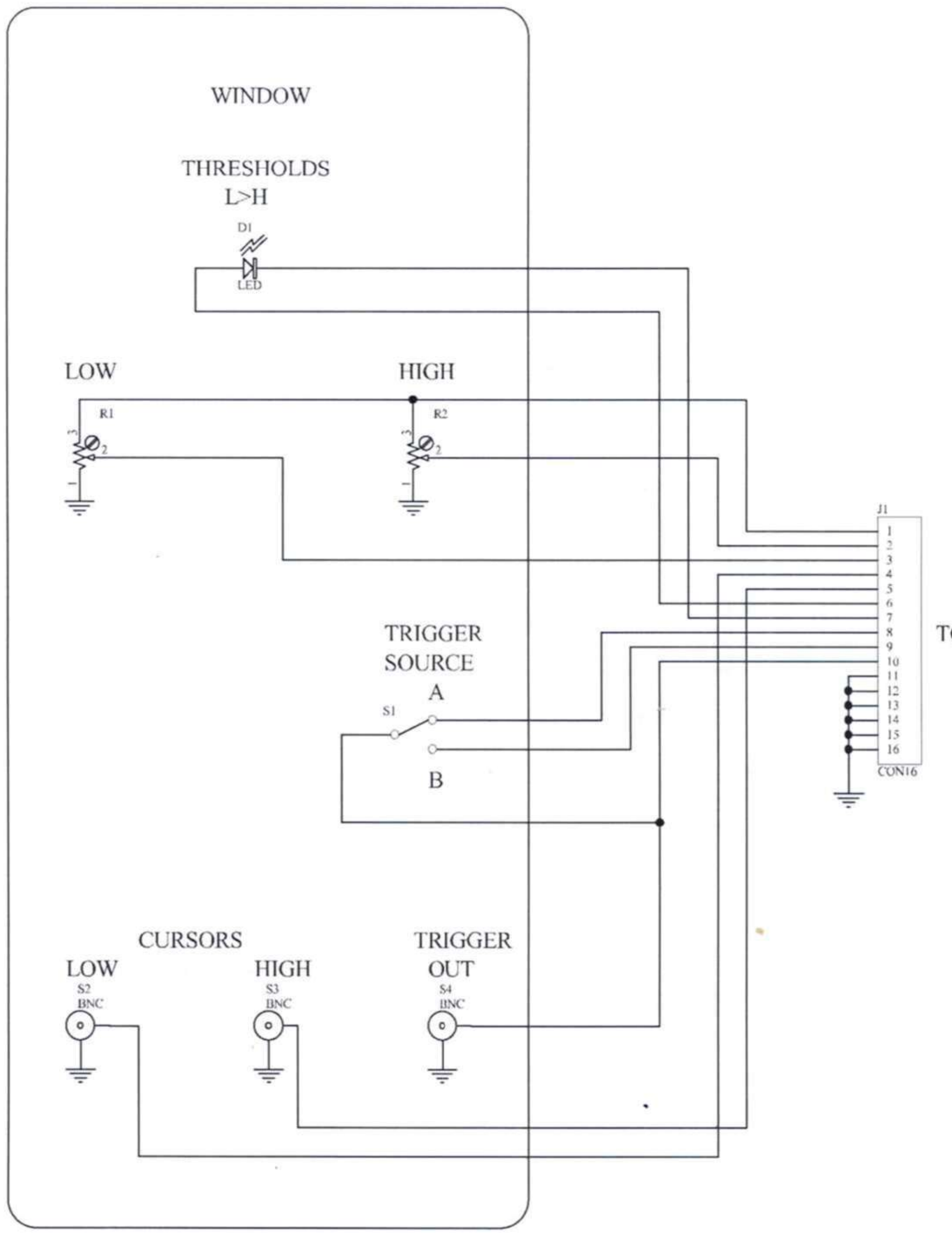

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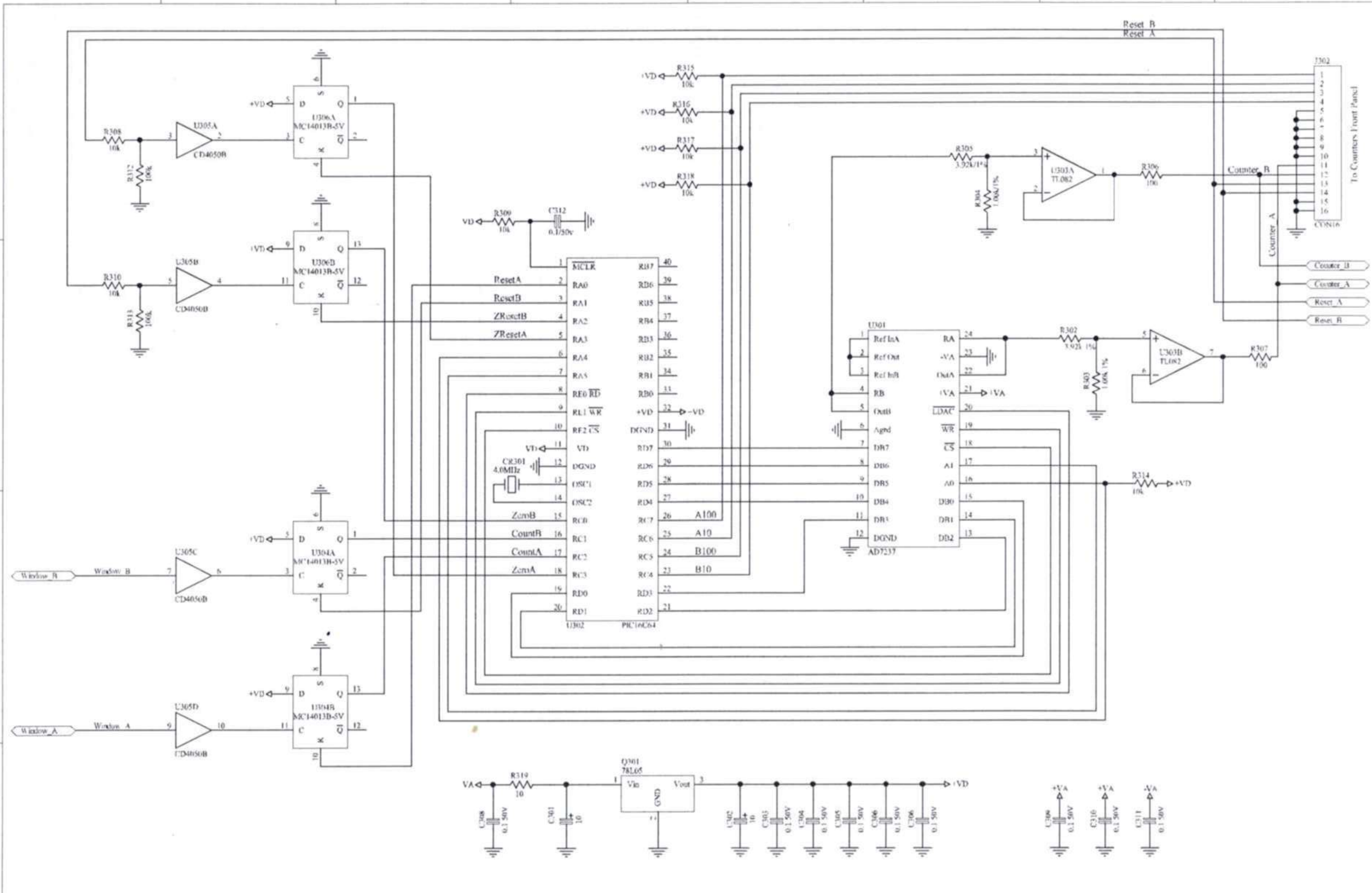

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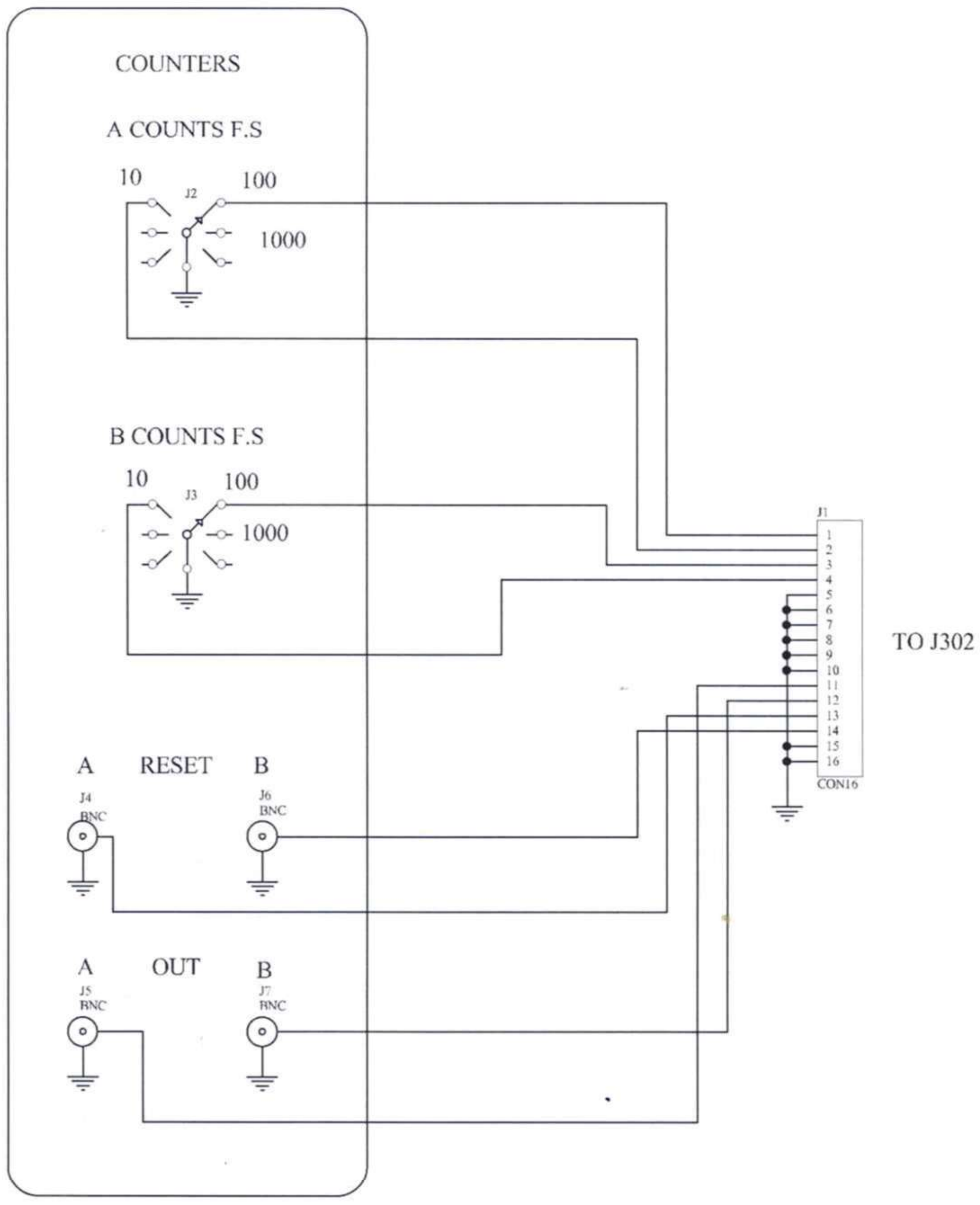

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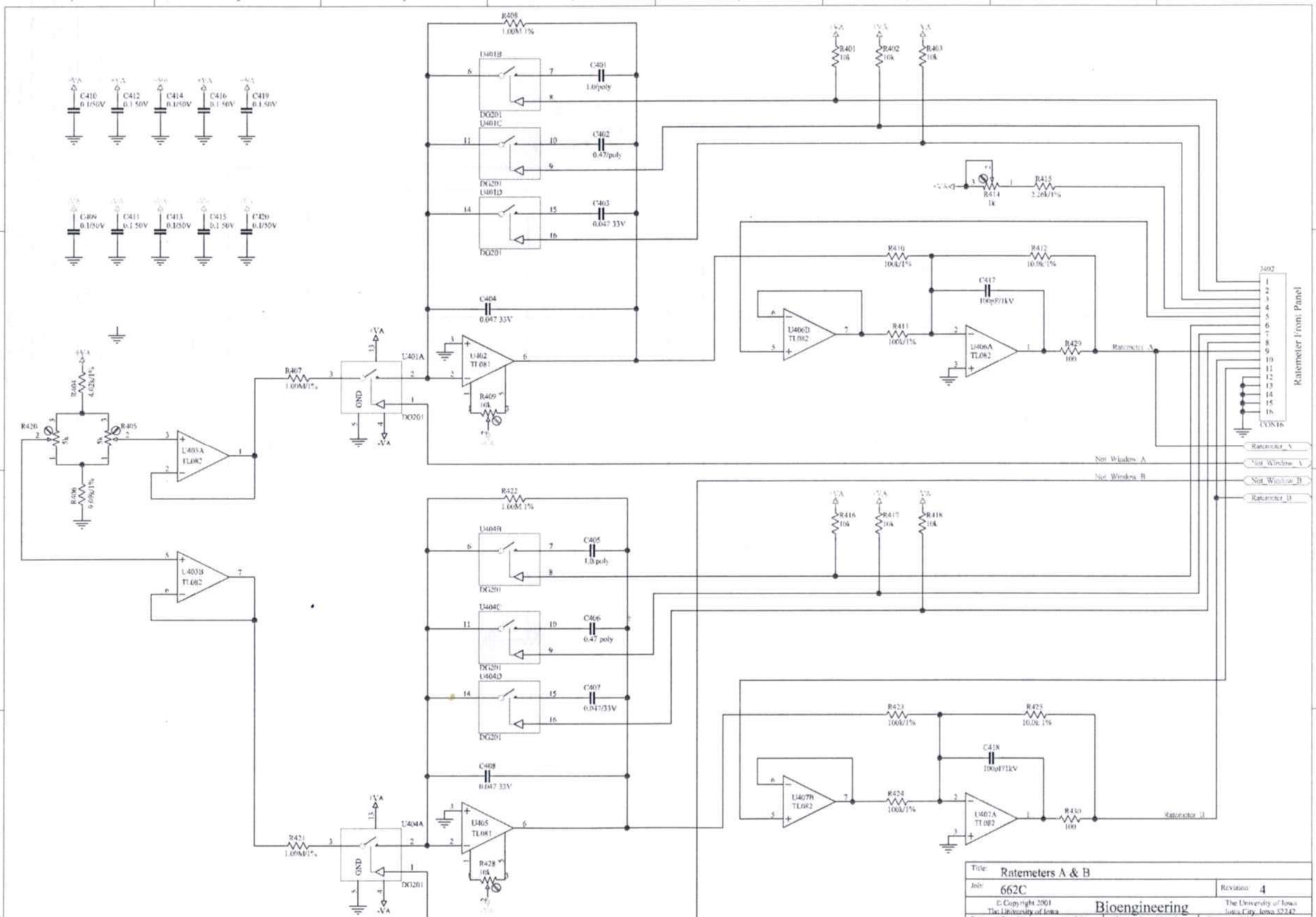

Ratemeter Front Panel
J402
CON16
Ratemeter_A
Not_Window_A
Not_Window_B
Ratemeter_B
U401A
U401B
U401C
U401D
DG201
U402
TL081
U403A
U403B
TL082
U404A
U404B
U404C
U404D
U405
U406A
U406D
U407A
U407B
R408 1.00M 1%
R422 1.00M 1%
C401 1.0/poly
C402 0.47/poly
C403 0.047 33V
C404 0.047 33V
C405 1.0 poly
C406 0.47 poly
C407 0.047/33V
C408 0.047 33V
C417 100pF/1kV
C418 100pF/1kV
R407 1.00M/1%
R421 1.00M/1%
R404 4.02k/1%
R406 9.09k/1%
R405 5k
R426 5k
R409 10k
R428 10k
R410 100k/1%
R411 100k/1%
R412 10.0k/1%
R423 100k/1%
R424 100k/1%
R425 10.0k 1%
R429 100
R430 100
R414 1k
R415 2.26k/1%
R401 10k
R402 10k
R403 10k
R416 10k
R417 10k
R418 10k
GND
+VA
-VA
Title: Ratemeters A & B
Job: 662C
Revision: 4
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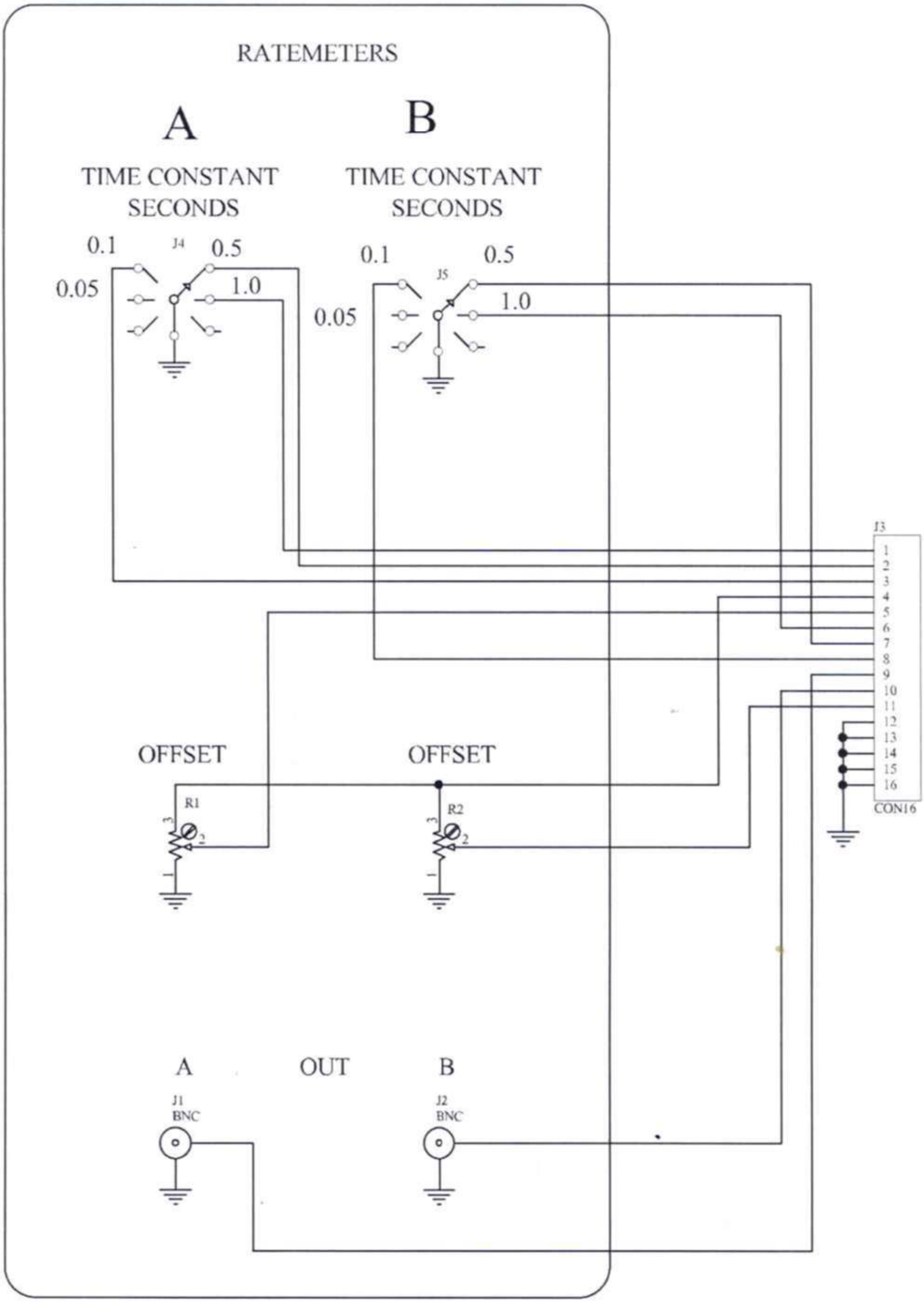
Bioengineering
The University of Iowa Iowa City, Iowa 52242



Title: Front Panel Ratemeters

Job: A662C

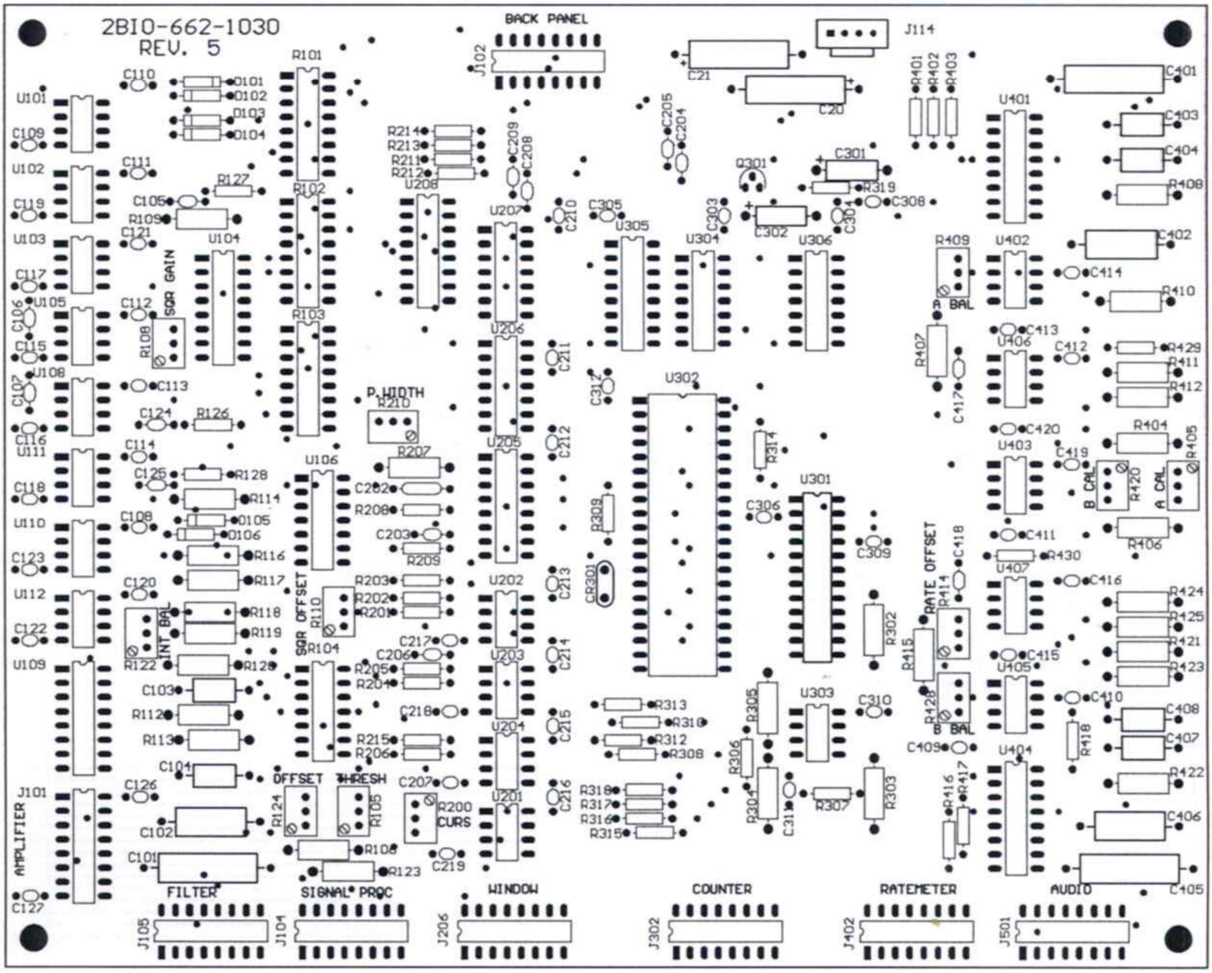
Revision: 4

Bioengineering

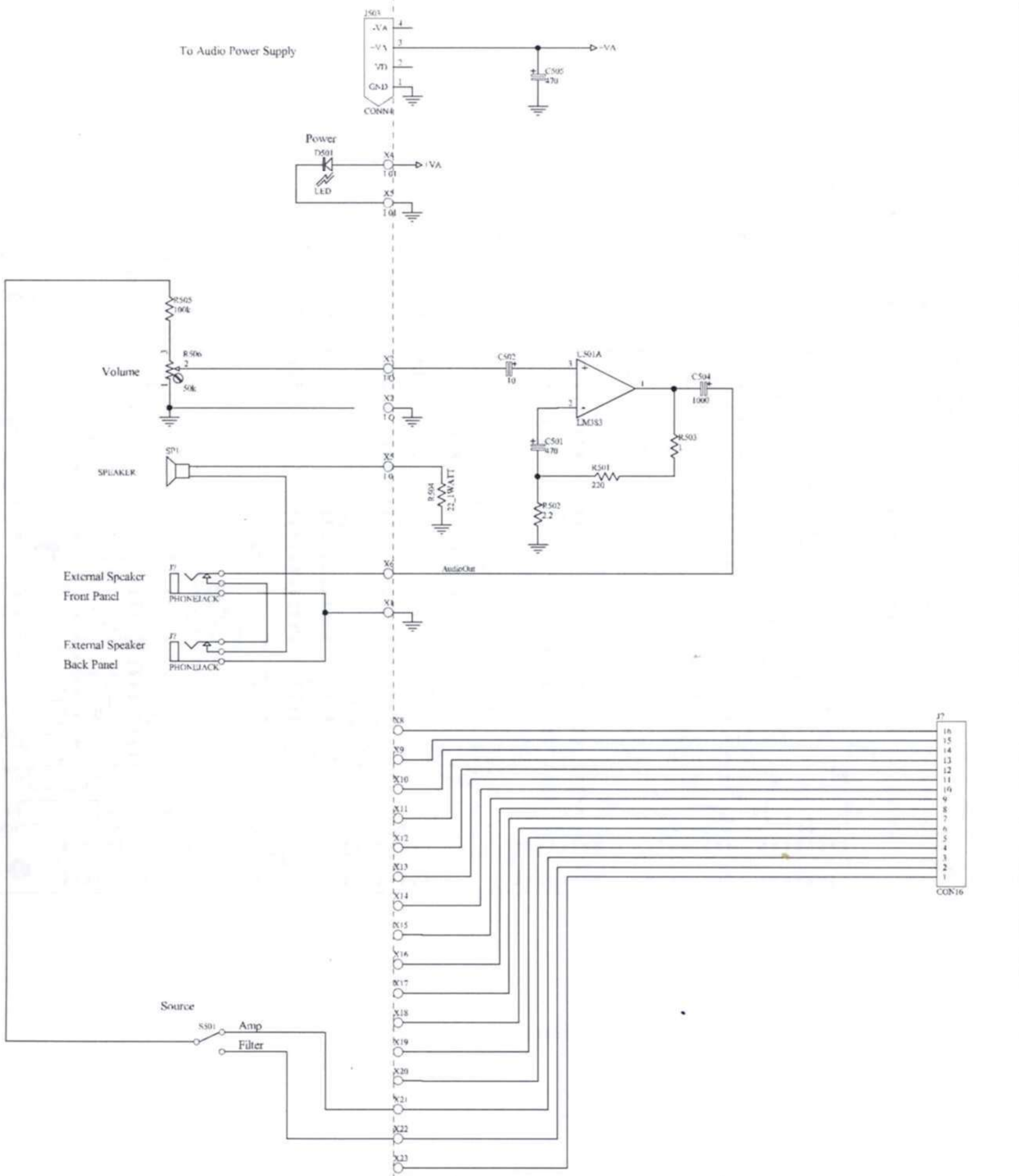
The University of Iowa Iowa City, Iowa 52242

Date: 26-Mar-2001 12:08:40 Sheet 1 of 1 Drawn:

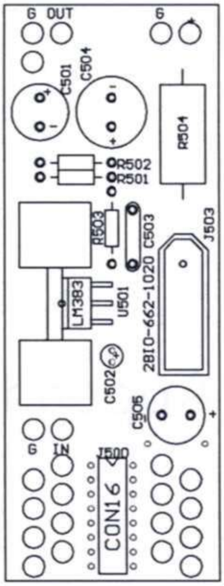
File: C:\CJOBS\A662c\Rev4\Protel\b662c5.ddb - Documents\RatemeterFP.sch



Main Board Layout



Title:	Audio Amplifier Schematic
Job: A662C-4	Revision 4
© Copyright 2001 The University of Iowa — Bioengineering	The University of Iowa, Iowa City, Iowa 52242
Date: 27-Mar-2001 15:17:38 — Sheet 1 of 1	Drawn: R.H.A.
File: C:\Program Files\Design Explorer 99 SE\Library\Sch Bio\BioSch.ddb - Templates\WordBIO1A3.dot	

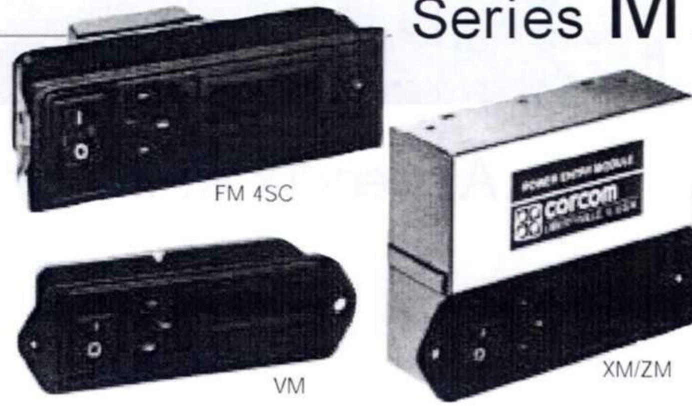


Audio Board Layout

Appendices

Appendix A: Power Entry Module

Power Entry Modules Patent No. 4,488,201 with Optional RFI Power Line Filters for General and Medical Applications



UL Recognized
CSA Certified
VDE Approved

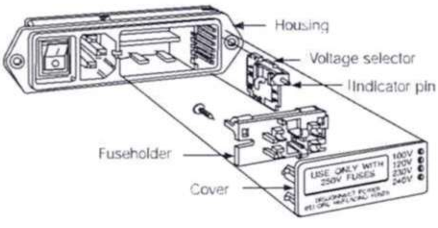
M Series

The M series power entry modules offer the most choices of power entry components and filtering options to fit a specific need. The fully configured M series expands the options of a manufacturer whose products are marketed worldwide. One component, fully assembled and tested, provides the capability of interfacing a multi-voltage power supply to any common voltage or fusing scheme in the world, without modification.

- The IEC connector provides an internationally accepted power entry termination, which can be used with a variety of line cords.
- The selectable fuseholder allows use of single or dual European fuses, or a single North American fuse.
- The optional DPST on/off switch breaks both sides of the line and is labeled with the international I/O markings.
- The optional voltage selector provides a convenient means to change transformer primary connection, and it is available in both 2-voltage and 4-voltage configurations.
- The series is available with four filter circuits to meet a variety of applications, and convenient connections are provided on unfiltered models to allow wiring of a separate RFI filter.

The M series is a family of components offering maximum flexibility and cost-effectiveness in the selection of primary power components. Wiring to the modules is accomplished via .110" terminals for labor savings and convenience.

The "C" suffix models of the M Series denote snap-in design for front mounting in panel thickness of .06 - .09.



Four filter circuits provide a choice of attenuation tailored to specific categories of susceptibility and emissions needs.

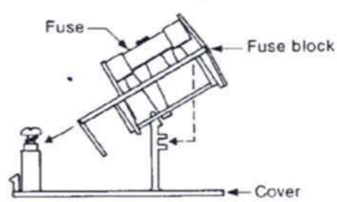
HM Models – This medical filter provides susceptibility protection without the leakage current associated with line-to-ground capacitors. Designed to allow equipment to meet UL544 for patient care and nonpatient care equipment, the HM filter has a maximum leakage current of 2 µA at 120 VAC60 Hz. See Appendix C for more information on medical applications and UL standards.

FM Models – General purpose RFI filter designed for susceptibility applications, effectively providing RFI control of line-to-ground noise. The design is compact and meets the very low leakage current requirements of SEV and VDE portable equipment as well as (120 Volt) UL544 nonpatient medical equipment.

XM Models – High performance RFI filter designed to bring most digital equipment (including switching power supplies) into compliance with FCC Part 15J, Class B conducted emissions limits.

ZM Models – Premium RFI filter designed to bring most digital equipment (including switching power supplies) into compliance with EN55022, Level B (as well as FCC Part 15J, Class B) conducted emissions limits.

Fuse Block/Cover Assembly



To change from North American to European fusing: open cover, using small blade screwdriver or similar tool; loosen Phillips screw two turns; remove fuse block by sliding up, then away from Phillips screw and lifting up from pedestal; change fuses; (note that *two* European fuses are required, although a dummy fuse may be used in the neutral [lower] holder); invert fuse block and slide back onto Phillips screw and pedestal; tighten Phillips screw, and replace cover (note that fuse(s) that go into the housing first are the active set).

M Series

Unfiltered Models

Part Number	Current Rating @120VAC (Amps)	Current Rating @250VAC (Amps)	Available Voltage Selection Position*	DPST On/Off Switch	Mounting Style	Fuseholder Type
6VM1	6	6	1	–	Flange	Selectable
6VM1C	6	6	1	–	Snap-in	Selectable
6VM1S	6	4	1	•	Flange	Selectable
6VM1SC	6	4	1	•	Snap-in	Selectable
6VM2	6	6	2	–	Flange	Selectable
6VM2S	6	6	2	•	Flange	Selectable
6VM4	6	6	4	–	Flange	Selectable
6VM4C	6	6	4	–	Snap-in	Selectable
6VM4S	6	4	4	•	Flange	Selectable
6VM4SC	6	4	4	•	Snap-in	Selectable

* 1 - 120V/240V Fixed 2 - 120/240V Selectable 4 - 100V, 120V, 230V, 240V Selectable • Includes DPST switch

Filtered Models

Part Number	RFI Filter Type	Current Rating @120VAC (Amps)	Current Rating @250VAC (Amps)	Available Voltage Selection Position	DPST On/Off Switch	Mounting Style	Fuseholder Type
5EHM1	Medical[1]	5	4	1	–	Flange	Selectable
5EHM1S	Medical[1]	5	4	1	•	Flange	Selectable
5EHM4	Medical[1]	5	4	4	–	Flange	Selectable
5EHM4S	Medical[1]	5	4	4	•	Flange	Selectable
5EFM1	General Purpose[2]	5	4	1	–	Flange	Selectable
5EFM1C	General Purpose[2]	5	4	1	–	Snap-in	Selectable
5EFM1S	General Purpose[2]	5	4	1	•	Flange	Selectable
5EFM1SC	General Purpose[2]	5	4	1	•	Snap-in	Selectable
5EFM4	General Purpose[2]	5	4	4	–	Flange	Selectable
5EFM4C	General Purpose[2]	5	4	4	–	Snap-in	Selectable
5EFM4S	General Purpose[2]	5	4	4	•	Flange	Selectable
5EFM4SC	General Purpose[2]	5	4	4	•	Snap-in	Selectable
3EXM1S	SMPS FCC-B[3]	3	2	1	•	Flange	Selectable
3EXM4	SMPS FCC-B[3]	3	2	4	–	Flange	Selectable
3EXM4S	SMPS FCC-B[3]	3	2	4	•	Flange	Selectable
3EZM1S	SMPS EN55022-B[4]	3	2	1	•	Flange	Selectable
3EZM4	SMPS EN55022-B[4]	3	2	4	–	Flange	Selectable
3EZM4S	SMPS EN55022-B[4]	3	2	4	•	Flange	Selectable

[1] Medical filter for very low leakage UL 544 health care applications.
[2] General purpose filter for susceptibility applications.
[3] Emissions filter for switching power supply applications where FCC-B level requirements must be met.
[4] Emissions filter for switching power supply applications where EN55022-B level requirements must be met.

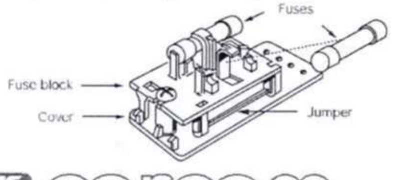
Consult your local Corcom sales representative for pricing.

Refer to catalog page 83 for more information on available RFI filter types.

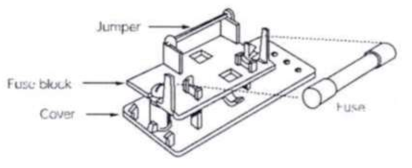
* 1 - 120V/240V Fixed 4 - 100V, 120V, 230V, 240V Selectable • Includes DPST switch

Fuse Changing

European Fusing Arrangement



North American Fusing Arrangement



Specifications – Unfiltered Models

Hipot rating (one minute):
- line-to-ground: 1500 VAC
- line-to-line: 1450 VDC
- line-to-load (switch off): 2500 VAC

Operating voltages: 100, 120, 230, 240 VAC

Operating frequency: 50/60 Hz

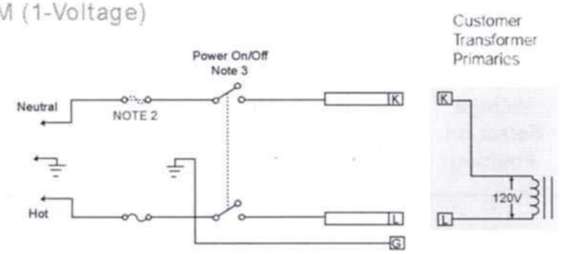
Switch: Double-insulated, rated for 100,000 operations at full load; 10,000 operations at 70 Amps inrush current.

Fuse (not included): Reversible fuseholder accepts one 1/4 x 1-1/4" fuse or two 5 x 20mm fuses.

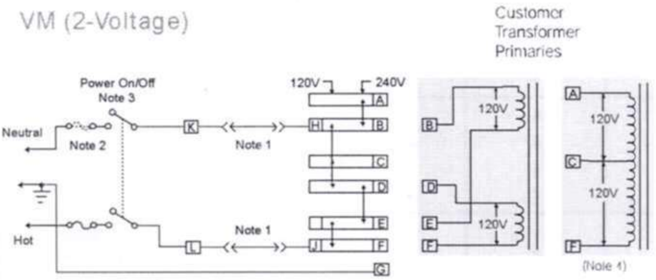
Terminals: .110" (2.79mm) terminals

Electrical Schematics – Unfiltered Models

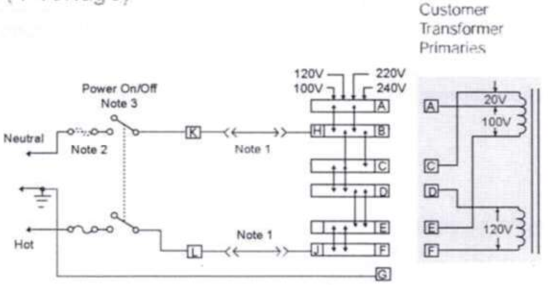
VM (1-Voltage)



VM (2-Voltage)



VM (4-Voltage)



Note 1: Jumpers required if no input filter is used.
Note 2: Provision for dual European style fusing.
Note 3: On/off switch present only with "S" suffix.
Note 4: When using a center-tapped transformer, the C-F winding should be the low voltage (high current) winding and must be capable of handling the full primary current in the 120V position.

Specifications – Filtered Models

Maximum leakage current, each line-to-ground:

@ 120 VAC 60 Hz:	HM Models	2 µA
	FM Models	0.25 mA
	XM/ZM Models	0.30 mA
@ 250 VAC 50 Hz:	HM Models	5 µA
	FM/XM/ZM Models	0.50 mA

Hipot rating (one minute):

line-to-ground	HM Models	1500 VAC
	FM/XM/ZM	1500 VAC
line-to-line	All Models	1450 VDC

Operating voltages: 100, 120, 230, 240 VAC

Operating frequency: 50/60 Hz

Rated voltage: 120/250 VAC

Switch: Double-insulated, rated for 100,000 operations at full load; 10,000 operations at 70 Amps inrush current.

Fuse (not included): Reversible fuseholder accepts one 1/4 x 1-1/4" fuse or two 5 x 20 mm fuses.

Terminals: .110" (2.79mm) terminals

Minimum insertion loss in dB:
Line-to-ground in 50 ohm circuit:

Frequency MHz	HM 5A	FM 5A	XM 3A	ZM 3A
.01	–	–	2	15
.05	–	–	13	29
.15	14	14	23	39
.5	18	21	40	46
1	19	26	46	43
5	22	40	44	40
10	22	45	44	40
30	17	40	44	40

Line-to-line in 50 ohm circuit

Frequency MHz	XM 3A	ZM 3A
.02	–	5
.03	–	13
.05	–	28
.07	5	37
.15	34	55
.5	62	75
1	68	75
5	60	62
10	50	54
30	40	44

230V Nomenclature relates to pending European CENELEC agreement.

M Series

Case Dimensions – Unfiltered Models

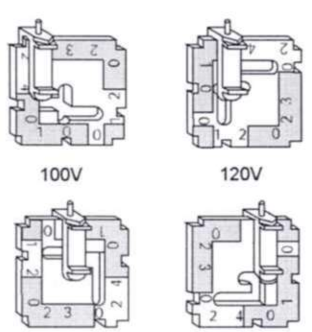
Metric shown in italics.

Part No.	A (max)	B ± 0.01 *± 0.25*	C (max)	D (max)	E (max)	F (max)
6VM1	3.39 / *86.1*	2.84 / *72.1*	1.14 / *29.0*	2.44 / *62.0*	1.45 / *36.8*	2.5 / *63.5*
6VM1C	2.56 / *86.1*	—	1.14 / *29.0*	2.44 / *62.0*	1.45 / *36.8*	2.5 / *63.2*
6VM1S	4.17 / *105.9*	3.62 / *91.9*	1.14 / *29.0*	3.22 / *81.8*	1.45 / *36.8*	3.28 / *83.3*
6VM1SC	3.34 / *84.8*	—	1.14 / *29.0*	3.27 / *83.1*	1.45 / *36.8*	3.27 / *83.1*
6VM2 6VM4	3.88 / *98.6*	3.32 / *84.3*	1.14 / *29.0*	2.92 / *74.2*	1.45 / *36.8*	2.98 / *75.7*
6VM4C	3.04 / *98.6*	—	1.14 / *29.0*	2.92 / *74.2*	1.45 / *36.8*	2.97 / *75.4*
6VM2S 6VM4S	4.65 / *118.1*	4.1 / *104.1*	1.14 / *29.0*	3.72 / *94.5*	1.45 / *36.8*	3.76 / *95.5*
6VM4SC	3.82 / *97.0*	—	1.14 / *29.0*	3.7 / *94.0*	1.45 / *36.8*	3.75 / *95.3*

Voltage Selection

To change selected voltage: open cover, using small blade screwdriver or similar tool; set aside cover/fuse block assembly; pull voltage selector card straight out of housing, using indicator pin; orient selector card so that desired voltage is readable at the bottom: orient indicator pin to point up when desired voltage is readable at bottom (note that when indicator pin is fixed, successive voltages are selected by rotating the card 90° clockwise); insert voltage selector card into housing, *printed side of card facing forward toward IEC connector and edge containing the desired voltage first;* replace cover, and verify that indicator pin shows the desired voltage.

Voltage Selector Card Orientation

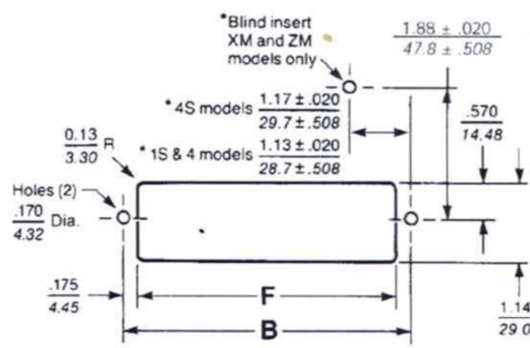


Case Dimensions – Filtered Models

Metric shown in italics.

Part No.	A (max)	B ± 0.01 *± 0.25*	C (max)	D (max)	E (max)	F (max)	G
5EFM1 5EHM1	3.39 / *86.1*	2.84 / *72.1*	1.14 / *29.0*	2.44 / *62.0*	2.19 / *55.6*	2.5 / *63.5*	—
5EFM1C	2.56 / *65.0*	—	1.14 / *29.0*	2.44 / *62.0*	2.19 / *55.6*	2.49 / *63.2*	—
5EFM1S 5EHM1S	4.17 / *105.9*	3.62 / *91.9*	1.14 / *29.0*	3.22 / *81.8*	2.19 / *55.6*	3.28 / *83.3*	—
5EFM1SC	3.34 / *84.8*	—	1.14 / *29.0*	3.27 / *83.1*	2.19 / *55.6*	3.27 / *83.1*	—
5EFM4 5EHM4	3.88 / *98.6*	3.32 / *84.3*	1.14 / *29.0*	2.92 / *74.2*	2.19 / *55.6*	2.98 / *75.7*	—
5EFM4C	3.04 / *77.2*	—	1.14 / *29.0*	2.92 / *74.2*	2.19 / *55.6*	2.97 / *75.4*	—
5EFM4S 5EHM4S	4.65 / *118.1*	4.1 / *104.1*	1.14 / *29.0*	3.7 / *94.0*	2.19 / *55.6*	3.76 / *95.5*	—
5EFM4SC	3.82 / *97.0*	—	1.14 / *29.0*	3.7 / *94.0*	2.19 / *55.6*	3.75 / *95.3*	—
3EXM1S 3EZM1S	4.17 / *105.9*	3.62 / *91.9*	1.14 / *29.0*	3.22 / *81.8*	1.72 / *43.7*	3.28 / *83.8*	3.3 / *83.8*
3EXM4 3EZM4	3.88 / *98.6*	3.32 / *84.3*	1.14 / *29.0*	2.92 / *74.2*	1.72 / *43.7*	2.98 / *75.7*	2.99 / *75.9*
3EXM4S 3EZM4S	4.65 / *118.1*	4.1 / *104.1*	1.14 / *29.0*	3.72 / *94.5*	1.72 / *43.7*	3.76 / *95.5*	3.8 / *96.5*

Recommended Panel Cutout



Note: Snap-in models allow front mount only.
XM and ZM models allow back mount only.
FM and HM models allow front or back mounting.

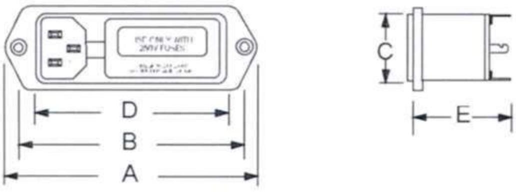
Accessories for M series include interconnection assembly, medical standoff bracket, voltage selector cards, and insulating shroud. See page 117.

All mounting holes countersunk.

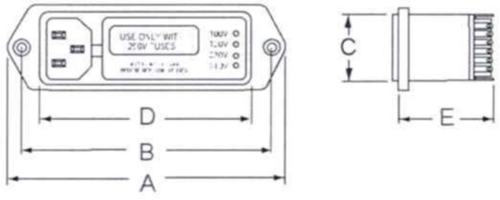
Case Styles – Unfiltered Models

Metric shown in italics.

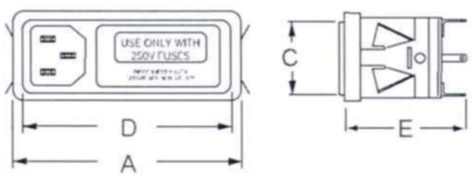
6VM1
IEC Connector, Selectable Fuseholder



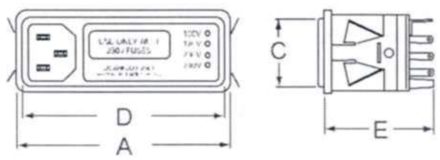
6VM2 & 6VM4
IEC Connector, Voltage Selector, Selectable Fuseholder



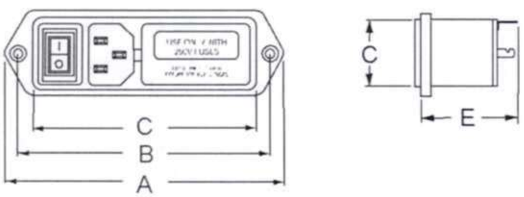
6VM1C
IEC Connector, Selectable Fuseholder, Snap-In



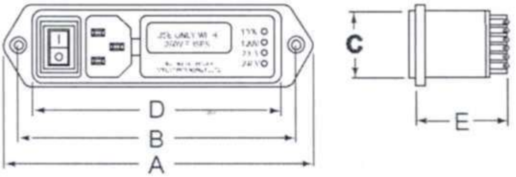
6VM4C
IEC Connector, Voltage Selector, Selectable Fuseholder, Snap-In



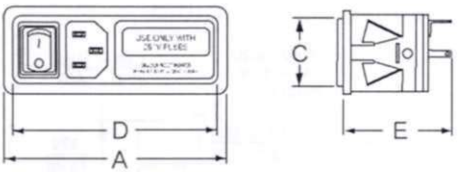
6VM1S
IEC Connector, DPST On/Off Switch, Selectable Fuseholder



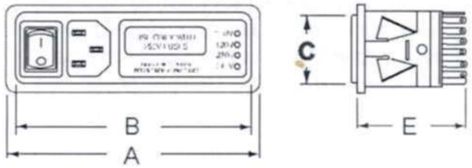
6VM2S & 6VM4S
IEC Connector, DPST On/Off Switch, Voltage Selector, Selectable Fuseholder



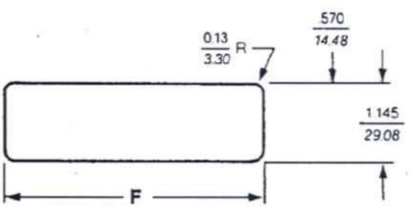
6VM1SC
IEC Connector, DPST On/Off Switch, Selectable Fuseholder, Snap-In



6VM4SC
IEC Connector, DPST On/Off Switch, Voltage Selector, Selectable Fuseholder, Snap-In



Recommended Panel Cutout
Snap-In Only



Mounting holes: .155 / *3.94* Dia. (2)
with .279 Dia. x 82° Countersunk

All mounting holes countersunk.

BURR - BROWN®

3656

Transformer Coupled ISOLATION AMPLIFIER

FEATURES

- INTERNAL ISOLATED POWER
- 8000V ISOLATION TEST VOLTAGE
- 0.5μA MAX LEAKAGE AT 120V, 60Hz
- 3-PORT ISOLATION
- IMR: 125dB REJECTION AT 60Hz
- 1" x 1" x 0.25" CERAMIC PACKAGE

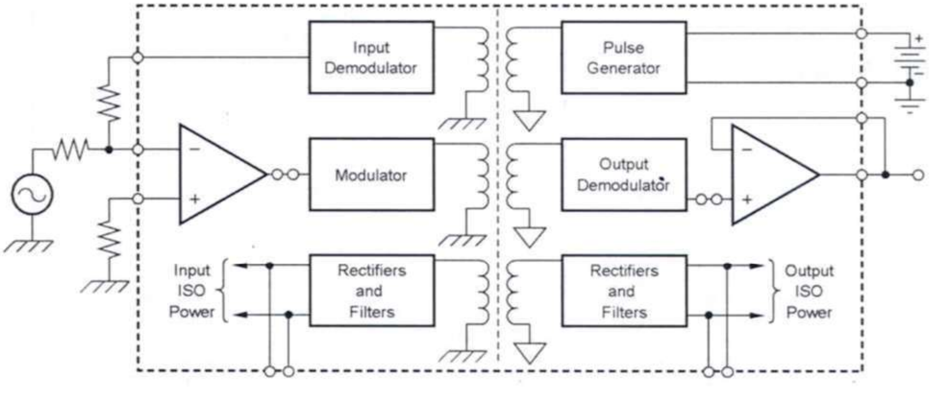
APPLICATIONS

- MEDICAL
  Patient Monitoring and Diagnostic Instrumentation
- INDUSTRIAL
  Ground Loop Elimination and Off-ground Signal Measurement
- NUCLEAR
  Input/Output/Power Isolation

DESCRIPTION

The 3656 was the first amplifier to provide a total isolation function, both signal and power isolation, in integrated circuit form. This remarkable advancement in analog signal processing capability was accomplished by use of a patented modulation technique and miniature hybrid transformer.

Versatility and performance are outstanding features of the 3656. It is capable of operating with three completely independent grounds (three-port isolation). In addition, the isolated power generated is available to power external circuitry at either the input or output. The uncommitted op amps at the input and the output allow a wide variety of closed-loop configurations to match the requirements of many different types of isolation applications.



This product is covered by the following United States patents: 4,066,974; 4,103,267; 4,082,908. Other patents pending may also apply upon the allowance and issuance of patents thereon. The product may also be covered in other countries by one or more international patents corresponding to the above-identified U.S. patents.

International Airport Industrial Park • Mailing Address: PO Box 11400, Tucson, AZ 85734 • Street Address: 6730 S. Tucson Blvd., Tucson, AZ 85706 • Tel: (520) 746-1111 • Twx: 910-952-1111
Internet: http://www.burr-brown.com/ • FAXLine: (800) 548-6133 (US/Canada Only) • Cable: BBRCORP • Telex: 066-6491 • FAX: (520) 889-1510 • Immediate Product Info: (800) 548-6132

SPECIFICATIONS

ELECTRICAL

At +25°C, V± = 15VDC and 15VDC between P+ and P–, unless otherwise specified.

PARAMETER	CONDITIONS	3656AG, BG, HG, JG, KG MIN	TYP	MAX	UNITS
ISOLATION					
Voltage					
Rated Continuous(1), DC		3500 (1000)			VDC
Test, 10s(1)		8000 (3000)			VDC
Test, 60s(1)	G_1 = 10V/V	2000 (700)			Vrms
Rejection					
DC			160		dB
60Hz, < 100Ω in I/P Com(2)			125		dB
60Hz, 5kΩ in I/P Com(2)					
3656HG		108			dB
3656AG, BG, JG, KG		112			dB
Capacitance(1)			6 (6.3)		pF
Resistance(1)			10^{12} (10^{12})		Ω
Leakage Current	120V, 60Hz		0.28	0.5	µA
GAIN					
Equations	See Text				
Accuracy of Equations					
Initial(3) 3656HG	G < 100V/V			1.5	%
3656AG, JG, KG				1	%
3656BG				0.3	%
vs Temperature 3656HG				480	ppm/°C
3656AG, JG				120	ppm/°C
3656BG, KG				60	ppm/°C
vs Time			0.02 (1 + log khrs.)		%
Nonlinearity	$R_A + R_F = R_B \geq 2M\Omega$				
External Supplies Used at					
Pins 12 and 16, 3656HG	Unipolar or Bipolar Output			±0.15	%
3656AG, JG, KG				±0.1	%
3656BG				±0.05	%
Internal Supplies Used for	Bipolar Output Voltage				
Output Stage	Swing, Full Load(4)		±0.15		%
OFFSET VOLTAGE(5), RTI					
Initial(3), 3656HG	15Vp between P+ and P–			$\pm[4 + (40/G_1)]$	mV
3656AG, JG				$\pm[2 + (20/G_1)]$	mV
3656BG, KG				$\pm[1 + (10/G_1)]$	mV
vs Temperature, 3656HG				$\pm[200 + (1000/G_1)]$	µV/°C
3656JG				$\pm[50 + (750/G_1)]$	µV/°C
3656AG				$\pm[25 + (500/G_1)]$	µV/°C
3656KG				$\pm[10 + (350/G_1)]$	µV/°C
3656BG				$\pm[5 + (350/G_1)]$	µV/°C
vs Supply Voltage	Supply between P+ and P–				
3656HG				$\pm[0.6 + (3.5/G_1)]$	mV/V
3656AG, BG, JG, KG				$\pm[0.3 + (2.1/G_1)]$	mV/V
vs Current(6)			$\pm[0.1 + (10/G_1)]$	$\pm[0.2 + (20/G_1)]$	mV/mA
vs Time			$\pm[10 + (100/G_1)]$ • (1 + log khrs.)		µV
AMPLIFIER PARAMETERS, Apply to A_1 and A_2					
Bias Current(7)					
Initial				100	nA
vs Temperature			0.5		nA/°C
vs Supply			0.2		nA/V
Offset Current(7)			5	20	nA
Impedance	Common-Mode		100 || 5		MΩ || pF
Input Noise Voltage	f_B = 0.05Hz to 100Hz		5		µVp-p
	f_B = 10Hz to 10kHz		5		µVrms
Input Voltage Range(8)					
Linear Operation	Internal Supply			±5	V
	External Supply			Supply –5	V
Output Current	V_{OUT} = ±5V				
	±15V External Supply	±5			mA
	Internal Supply	±2.5			mA
	V_{OUT} = ±10V				
	±15V External Supply	±2.5			mA
	V_{OUT} = ±2V, $V_{P+, P-}$ = 8.5V				
	Internal Supply		±1		mA
Quiescent Current			150	450	µA

SPECIFICATIONS (CONT)

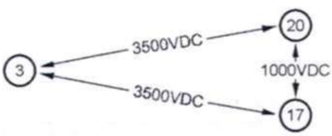
ELECTRICAL

At +25°C, V± = 15VDC and 15VDC between P+ and P–, unless otherwise specified.

PARAMETER	CONDITIONS	3656AG, BG, HG, JG, KG			UNITS
		MIN	TYP	MAX	
FREQUENCY RESPONSE					
±3dB Response	Small Signal		30		kHz
Full Power			1.3		kHz
Slew Rate	Direction Measured at Output	+0.1, –0.04			V/µs
Settling Time	to 0.05%		500		µs
OUTPUT					
Noise Voltage (RTI)	f_B = 0.05Hz to 100Hz		$\sqrt{(5)^2 + (22/G_1)^2}$		µVp-p
	f_B = 10Hz to 10kHz		$\sqrt{(5)^2 + (11/G_1)^2}$		µVrms
Residual Ripple(9)			5		mVp-p
POWER SUPPLY IN, at P+, P–					
Rated Performance			15		VDC
Voltage Range(10)	Derated Performance	8.5		16	VDC
Ripple Current(9)			10	25	mAp-p
Quiescent Current(11)	Average		14	18	mA/DC
Current vs Load Current(12)	vs Current from +V, –V, V+, V–		0.7		mA/mA
ISOLATED POWER OUT, At +V, –V, V+, V– pins(13)					
Voltage, No Load	15V Between P+ and P–	8.5	9	9.5	V
Voltage, Full Load	±5mA (10mA sum) Load(12)	7	8	9	V
Voltage vs Power Supply	vs Supply Between P+ and P–		0.66		V/V
Ripple Voltage(9)					
No Load			40		mVp-p
Full Load	±5mA Load		80	200	mVp-p
TEMPERATURE RANGE					
Specification 3656AG, BG		–25		+85	°C
3656HG, JG, KG		0		+70	°C
Operation(10)		–55		+100	°C
Storage(14)		–65		+125	°C

NOTES: (1) Ratings in parenthesis are between P- (pin 20) and O/P Com (pin 17). Other isolation ratings are between I/P Com and O/P Com or I/P Com and P–. (2) See Performance Curves. (3) May be trimmed to zero. (4) If output swing is unipolar, or if the output is not loaded, specification same as if external supply were used. (5) Includes effects of A_1 and A_2 offset voltages and bias currents if recommended resistors used. (6) Versus the sum of all external currents drawn from V+, V–, +V, –V (= ISO). (7) Effects of A_1 and A_2 bias currents and offset currents are included in Offset Voltage specifications. (8) With respect to I/P Com (pin 3) for A_1 and with respect to O/P Com (pin 17) for A_2. CMR for A_1 and A_2 is 100dB, typical. (9) In configuration of Figure 3. Ripple frequency approximately 750kHz. Measurement bandwidth is 30kHz. (10) Decreases linearly from 16VDC at 85°C to 12VDC at 100°C. (11) Instantaneous peak current required from pins 19 and 20 at turn-on is 100mA for slow rising voltages (50ms) and 300mA for fast rises (50µs). (12) Load current is sum drawn form +V, –V, V+, V– (= I_{SO}). (13) Maximum voltage rating at pins 1 and 4 is ±18VDC; maximum voltage rating at pins 12 and 16 is ±18VDC. (14) Isolation ratings may degrade if exposed to 125°C for more than 1000 hours or 90°C for more than 50,000 hours.

Example of the ratings for 3-port continuous isolation.



PACKAGE INFORMATION

PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER (1)
3656	20-Lead ISO Omni	102A

NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix C of Burr-Brown IC Data Book.

PIN DESIGNATIONS

NO.	DESCRIPTION	NO.	DESCRIPTION
1	+V	11	Output DEMOD
2	MOD Input	12	V–
3	Input DEMOD COM	13	A_2 Noninverting Input
4	–V	14	A_2 Inverting Input
5	Balance	15	A_2 Output
6	A_1 Inverting Input	16	V+
7	A_1 Noninverting Input	17	Output DEMOD COM
8	Balance	18	No Pin
9	A_1 Output	19	P+
10	Input DEMOD	20	P–

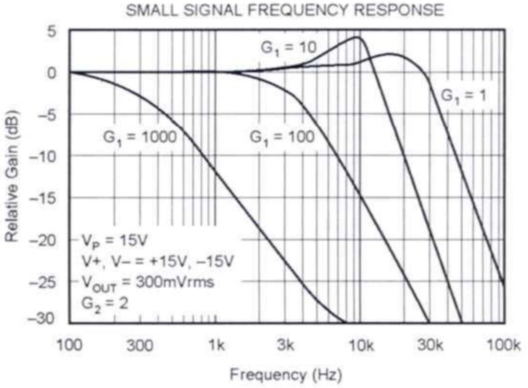
ABSOLUTE MAXIMUM RATINGS

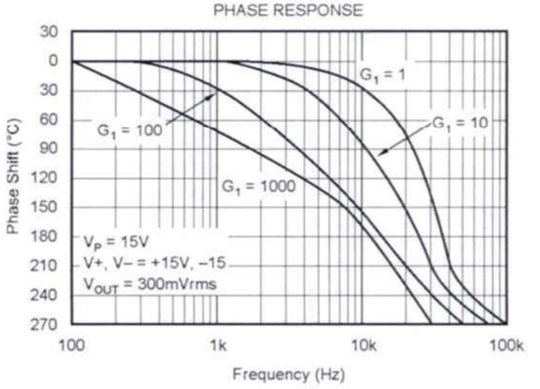
Supply Without Damage	16V
Input Voltage Range Using Internal Supply	±8V
Input Voltage Range Using External Supply	Supply
Continuous Isolation Voltage(1)	3500, (1000) VDC
Storage Temperature	–65°C to +125°C
Lead Temperature, (soldering, 10s)	+300°C

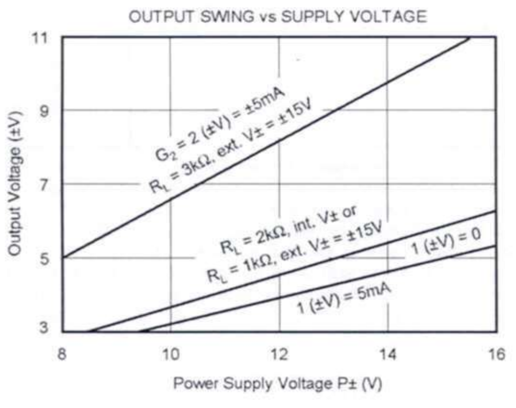
NOTE: (1) Ratings in parenthesis are between P– (pin 20) and O/P Com (pin 17). Other isolation ratings are between I/P Com and O/P Com or I/P Com and P–.

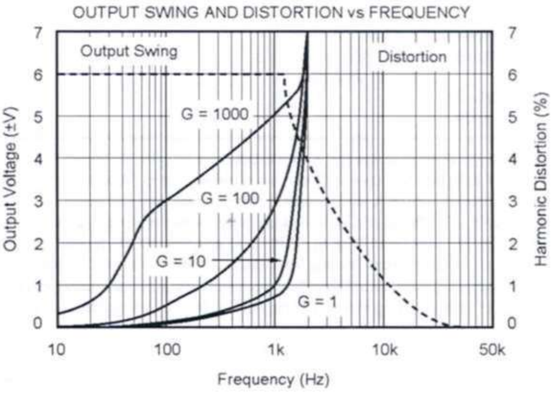
TYPICAL PERFORMANCE CURVES

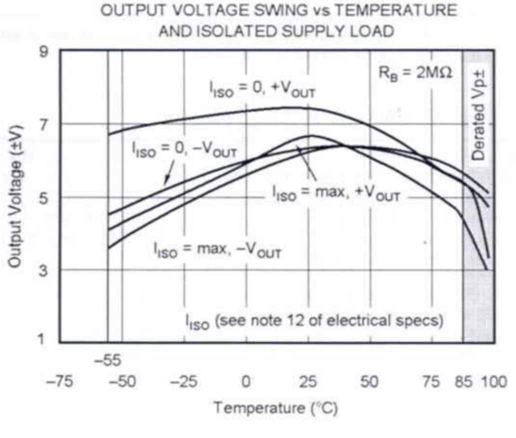
All specifications typical at +25°C, unless otherwise specified.

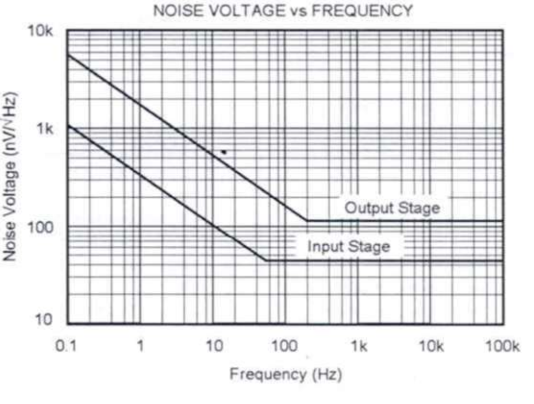








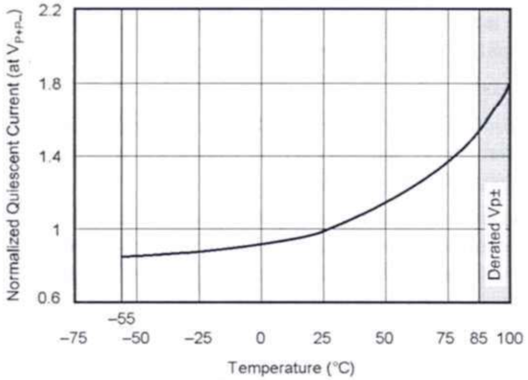




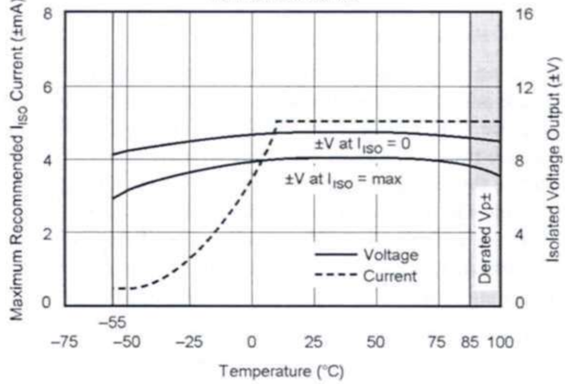
TYPICAL PERFORMANCE CURVES (CONT)

All specifications typical at +25°C, unless otherwise specified.

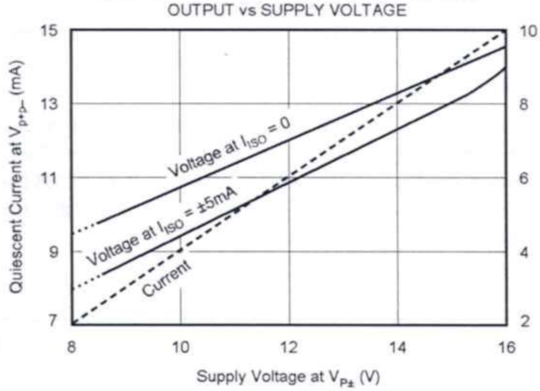
QUIESCENT CURRENT vs TEMPERATURE



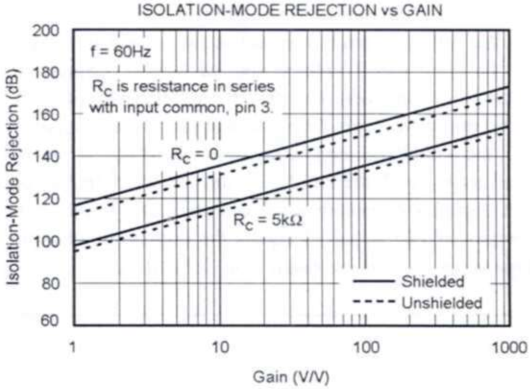
ISOLATED OUTPUT VOLTAGE AND CURRENT vs TEMPERATURE



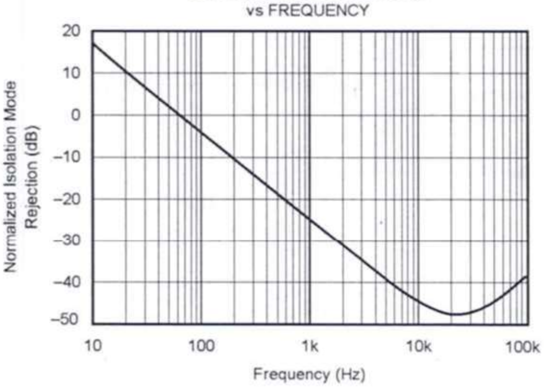
QUIESCENT CURRENT AND ISOLATED VOLTAGE OUTPUT vs SUPPLY VOLTAGE



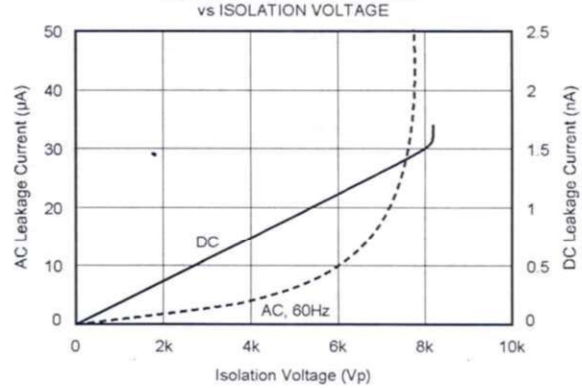
ISOLATION-MODE REJECTION vs GAIN



ISOLATION MODE REJECTION vs FREQUENCY



AC AND DC LEAKAGE CURRENT vs ISOLATION VOLTAGE



THEORY OF OPERATION

Details of the 3656 are shown in Figure 1. The external connections shown, place it in its simplest gain configuration —unity gain, noninverting. Several other amplifier gain configurations and power isolation configurations are possible. See Installation and Operating Instructions and Applications sections for details.

Isolation of both signal and power is accomplished with a single miniature toroid transformer with multiple windings. A pulse generator operating at approximately 750kHz provides a two-part voltage waveform to transformer, T_1. One part of the waveform is rectified by diodes D_1 through D_4 to provide the isolated power to the input and output stages (+V, –V and V+, V–). The other part of the waveform is modulated with input signal information by the modulator operating into the V_2 winding of the transformer.

The modulated signal is coupled by windings W_6 and W_7 to two matched demodulators—one in the input stage and one in the output stage—which generate identical voltages at their outputs, pins 10 and 11 (Voltages identical with respect to their respective commons, pins 3 and 17). In the input stage the input amplifier, A_1, the modulator and the input demodulator are connected in a negative feedback loop. This forces the voltage at pin 6 (connect as shown in Figure 1) to equal the input signal voltage applied at pin 7. Since the input and the output demodulators are matched and produce identical output voltages, the voltage at pin 11 (referenced to pin 17, the output common) is equal to the voltage at pin 10 (referenced to pin 3, the input common). In the output stage, output amplifier A_2 is connected as a unity gain buffer, thus the output voltage at pin 15 equals the output demodulator voltage at pin 11. The end result is an isolated output voltage at pin 15 equal to the input voltage at pin 7 with no galvanic connection between them.

Several amplifier and power connection variations are possible:

1. The input stage may be connected in various operational amplifier gain configurations.
2. The output stage may be operated at gains above unity.
3. The internally generated isolated voltages which provide power to A_1 and A_2 may be overridden and external supply voltages used instead.

Versatility and its three independent isolated grounds allow simple solutions to demanding analog signal conditioning problems. See the Installation and Operating Instructions and Applications sections for details.

INSTALLATION AND OPERATING INSTRUCTIONS

The 3656 is a very versatile device capable of being used in a variety of isolation and amplification configurations. There are several fundamental considerations that determine configuration and component value constraints:

1. Consideration must be given to the load placed on the resistance (pin 10 and pin 11) by external circuitry. Their output resistance is 100k Ω and a load resistor of 2M Ω or greater is recommended to prevent a voltage divider loading effect in excess of 5%.

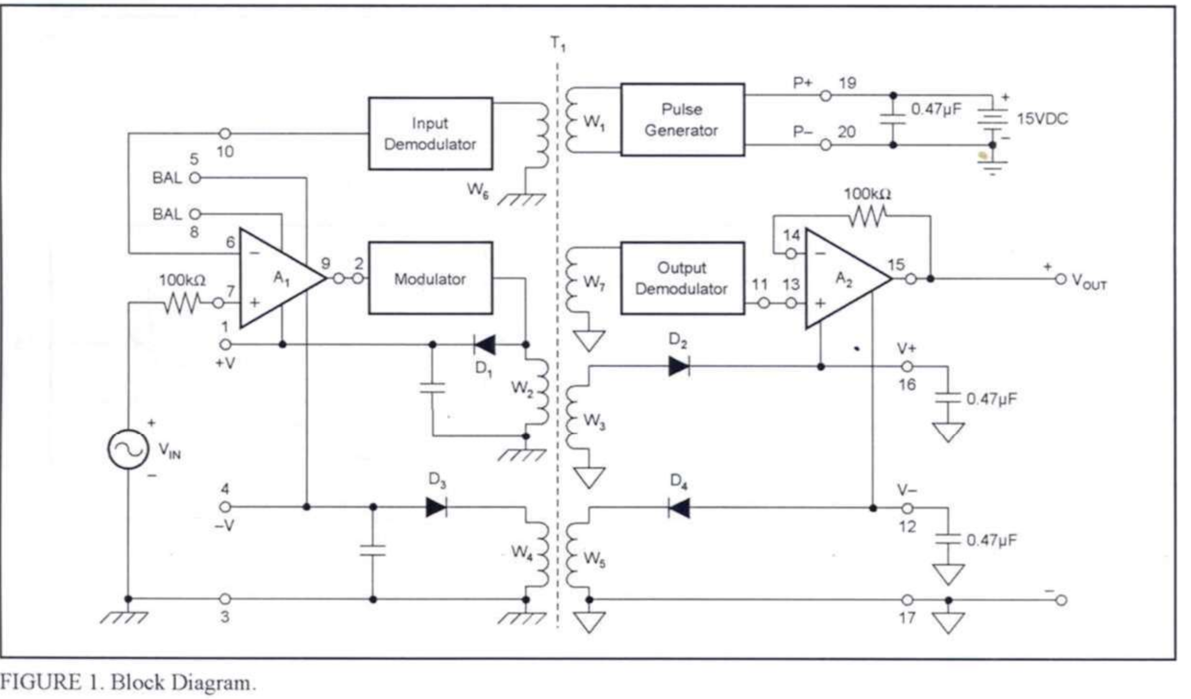


FIGURE 1. Block Diagram.

2. Demodulator loadings should be closely matched so their output voltages will be equal. (Unequal demodulator output voltages will produce a gain error.) At the 2M Ω level, a matching error of 5% will cause an additional gain error of 0.25%.

3. Voltage swings at demodulator outputs should be limited to 5V. The output may be distorted if this limit is exceeded. This constrains the maximum allowed gains of the input and output stages. Note that the voltage swings at demodulator outputs are tested with 2M Ω load for a minimum of 5V.

4. Total current drawn from the internal isolated supplies must be limited to less than ±5mA per supply and limited to a total of 10mA. In other words, the combination of external and internal current drawn from the internal circuitry which feeds the +V, –V, V+ and V– pins should be limited to 5mA per supply (total current to +V, –V, V+ and V– limited to 10mA). The internal filter capacitors for ±V are 0.01µF. If more than 0.1mA is drawn to provide isolated power for external circuitry (see Figure 12), additional capacitors are required to provide adequate filtering. A minimum of 0.1µF/mA is recommended.

5. The input voltage at pin 7 (noninverting input to A_1) must not exceed the voltage at pin 4 (negative supply voltage for A_1) in order to prevent a possible lockup condition. A low leakage diode connected between pins 7 and 4, as shown in Figure 2, can be used to limit this input voltage swing.

6. Impedances seen by each amplifier's + and – input terminals should be matched to minimize offset voltages caused by amplifier input bias currents. Since the demodulators have a 100kΩ output resistance, the amplifier input not connected to the demodulator should also see 100kΩ.

7. All external filter capacitors should be mounted as close to the respective supply pins as possible in order to prevent excessive ripple voltages on the supplies or at the output. (Optimum spacing is less than 0.5". Ceramic capacitors recommended.)

POWER AND SIGNAL CONFIGURATIONS

NOTE: Figures 2, 3 and 4 are used to illustrate both signal and power connection configurations. In the circuits shown, the power and signal configurations are independent so that any power configuration could be used with any signal configuration.

ISOLATED POWER CONFIGURATIONS

The 3656 is designed with isolation between the input, the output, and the power connections. The internally generated isolated voltages supplied to A_1 and A_2 may be overridden with external voltages greater than the internal supply voltages. These two features of 3656 provide a great deal of versatility in possible isolation and power supply hook-ups. When external supplies are applied, the rectifying diodes (D_1 through D_4) are reverse biased and the internal voltage sources are decoupled from the amplifiers (see Figure 1). Note that when external supplies are used, they must never be lower than the internal supply voltage.

Three-Port

The power supply connections in Figure 2 show the full three-port isolation configuration. The system has three separate grounds with no galvanic connections between them. The two external 0.47µF capacitors at pins 12 and 16 filter the rectified isolated voltage at the output stage. Filtering on the input stage is provided by internal capacitors. In this configuration continuous isolation voltage ratings are: 3500V between pins 3 and 17; 3500V between pins 3 and 19; 1000V between pins 17 and 19.

Two-Port Bipolar Supply

Figure 3 shows two-port isolation which uses an external bipolar supply with its common connected to the output stage ground (pin 17). One of the supplies (either + or – could be used) provides power to the pulse generator (pins 19 and 20). The same sort of configuration is possible with the external supplies connected to the input stage. With the connection shown, filtering at pins 12 and 16 is not required. In this configuration continuous isolation voltage rating is: 3500VDC between pins 3 and 17; not applicable between pins 17 and 19; 3500VDC between pins 3 and 19.

Two-Port Single Supply

Figure 4 demonstrates two-port isolation using a single polarity supply connected to the output common (pin 17). The other polarity of supply for A_2 is internally generated (thus the filtering at pin 12). This isolated power configuration could be used at the input stage as well and either polarity of supply could be employed. In this configuration continuous isolation voltage rating is: 3500V between pins 3 and 17; 3500V between pins 3 and 19; not applicable between pins 17 and 19.

SIGNAL CONFIGURATIONS

Unity Gain Noninverting

The signal path portion of Figure 2 shows the 3656 is its simplest gain configuration: unity gain noninverting. The two 100kΩ resistors provide balanced resistances to the inverting and noninverting inputs of the amplifiers. The diode prevents latch up in case the input voltage goes more negative than the voltage at pin 4.

Noninverting With Gain

The signal path portion of Figure 3 demonstrates two additional gain configurations: gain in the output stage and noninverting gain in the input stage. The following equations apply:

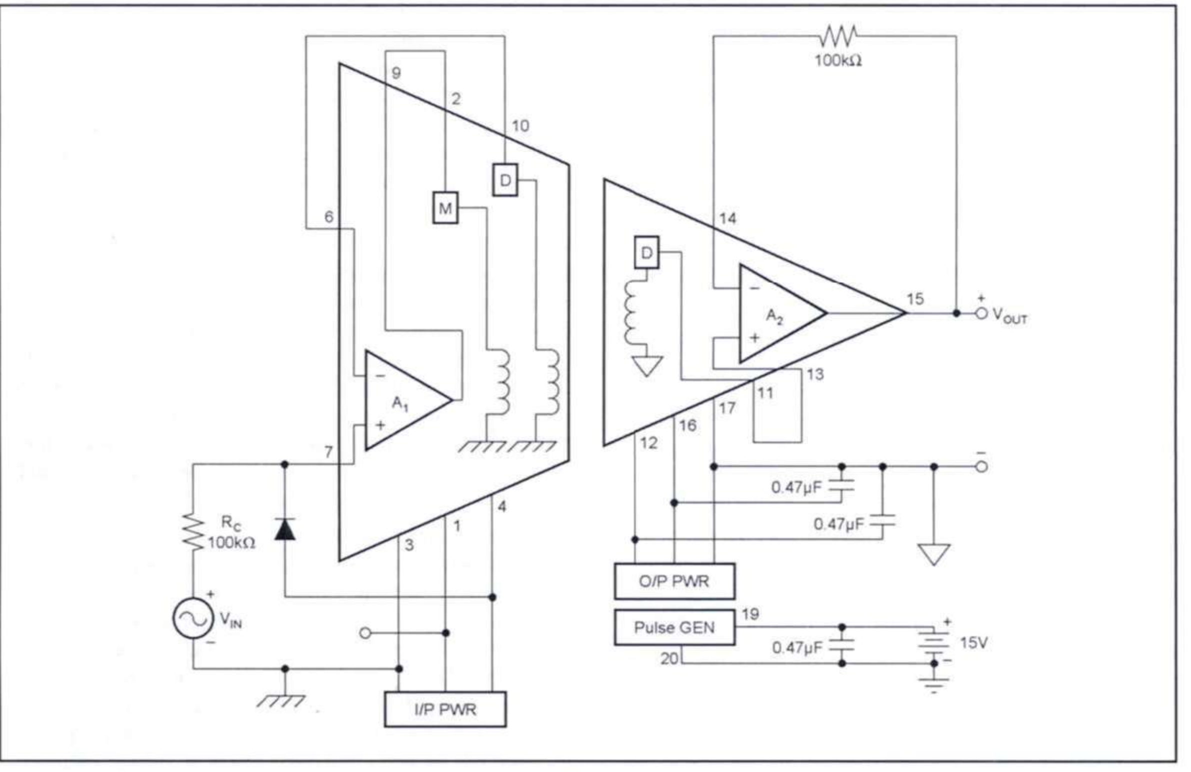


FIGURE 2. Power: Three-Port Isolation; Signal: Unity-Gain Noninverting.

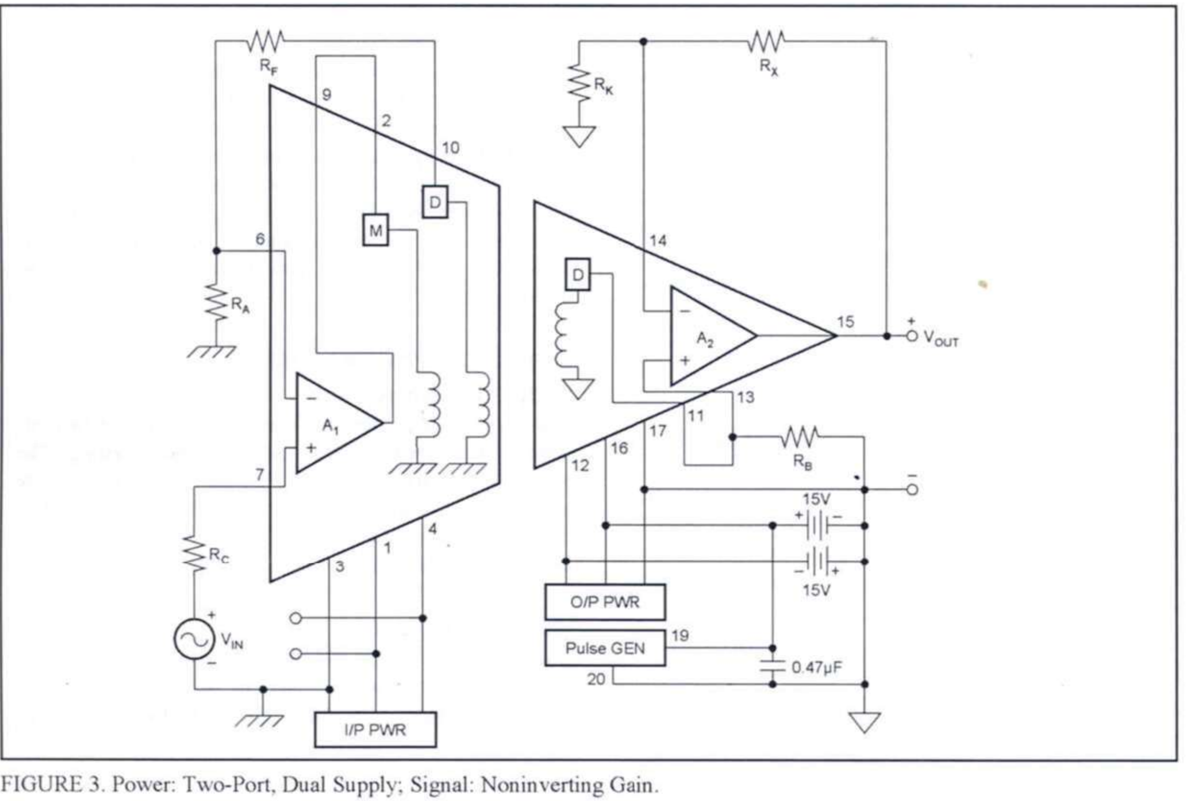


FIGURE 3. Power: Two-Port, Dual Supply; Signal: Noninverting Gain.

Total amplifier gain:

$$G = G_1 \bullet G_2 = V_{OUT} \; V_{IN} \quad (1)$$

Input Stage:

$$G_1 = 1 + (R_A/F_A) \quad (2)$$

(Select G_1 to be less than 5V/full scale V_{IN} to limit demodulator output to 5V).

$$R_A + R_F \geq 2M\Omega \quad (3)$$

(Select to load input demodulator with at least 2M Ω).

$$R_C = R_A \parallel (R_F + 100k\Omega) = \frac{R_A\,(R_F + 100k\Omega)}{R_A + R_F + 100k\Omega} \quad (4)$$

(Balance impedances seen by the + and – inputs of A_1 to reduce input offset caused by bias current).

Output Stage:

$$G_2 = 1 + (R_X/R_K) \quad (5)$$

(Select ratio to obtain V_{OUT} between 5V and 10V full scale with V_{IN} at its maximum).

$$R_X \parallel R_K = 100k\Omega \quad (6)$$

(Balance impedances seen by the + and – inputs of A_2 to reduce effect of bias current on the output offset).

$$R_B = R_A + R_F \quad (7)$$

(Load output demodulator equal to input demodulator).

Inverting Gain, Voltage or Current Input

The signal portion of Figure 4 shows two possible inverting input stage configurations: current and input, and voltage input.

Input Stage:

For the voltage input case:

$$G_1 = -R_F/R_S \quad (8)$$

(Select G_1 to be less than 5V/full scale V_{IN} to limit the demodulator output voltage to 5V).

$$R_F = 2M\Omega \quad (9)$$

(Select to load the demodulator with at least 2MΩ).

$$R_C = R_S \parallel (R_1 + 100k\Omega) = \frac{R_S\,(R_F + 100k\Omega)}{R_S + R_F + 100k\Omega} \quad (10)$$

(Balance the impedances seen by the + and– inputs of A_1).

For the current input case:

$$V_{OUT} = -I_{IN}\,R_F \bullet G_2 \quad (11)$$

$$R_C = R_F \quad (12)$$

R_F may be made larger than 2MΩ if desired. The 10pF capacitors are used to compensate for the input capacitance of A_1 and to insure frequency stability.

Output Stage:

The output stage is the same as shown in equations (5), (6), and (7).

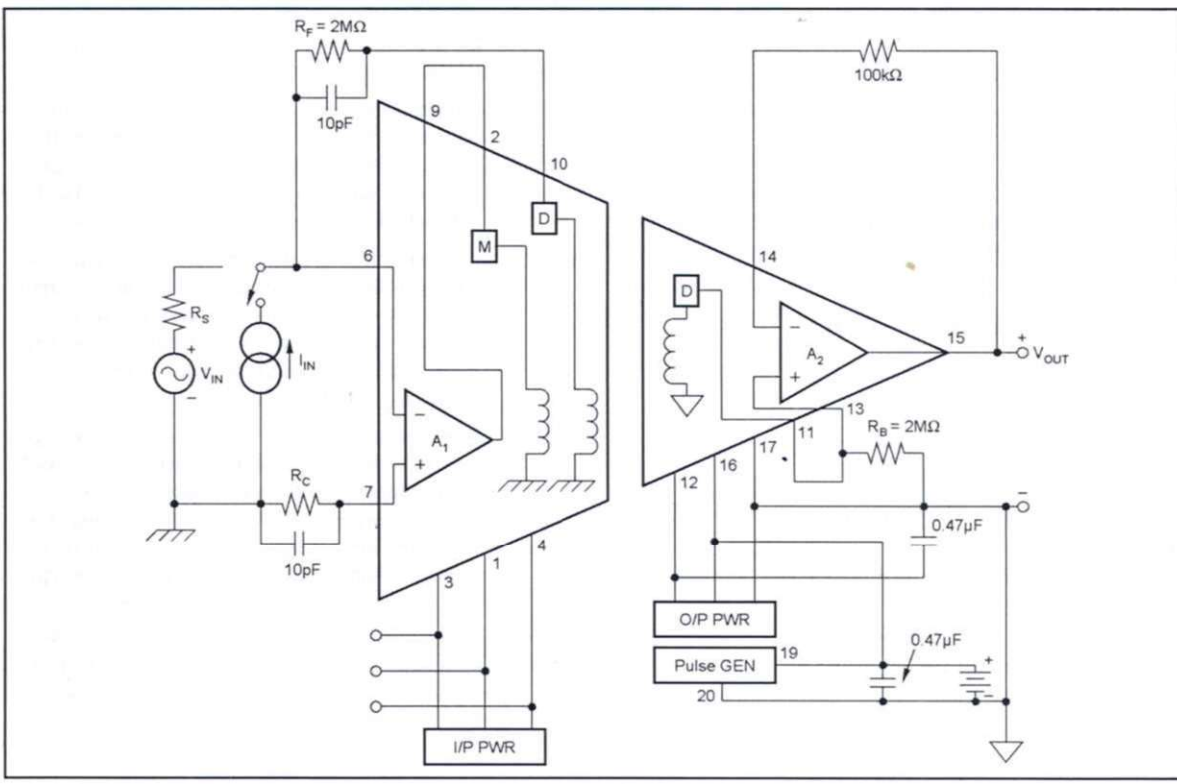


FIGURE 4. Power: Two-Port, Single Supply; Signal: Inverting Gains.

Illustrative Calculations:

The maximum input voltage is 100mV. It is desired to amplify the input signal for maximum accuracy. Noninverting output is desired.

Input Stage:

Step 1

G_1 max = 5V/max Input Signal = 5V 0.1V = 50V/V

With the above gain of 50V/V, if the input ever exceeds 100mV, it would drive the output to saturation. Therefore, it is good practice to allow reasonable input overrange.

So, to allow for 25% input overrange without saturation at the output, select:

$G_1 = 40V/V$

$G_1 = 1 + (R_F + R_A) = 40$

$\therefore R_F + R_A = 39$ (13)

Step 2

$R_A + R_F$ forms a voltage divider with the 100kΩ output resistance of the demodulator. To limit the voltage divider loading effect to no more than 5%, $R_A + R_F$ should be chosen to be at least 2MΩ. For most applications, the 2MΩ should be sufficiently large for $R_A + R_F$. Resistances greater than 2MΩ may help decrease the loading effect, but would increase the offset voltage drift.

The voltage divider with $R_A + R_F$ = 2MΩ is 2MΩ/(2MΩ + 100kΩ) = 2/(2 + 0.1) = 95.2%, i.e., the percent loading is 4.8%.

Choose $R_A + R_F$ = 2MΩ (14)

Step 3

Solving equations (13) and (14)

R_A = 50kΩ and R_F = 1.95MΩ

Step 4

The resistances seen by the + and – input terminals of the input amplifier A_1 should be closely matched in order to minimize offset voltage due to bias currents.

$\therefore R_C = R_A \parallel (R_F + 100k\Omega)$

$= 50k\Omega \parallel (1.95M\Omega + 100k\Omega)$

$\approx 49k\Omega$

Output Stage:

Step 5

$V_{OUT} = V_{IN\ MAX} \cdot G_1 \cdot G_2$

As discussed in Step 1, it is good practice to provide 25% input overrange.

So we will calculate G_2 for 10V output and 125% of the maximum input voltage.

$\therefore V_{OUT} = (1.25 \cdot 0.1)(G_1)(G_2)$

i.e., $10V = 0.125 \cdot 40 \cdot G_2$

$\therefore G_2 = 10V/5V = 2V/V$

Step 6

$G_2 = 1 + (R_X/R_K) = 2.0$

$\therefore R_X/R_K = 1.0$

$\therefore R_X = R_K$ (15)

Step 7

The resistance seen by the + input terminal of the output stage amplifier A_2 (pin 13) is the output resistance 100k Ω of the output demodulator. The resistance seen by the (–) input terminal of A_2 (pin 14) should be matched to the resistance seen by the + input terminal.

The resistance seen by pin 14 is the parallel combination of R_X and R_K.

$\therefore R_X \parallel R_K = 100k\Omega$

$(R_X \cdot R_K/(R_X + R_K) = 100k\Omega$

$R_K/[1 + (R_K/R_X)] = 100k\Omega$ (16)

Step 8

Solving equations (15) and (16) R_K = 20kΩ and R_X = 200kΩ.

Step 9

The output demodulator must be loaded equal to the input demodulator.

$\therefore R_B = R_A + R_F = 2M\Omega$

(See equation (14) above in Step 2).

Use the resistor values obtained in Steps 3, 4, 8 and 9, and connect the 3656 as shown in Figure 3.

OFFSET TRIMMING

Figure 5 shows an optional offset voltage trim circuit. It is important that $R_A + R_F = R_B$.

CASE 1: Input and output stages in low gain, use output potentiometer (R_2) only. Input potentiometer (R_1) may be disconnected. For example, unity gain could be obtained by setting $R_A = R_B$ = 20MΩ, R_C = 100kΩ, R_F = 0, R_X = 100kΩ, and $R_K = \infty$.

CASE 2: Input stage in high gain and output stage in low gain, use input potentiometer (R_1) only. Output potentiometer (R_2) may be disconnected. For example, G_T = 100 could be obtained by setting R_F = 2MΩ, R_B = 2MΩ returned to pin 17, R_A = 20kΩ, R_X = 100kΩ, and $R_K = \infty$.

CASE 3: When it is necessary to perform a two-stage precision trim (to maintain a very small offset change under conditions of changing temperature and changing gain in A_1 and A_2), use step 1 to adjust the input stage and step 2 for the output stage. Carbon composition resistors are acceptable, but potentiometers should be stable.

Step 1: Input stage trim ($R_A = R_C$ = 20kΩ, $R_1 = R_B$ = 20MΩ. R_X = 100kΩ, $R_K = \infty$, R_2 disconnected); A_1 high, A_2 low gain. Adjust R_1 for 0V ±5mV or desired setting at V_{OUT}, pin 15.

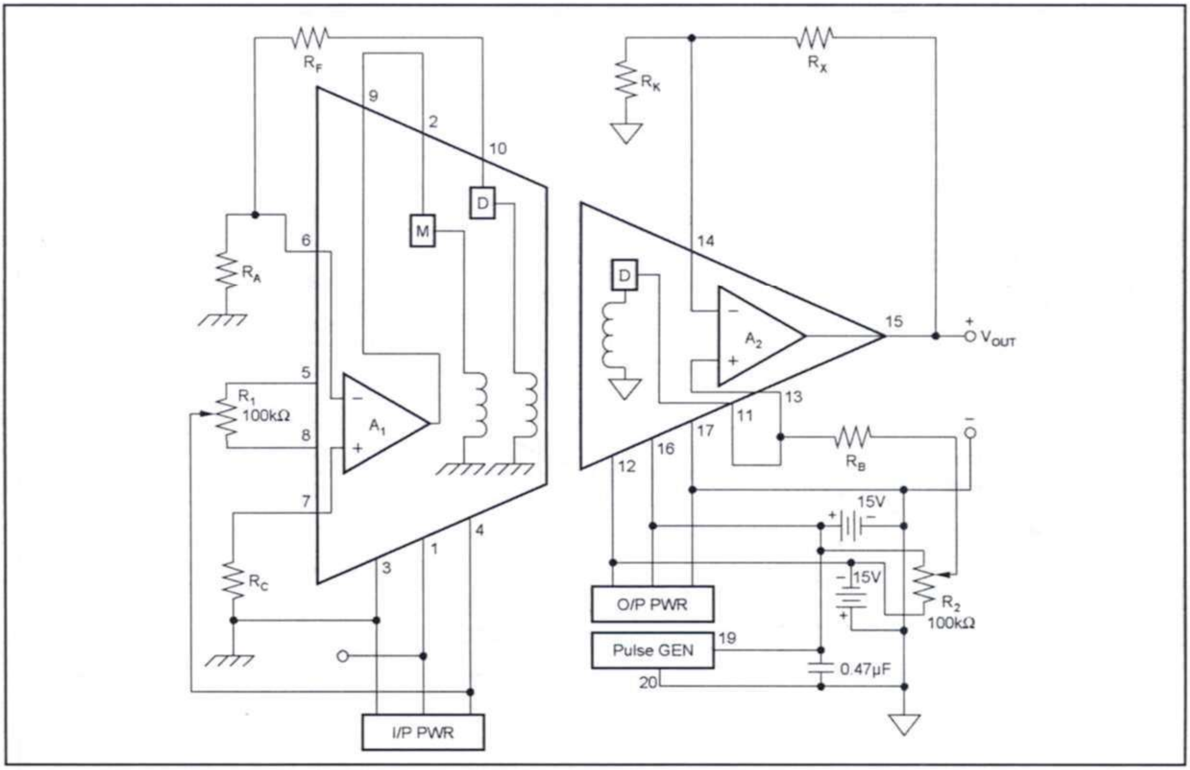


FIGURE 5. Optional Offset Voltage Trim.

Step 2: Output stage trim ($R_A = R_B = 20M\Omega$, $R_C = 100k\Omega$, $R_F = 0$, $R_X = 100k\Omega$, $R_K = \infty$, R_1 and R_2 connected); A_1 low, A_2 low gain. Adjust R_2 for 0V ±1mV or desired setting at V_{OUT}, pin 15 (±110mV approximate total range).

NOTE: Other circuit component values can be used with valid results.

APPLICATIONS

ECG AMPLIFIER

Although the features of the circuit shown in Figure 6 are important in patient monitoring applications, they may also be useful in other applications. The input circuitry uses an external, low quiescent current op amp (OPA177 type) powered by the isolated power of the input stage to form a high impedance instrumentation amplifier input (true three-wire input). R_3 and R_4 give the input stage amplifier of the 3656 a noninverting gain of 10 and an inverting gain of −9. R_1 and R_2 give the external amplifier a noninverting gain of 1 + 1/9. The inputs are applied to the noninverting inputs of the two amplifiers and the composite input stage amplifier has a gain of 10.

The 330kΩ, 1W, carbon resistors and diodes D_1 - D_4 provide protection for the input amplifiers from defibrillation pulses.

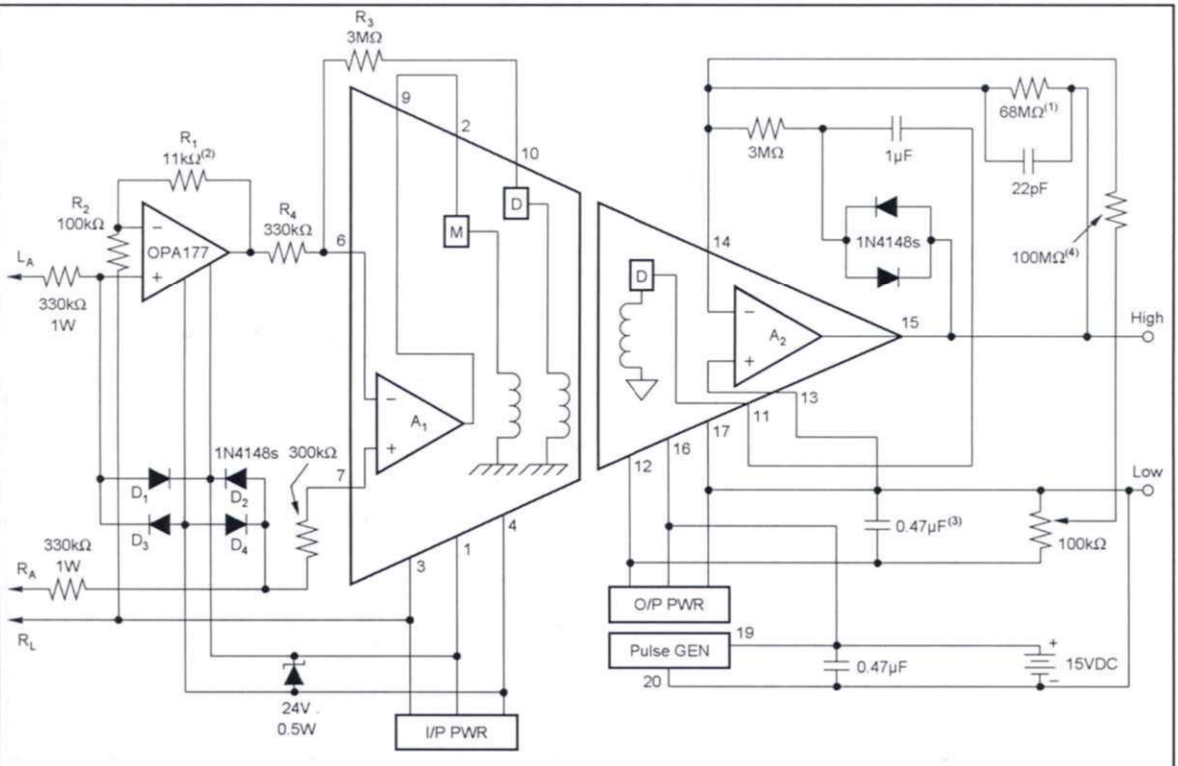
The output stage in Figure 6 is configured to provide a bandpass filter with a gain of 22.7 (68MΩ/3MΩ). The high-pass section (0.05Hz cutoff) is formed by the 1µF capacitor and 3MΩ resistor which are connected in series between the output demodulator and the inverting input of the output stage amplifier. The low-pass section (100Hz cutoff) is formed by the 68MΩ resistor and 22pF capacitor located in the feedback loop of the output stage. The diodes provide for quick recovery of the high-pass filter to overvoltages at the input. The 100kΩ pot and the 100MΩ resistor allow the output voltage to be trimmed to compensate for increased offset voltage caused by unbalanced impedances seen by the inputs of the output stage amplifier.

In many modern electrocardiographic systems, the patient is not grounded. Instead, the right-leg electrode is connected to the output of an auxiliary operational amplifier as shown in Figure 7. In this circuit, the common-mode voltage on the body is sensed by the two averaging resistors, R_1 and R_2, inverted, amplified, and fed back to the right-leg through resistor R_4. This negative feedback drives the common-mode voltage to a low value. The body's displacement current i_d does not flow to ground, but rather to the output circuit of A_3. This reduces the pickup as far as the ECG amplifier is concerned and effectively grounds the patient.

The value of R_4 should be as large as practical to isolate the patient from ground. The resistors R_3 and R_4 may be selected by these equations:

$R_3 = (R_1/2)(V_O/V_{CM})$ and $R_4 = (V_{CM} - V_O)/i_d$

$(-10V \leq V_O \leq +10V$ and $-10V \leq V_{CM} \leq +10V)$



NOTES: (1) Bandpass 0.05Hz to 100Hz. (2) Adjustable resistor may be used to achieve max common-mode rejection between L_A /R_A and RL. (3) Negative 15V supply may be connected in place of 0.47μF capacitor if available. (4) See offset trimming section.

FIGURE 6. ECG Amplifier.

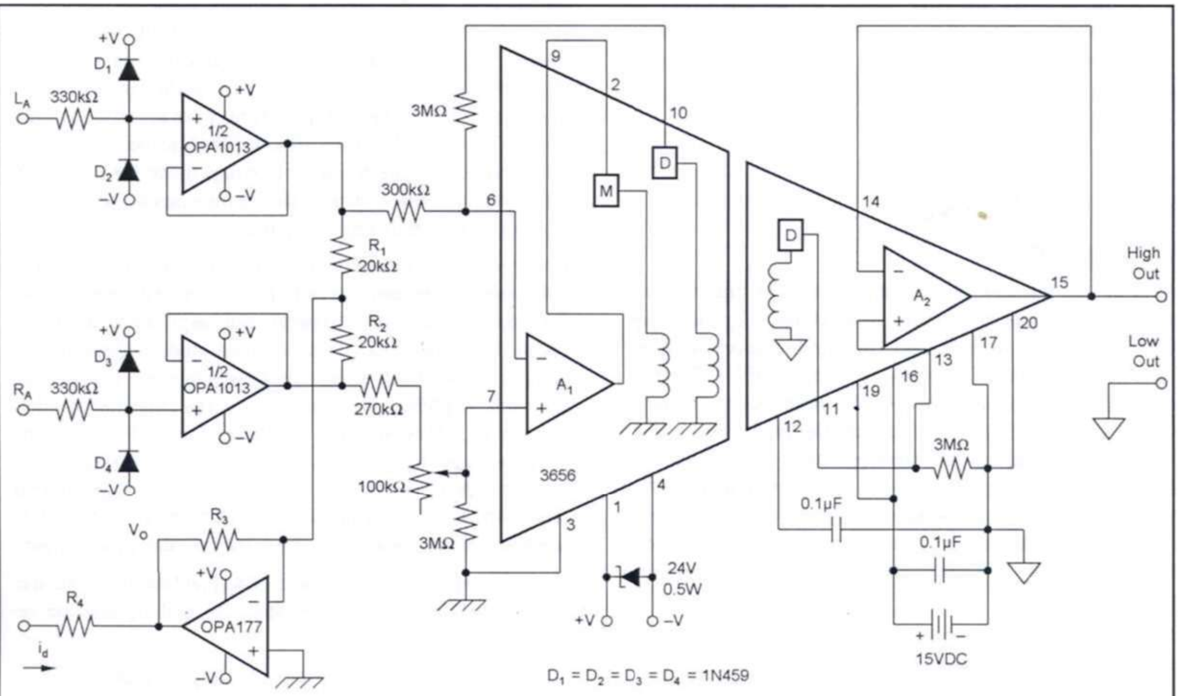


FIGURE 7. Driven Right-Leg Amplifier.

where V_O is the output voltage of A_3, and V_{CM} is the common-mode voltage between the inputs L_A and R_A and the input common at pin 3 of the 3656.

This circuit has the added benefit of having higher common-mode rejection than the circuit in Figure 6 (approximately 10dB improvement).

BIPOLAR CURRENT OUTPUT

The three-port capability of the 3656 can be used to implement a current output isolation amplifier function—usually difficult to implement when grounded loads are involved. The circuit is shown in Figure 8 and the following equations apply:

$$G = I_{OUT}/V_{IN} = 1 + \frac{R_F}{R_A} \times \frac{R_2}{(R_1 + R_2) \cdot R_S}$$

$I_{OUT} \leq \pm 2.5mA$

$V_1 \leq \pm 4V$ (compliance)

$R_L \leq 1.6k\Omega$

$R_F + R_A = R_1 + R_2 \leq 2M\Omega$

CURRENT OUTPUT— LARGER UNIPOLAR CURRENTS

A more practical version of the current output function is shown in Figure 9. If the circuit is powered from a source greater than 15V as shown, a three-terminal regulator should be used to provide 15V for the pulse generator (pins 19 and 20). The input stage is configured as a unity gain buffer, although other configurations such as current input could be used. The circuit uses the isolation feature between the output stage and the primary power supply to generate the output current configuration that can work into a grounded load. Note that the output transistors can only drive positive current into the load. Bipolar current output would require a second transistor and dual supply.

ISOLATED 4mA TO 20mA OUTPUT

Figure 10 shows the circuit of an expanded version of the isolated current output function. It allows any input voltage range to generate the 4mA to 20mA output excursion and is also capable of zero suppression. The "span" (gain) is adjusted by R_2 and the "zero" (4mA output for minimum input) is set by the 200kΩ pot in the output stage. A three-terminal 5V reference is used to provide a stable 4mA operating point. The reference is connected to insert an adjustable bias between the demodulator output and the noninverting input of the output stage.

DIFFERENTIAL INPUT

Figure 11 shows the proper connections for differential input configuration. The 3656 is capable of operating in this input configuration only for floating loads (i.e., the source V_{IN} has no connection to the ground reference established at pin 3). For this configuration the usual 2MΩ resistor used in

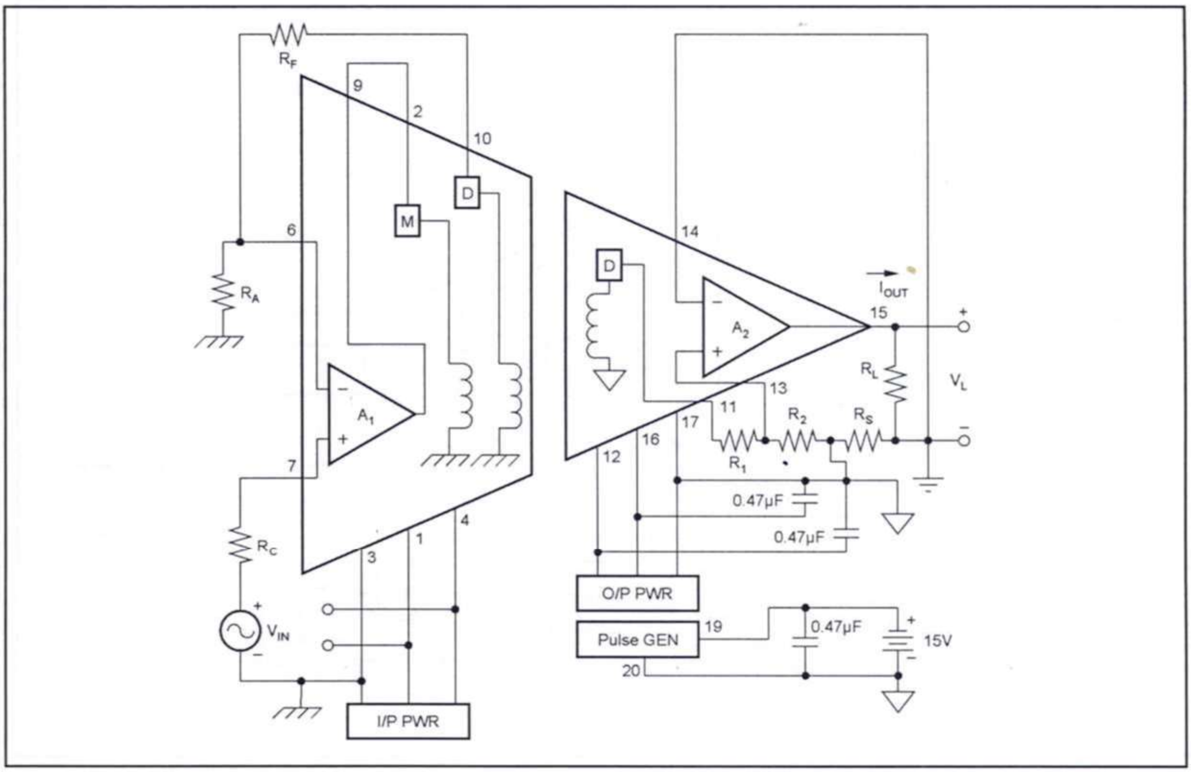


FIGURE 8. Bipolar Current Output.

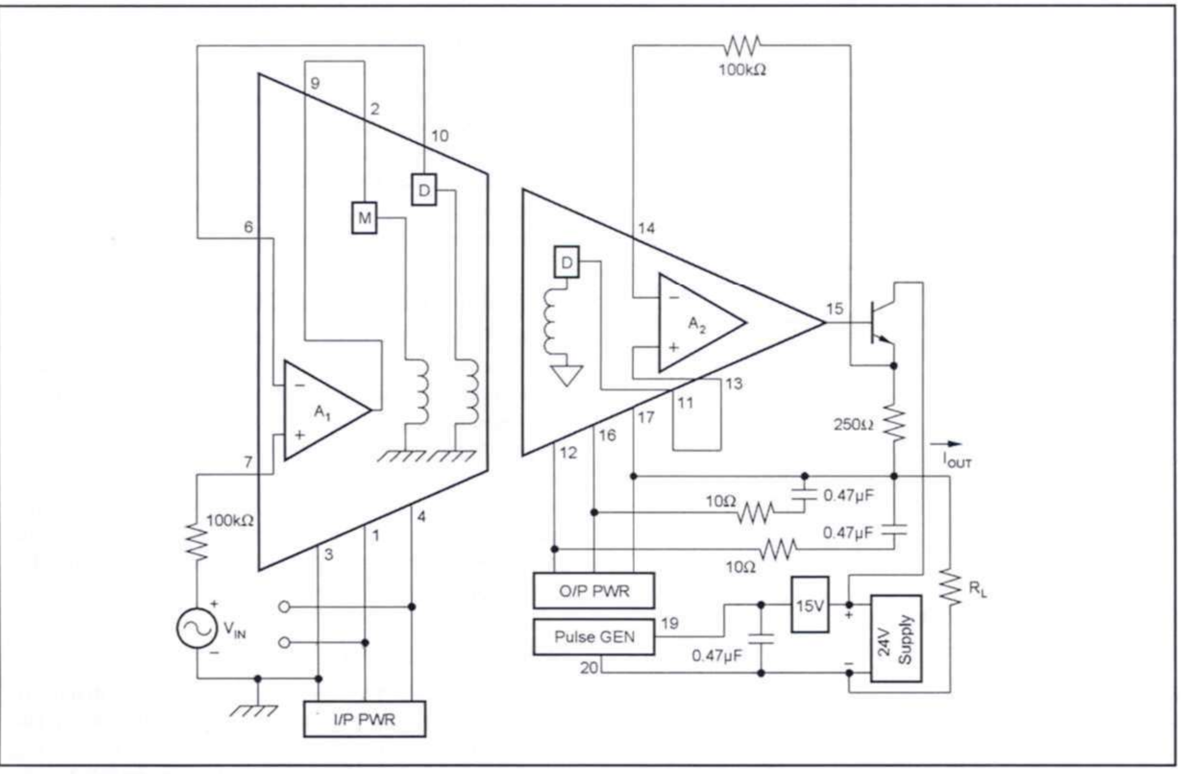


FIGURE 9. Isolated 1 to $5V_{IN}$/ 4mA to 20mA I_{OUT}.

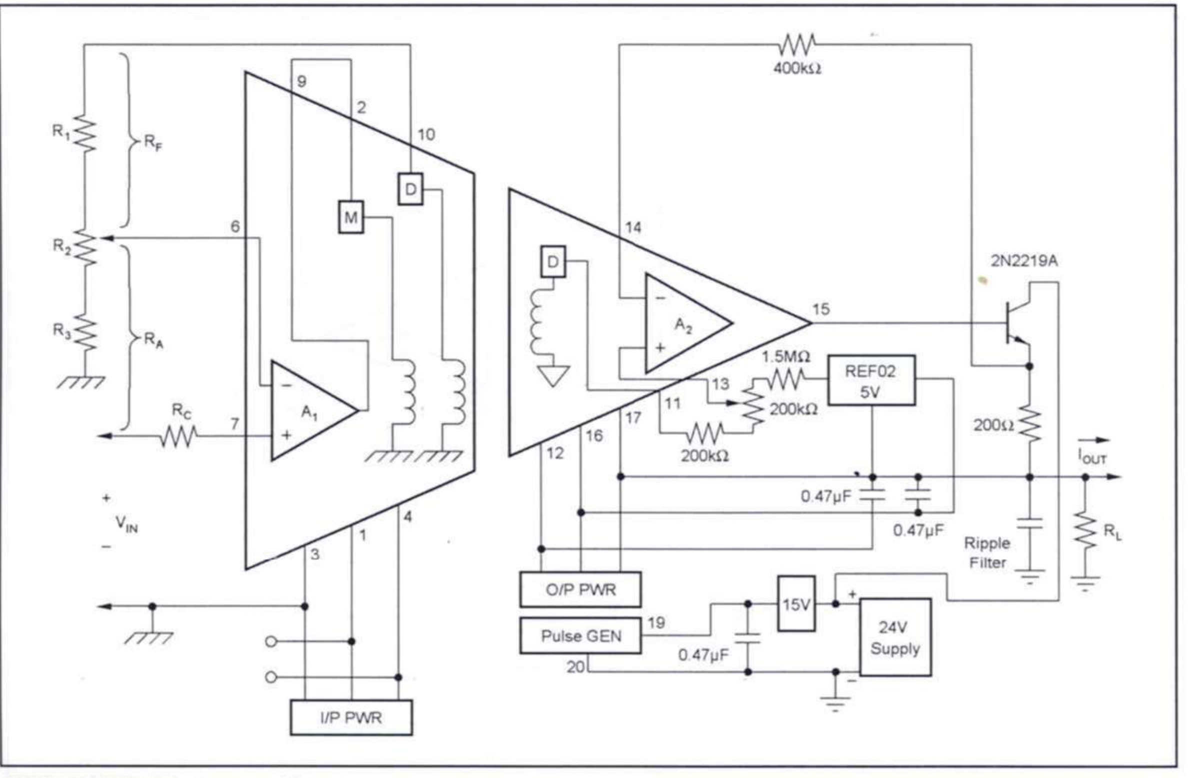


FIGURE 10. Isolated 4mA to 20mA I_{OUT}.

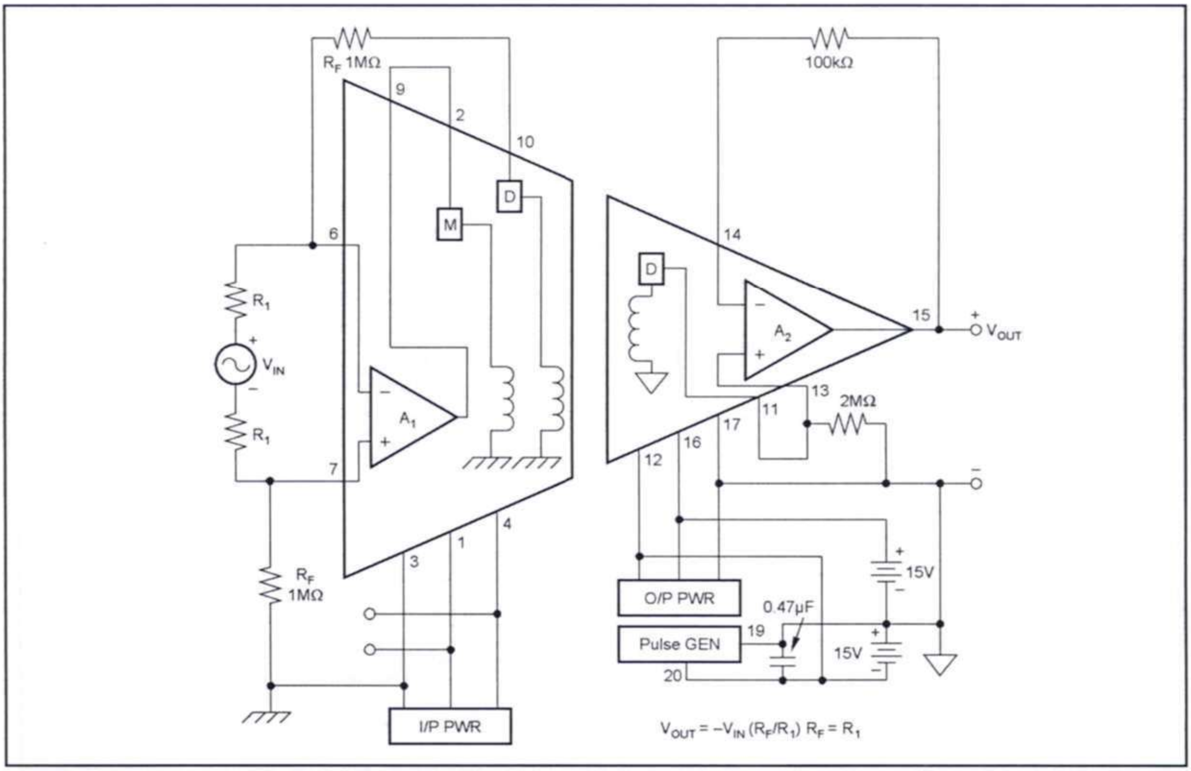


FIGURE 11. Differential Input, Floating Source.

the input stage is split into two halves, R_F and R_{F-}. The demodulator load (seen by pin 10 with respect to pin 3) is still 2MΩ for the floating load as shown. Notice pin 19 is common in Figure 11 whereas pin 20 is common in previous figures.

SERIES STRING SOURCE

Figure 12 shows a situation where a small voltage, which is part of a series string of other voltages, must be measured. The basic problem is that the small voltage to be measured is 500V above the system ground (i.e., a system common-mode voltage of 500V exists). The circuit converts this system CMV to an amplifier isolation mode voltage. Thus, the isolation voltage ratings and isolation-mode rejection specifications apply.

IMPROVED INPUT CHARACTERISTICS

In situations where it is desired to have better DC input amplifier characteristics than the 3656 normally provides, it is possible to add a precision operational amplifier as shown in Figure 13. Here the instrumentation grade OPA177 is supplied from the isolated power of the input stage. The 3656 is configured as a unity-gain buffer. The gain of the OPA177 stage must be chosen to limit its full scale output voltage to 5V and avoid overdriving the 3656's demodulators. Since the 3656 draws a significant amount of supply current, extra filtering or the input supply is required as shown (2 x 0.47µF).

ELECTROMAGNETIC RADIATION

The transformer coupling used in 3656 for isolation makes the 3656 a source of electromagnetic radiation unless it is properly shielded. Physical separation between the 3656 and sensitive components may not give sufficient attenuation by itself. In these applications, the use of an electromagnetic shield is a must. A shield, Burr-Brown 100MS, is specially designed for use with the 3656 package. Note that the offset voltage appearing at pin 15 may change by 4mV to 12mV with use of the shield; however, this can be trimmed (see Offset Trimming section).

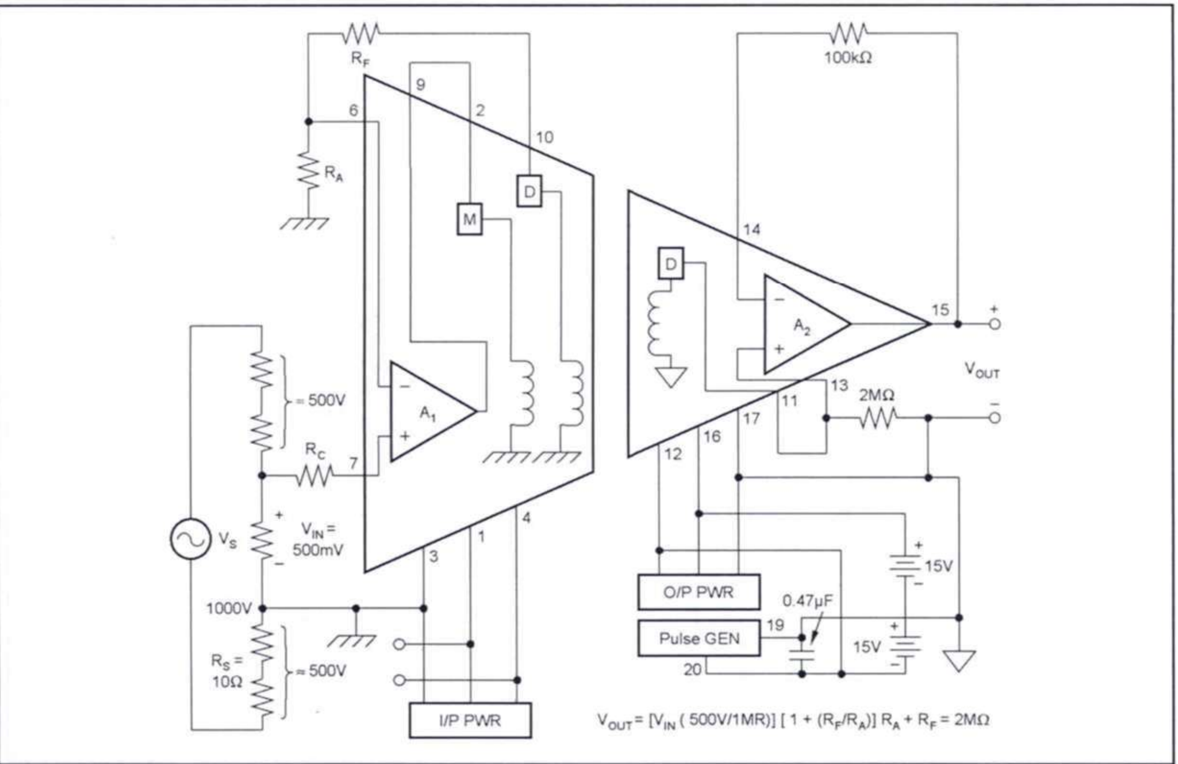


FIGURE 12. Series Source.

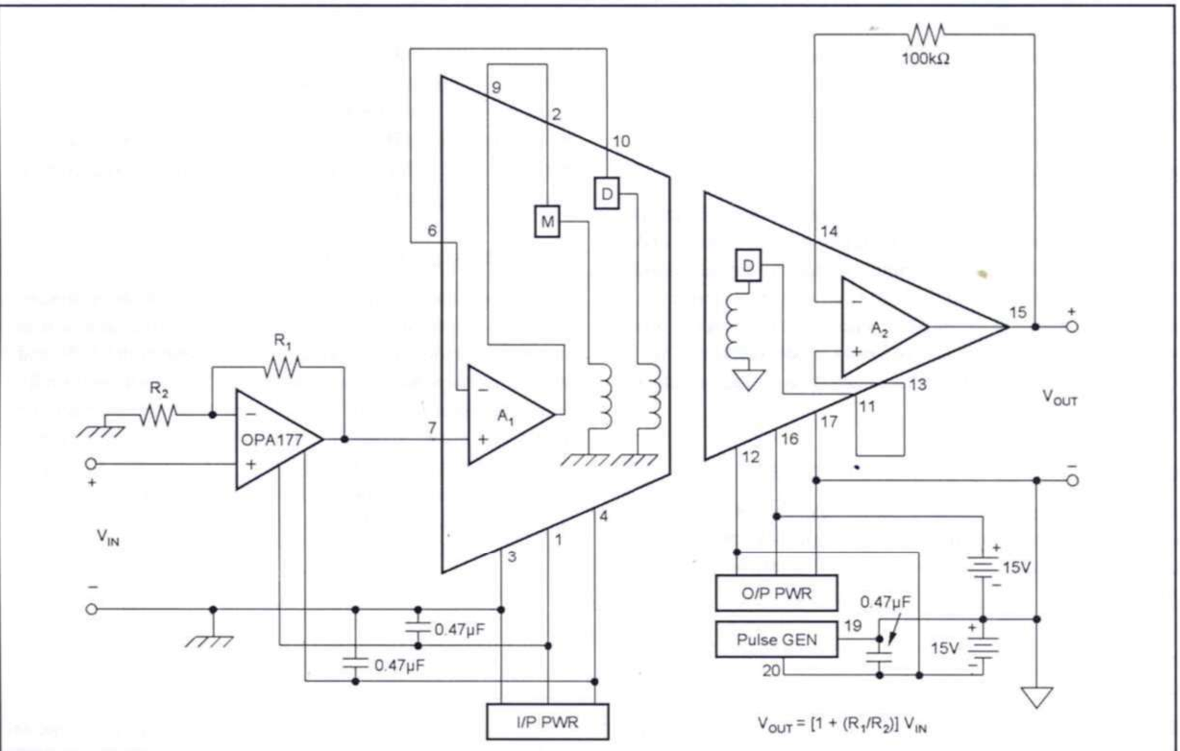


FIGURE 13. Isolator for Low-Level Signals.