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## INSTRUCTIONS

MODEL AVR-EB4-B-BOB

0 TO  $\pm 10$ A REVERSE RECOVERY  
MEASUREMENT SYSTEM  
WITH 2 ns SWITCHING TIME

SERIAL NUMBER: \_\_\_\_\_

### WARRANTY

Avtech Electrosystems Ltd. warrants products of its manufacture to be free from defects in material and workmanship under conditions of normal use. If, within one year after delivery to the original owner, and after prepaid return by the original owner, this Avtech product is found to be defective, Avtech shall at its option repair or replace said defective item. This warranty does not apply to units which have been disassembled, modified or subjected to conditions exceeding the applicable specifications or ratings. This warranty is the extent of the obligation assumed by Avtech with respect to this product and no other warranty or guarantee is either expressed or implied.

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## TABLE OF CONTENTS

<b>WARRANTY.....</b>	<b>2</b>
<b>TECHNICAL SUPPORT.....</b>	<b>2</b>
<b>TABLE OF CONTENTS.....</b>	<b>3</b>
<b>INTRODUCTION.....</b>	<b>5</b>
<b>SPECIFICATIONS.....</b>	<b>6</b>
<b>EUROPEAN REGULATORY NOTES.....</b>	<b>7</b>
EC DECLARATION OF CONFORMITY.....	7
DIRECTIVE 2002/95/EC (RoHS).....	7
<b>CSA EVALUATION.....</b>	<b>8</b>
<b>INSTALLATION.....</b>	<b>9</b>
VISUAL CHECK.....	9
POWER RATINGS.....	9
CONNECTION TO THE POWER SUPPLY.....	9
PROTECTION FROM ELECTRIC SHOCK.....	10
ENVIRONMENTAL CONDITIONS.....	10
<b>FUSES.....</b>	<b>12</b>
AC FUSE REPLACEMENT.....	12
DC FUSE REPLACEMENT.....	13
FUSE RATINGS.....	13
<b>FRONT PANEL CONTROLS.....</b>	<b>14</b>
<b>REAR PANEL CONTROLS.....</b>	<b>16</b>
<b>TIMING CONTROL.....</b>	<b>18</b>
BASIC TIMING CONTROL.....	18
TRIGGER MODES.....	20
GATING MODES.....	20
<b>BASIC AMPLITUDE CONTROL.....</b>	<b>21</b>
SETTING THE AMPLITUDE LEVELS.....	22
AMPLITUDE ACCURACY.....	23
DC OFFSET.....	23
INCORRECT ORIENTATION.....	24
ACCESSIBLE VOLTAGES.....	24
<b>TEST JIG MECHANICAL ASPECTS.....</b>	<b>25</b>
TRR A TEST JIG.....	25

TRR B TEST JIG.....	26
<b>TYPICAL RESULTS.....</b>	<b>28</b>
CREE CSD10120.....	28
IR HFA16PB120 HEXFRED.....	29
ADVANCED POWER APT15S20K.....	30
DIODES INC. FR803.....	31
DIODES INC. 1N5819.....	32
TRANSIENT REFLECTIONS.....	33
<b>PROGRAMMING YOUR PULSE GENERATOR.....</b>	<b>34</b>
KEY PROGRAMMING COMMANDS.....	34
ALL PROGRAMMING COMMANDS.....	35
<b>MECHANICAL INFORMATION.....</b>	<b>37</b>
TOP COVER REMOVAL.....	37
RACK MOUNTING.....	37
ELECTROMAGNETIC INTERFERENCE.....	37
<b>MAINTENANCE.....</b>	<b>38</b>
REGULAR MAINTENANCE.....	38
CLEANING.....	38
<b>WIRING DIAGRAMS.....</b>	<b>39</b>
WIRING OF AC POWER, 1/2.....	39
WIRING OF AC POWER, 2/2.....	40
PCB 158J - LOW VOLTAGE DC POWER SUPPLY, 1/3.....	41
PCB 158J - LOW VOLTAGE DC POWER SUPPLY, 2/3.....	42
PCB 158J - LOW VOLTAGE DC POWER SUPPLY, 3/3.....	43
PCB 168B - HIGH VOLTAGE DC POWER SUPPLY.....	44
PCB 104D - KEYPAD / DISPLAY BOARD, 1/3.....	45
PCB 104D - KEYPAD / DISPLAY BOARD, 2/3.....	46
PCB 104D - KEYPAD / DISPLAY BOARD, 3/3.....	47
MAIN WIRING.....	48
<b>PERFORMANCE CHECK SHEET.....</b>	<b>50</b>

## INTRODUCTION

The AVR-EB4-B-BOB is a high performance, GPIB and RS232-equipped instrument capable of generating a bipolar  $\pm 10\text{A}$  "monocycle" waveform into a diode load. More specifically, the AVR-EB4-B-BOB mainframe generates a 100 ns wide forward-bias pulse with amplitude adjustable up to +10A, which is immediately followed by a 100 ns width reverse-bias pulse with amplitude up to -10A. The forward and reverse amplitudes are independently variable.

Two output modules (also called test jigs) are provided. Only one output module is used at a time. The instrument mainframe is connected to output module in use by two 24" coaxial cables (one for the monocycle drive waveform, and one for the DC bias voltage). One output module contains a circuit board with spring-loaded contacts suitable for use with the custom surface-mount package specified by the customer. The other output module provides two pin sockets that will accept a Cree CSD10120 TO-220 packaged diode.

The diode-under-test is connected in series with a 3 Ohm resistance on the output module. In order to achieve the full +/- 10A amplitude, the diode resistance must be much less than 3 Ohms (i.e., 0.1 Ohms or lower).

One end of the 3 Ohm resistance is connected to ground, and access to the other end is provided through a BNC connector. This output should be connected to a high-bandwidth (> 2 GHz) oscilloscope. The voltage across this resistance is directly proportional to the current through the diode. By observing the current waveform through the diode, the reverse recovery time may be determined.

A reverse bias of 0 to -12V may be applied across the diode under test. (-10 mA maximum current). This internally-generated reverse DC bias voltage acts to decrease the maximum forward pulse current and increase the maximum reverse pulse current. It is provided for waveform tweaking purposes.

The AVR-EB4-B-BOB includes an internal trigger source, but it can also be triggered or gated by an external source. A front-panel pushbutton can also be used to trigger the instrument.

The AVR-EB4-B-BOB features front panel keyboard and adjust knob control of the output pulse parameters along with a four line by 40-character backlit LCD display of the output amplitude, pulse repetition frequency, and delay. The instrument includes memory to store up to four complete instrument setups. The operator may use the front panel or the computer interface to store a complete "snapshot" of all key instrument settings, and recall this setup at a later time.

This instrument is intended for use in research, development, test and calibration laboratories by qualified personnel.

## SPECIFICATIONS

Model:	AVR-EB4-B-BOB
Description:	Customized +/-10A reverse recovery time measurement system with 2 ns switching time.
Diode drive waveform:	A 100 ns wide forward-bias pulse with amplitude adjustable up to +10A is immediately followed by a 100 ns width reverse-bias pulse with amplitude up to -10A. The forward and reverse amplitudes are independently variable.
Forward bias amplitude:	+10 Amps maximum. (For proper results, the diode under test must be able to fully turn on within 100 ns, and must be capable of conducting +10 Amps.)
Reverse bias amplitude:	-10 Amps maximum. (For proper results, the diode reverse recovery time must be less than 100 ns, and the diode must be capable of conducting -10 Amps.)
Diode resistance:	The diode-under-test is connected in series with a 3 Ohm resistance on the output module. In order to achieve the full +/- 10A amplitude, the diode resistance must be much less than 3 Ohms (i.e., 0.1 Ohms or lower).
Amplitude accuracy:	Due to the unpredictable effects of the diode-under-test's switching dynamics, the actual output currents must be confirmed using oscilloscope measurements. The programmed settings should not be relied upon for accuracy.
Forward bias pulse width:	100 ns (fixed)
Reverse bias pulse width:	100 ns (fixed)
Switching time from forward to reverse bias:	< 2 ns (20%-80%)
DC bias:	A reverse bias of 0 to -12V may be applied across the diode under test. (-10 mA maximum current). This internally-generated reverse DC bias voltage acts to decrease the maximum forward pulse current and increase the maximum reverse pulse current. It is provided for waveform tweaking purposes.
Repetition rate:	1 Hz to 1 kHz, adjustable
Device connections:	The output modules are supplied with the instrument. Only one output module is used at a time. The instrument mainframe is connected to output module in use by two 24" coaxial cables (one for the monocycle drive waveform, and one for the DC bias voltage). One output module contains a circuit board with spring-loaded contacts suitable for use with the custom surface-mount package shown in the email of May 19, 2005. The other output module provides two pin sockets that will accept a Cree CSD10120 TO-220 packaged diode.
GPIB, RS-232 ports:	included
Power requirements:	100 - 240 Volts, 50 - 60 Hz
CSA evaluation:	The AVR-EB4-B-BOB instrument has received a field evaluation (FE-25090-4) for compliance with CSA Model Code SPE-1000 and Canadian Electrical Code Part 1. Please see the "CSA Evaluation" section for details.
Dimensions: (H x W x D)	100 mm x 430 mm x 375 mm (3.9" x 17" x 14.8")
Chassis material:	Cast aluminum frame & handles, blue vinyl on aluminum cover plates
Mounting:	Any
Temperature range:	+5°C to +40°C

## EUROPEAN REGULATORY NOTES

### EC DECLARATION OF CONFORMITY

We

Avtech Electrosystems Ltd.  
P.O. Box 5120, LCD Merivale  
Ottawa, Ontario  
Canada K2C 3H4

declare that this pulse generator meets the intent of Directive 89/336/EEC for Electromagnetic Compatibility. Compliance pertains to the following specifications as listed in the official Journal of the European Communities:

EN 50081-1 Emission

EN 50082-1 Immunity

and that this pulse generator meets the intent of the Low Voltage Directive 72/23/EEC as amended by 93/68/EEC. Compliance pertains to the following specifications as listed in the official Journal of the European Communities:

EN 61010-1:2001 Safety requirements for electrical equipment for measurement, control, and laboratory use



### DIRECTIVE 2002/95/EC (RoHS)

This instrument is exempt from Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the Restriction of the use of certain Hazardous Substances (RoHS) in electrical and electronic equipment. Specifically, Avtech instruments are considered "Monitoring and control instruments" (Category 9) as defined in Annex 1A of Directive 2002/96/EC. The Directive 2002/95/EC only applies to Directive 2002/96/EC categories 1-7 and 10, as stated in the "Article 2 - Scope" section of Directive 2002/95/EC.

CSA EVALUATION

The AVR-EB4-B-BOB instrument has received a field evaluation (FE-25090-4) for compliance with CSA Model Code SPE-1000 and Canadian Electrical Code Part 1. The report is attached below:



FIELD EVALUATION REPORT HISTORY DOCUMENT

Date: NOV. 15/05 FE - 25090-4
Report by: M.A.
Office:
Location of Inspection: CUSTOMER
Attention: MIKA CHUDOBIAK
CUSTOMER: AVTECH
PRODUCT: PULSER GENERATOR

CAUTION NOTICES

Replace fuse with same type and rating More than one (1) power supply Other: See alterations
Disconnect supply before servicing
Permanent Cord Connected # of Conductors 3
Manufacturer's Name: AVTECH Cat/Model No: AVR-EB4-B-BOB
Electrical Rating 24 Volts AC 60 Hz 0.5 AMPS 1 ph
Dielectric Strength n/a Volts AC By Inspector On File
Flame Test O.K. n/a Max Risk Current ua Risk Class

DECLARATION: The following technical requirements were used in the evaluation of the product covered in this report.

CSA Std C22.2 No(s): Provincial Guidelines Model Code SPE 1000
UL Std(s): CEC Code NEC Code

ALTERATIONS:

n/a

Note: Evaluation made under the Field Evaluation Service shall not be considered as the equivalent of Certification.



## INSTALLATION

### VISUAL CHECK

After unpacking the instrument, examine to ensure that it has not been damaged in shipment. Visually inspect all connectors, knobs, liquid crystal displays (LCDs), and the handles. If the instrument has been damaged, file a claim immediately with the company that transported the instrument.

The following items should be with the instrument:

- 1) A power cord.
- 2) A GPIB cable
- 3) Two instrumentation manuals (this manual and the "Programming Manual for -B Instruments").
- 4) Two output modules (labeled "TRR A" and "TRR B").
- 5) A 24" (60 cm) length of SMA-to-SMA coaxial cable.
- 6) A 24" (60 cm) length of BNC-to-BNC coaxial cable.

### POWER RATINGS


This instrument is intended to operate from 100 - 240 V, 50 - 60 Hz.

The maximum power consumption is 57 Watts. Please see the "FUSES" section for information about the appropriate AC and DC fuses.

This instrument is an "Installation Category II" instrument, intended for operation from a normal single-phase supply.

### CONNECTION TO THE POWER SUPPLY


An IEC-320 three-pronged recessed male socket is provided on the back panel for AC power connection to the instrument. One end of the detachable power cord that is supplied with the instrument plugs into this socket. The other end of the detachable power cord plugs into the local mains supply. Use only the cable supplied with the instrument. The mains supply must be earthed, and the cord used to connect the instrument to the mains supply must provide an earth connection. (The supplied cord does this.)

 Warning: Failure to use a grounded outlet may result in injury or death due to electric shock. This product uses a power cord with a ground connection. It must be connected to a properly grounded outlet. The instrument chassis is connected to the ground wire in the power cord.

The table below describes the power cord that is normally supplied with this instrument, depending on the destination region:

Destination Region	Description	Manufacturer	Part Number
Continental Europe	European CEE 7/7 "Schuko" 230V, 50Hz	Volex ( <a href="http://www.volex.com">http://www.volex.com</a> )	17850-C3-326
		Qualtek ( <a href="http://www.qualtekusa.com">http://www.qualtekusa.com</a> )	319004-T01
United Kingdom	BS 1363, 230V, 50Hz	Qualtek ( <a href="http://www.qualtekusa.com">http://www.qualtekusa.com</a> )	370001-E01
Switzerland	SEV 1011, 2 30V, 50Hz	Volex ( <a href="http://www.volex.com">http://www.volex.com</a> )	2102H-C3-10
Israel	SI 32, 220V, 50Hz	Volex ( <a href="http://www.volex.com">http://www.volex.com</a> )	2115H-C3-10
North America, and all other areas	NEMA 5-15, 120V, 60 Hz	Qualtek ( <a href="http://www.qualtekusa.com">http://www.qualtekusa.com</a> )	312007-01

### PROTECTION FROM ELECTRIC SHOCK

 Operators of this instrument must be protected from electric shock at all times. The owner must ensure that operators are prevented access and/or are insulated from every connection point. In some cases, connections must be exposed to potential human contact. Operators must be trained to protect themselves from the risk of electric shock. This instrument is intended for use by qualified personnel who recognize shock hazards and are familiar with safety precautions required to avoid possibly injury. In particular, operators should:

- 1) Keep exposed high-voltage wiring to an absolute minimum.
- 2) Wherever possible, use shielded connectors and cabling.
- 3) Connect and disconnect loads and cables only when the instrument is turned off.
- 4) Keep in mind that all cables, connectors, oscilloscope probes, and loads must have an appropriate voltage rating.
- 5) Do not attempt any repairs on the instrument, beyond the fuse replacement procedures described in this manual. Contact Avtech technical support (see page 2 for contact information) if the instrument requires servicing. Service is to be performed solely by qualified service personnel.

### ENVIRONMENTAL CONDITIONS

This instrument is intended for use under the following conditions:

1. indoor use;
2. altitude up to 2 000 m;
3. temperature 5 °C to 40 °C;
4. maximum relative humidity 80 % for temperatures up to 31 °C decreasing linearly to 50 % relative humidity at 40 °C;
5. Mains supply voltage fluctuations up to  $\pm 10$  % of the nominal voltage;
6. no pollution or only dry, non-conductive pollution.

## FUSES

This instrument contains four fuses. All are accessible from the rear-panel. Two protect the AC prime power input, and two protect the internal DC power supplies. The locations of the fuses on the rear panel are shown in the figure below:



### AC FUSE REPLACEMENT

To physically access the AC fuses, the power cord must be detached from the rear panel of the instrument. The fuse drawer may then be extracted using a small flat-head screwdriver, as shown below:



## DC FUSE REPLACEMENT

The DC fuses may be replaced by inserting the tip of a flat-head screwdriver into the fuse holder slot, and rotating the slot counter-clockwise. The fuse and its carrier will then pop out.

## FUSE RATINGS

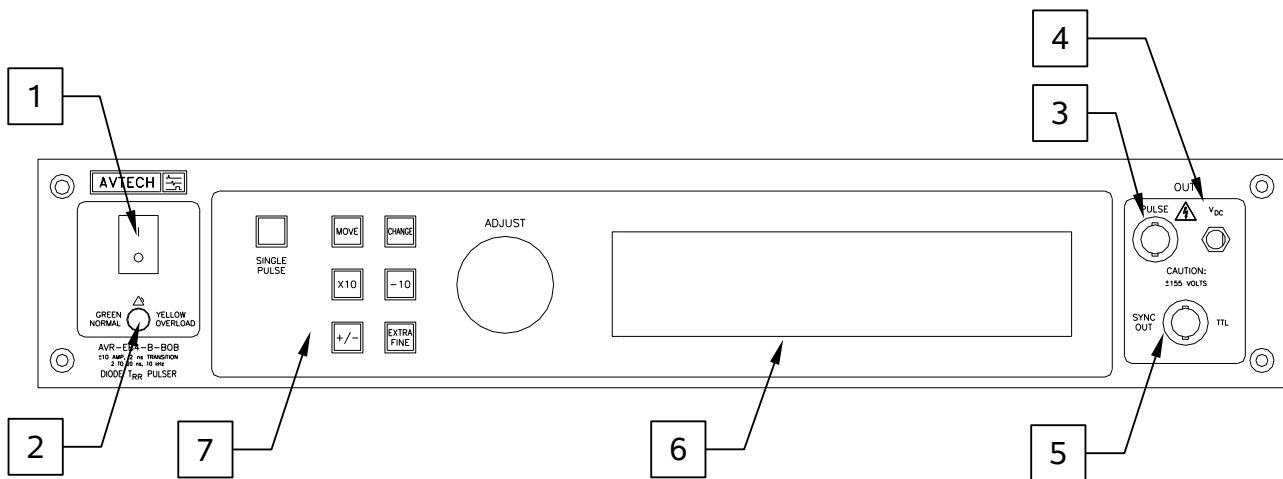
The following table lists the required fuses:

Fuses	Nominal Mains Voltage	Rating	Case Size	Manufacturer's Part Number (Wickmann)	Distributor's Part Number (Digi-Key)
#1, #2 (AC)	100-240V	0.5A, 250V, Time-Delay	5×20 mm	1950500000	WK5041-ND
#3 (DC)	N/A	2.0A, 250V, Time-Delay	5×20 mm	1951200000	WK5057-ND
#4 (DC)	N/A	0.8A, 250V, Time-Delay	5×20 mm	1950800000	WK5046-ND

The fuse manufacturer is Wickmann (<http://www.wickmann.com/>).

Replacement fuses may be easily obtained from Digi-Key (<http://www.digikey.com/>) and other distributors.

## FRONT PANEL CONTROLS



1. POWER Switch. This is the main power switch. When turning the instrument on, there may be a delay of several seconds before the instrument appears to respond.
2. OVERLOAD Indicator. When the instrument is powered, this indicator is normally green, indicating normal operation. If this indicator is yellow, an internal automatic overload protection circuit has been tripped. If the unit is overloaded (by operating at an exceedingly high duty cycle or by operating into a very low impedance), the protective circuit will disable the output of the instrument and turn the indicator light yellow. The light will stay yellow (i.e. output disabled) for about 5 seconds after which the instrument will attempt to re-enable the output (i.e. light green) for about 1 second. If the overload condition persists, the output will be disabled again (i.e. light yellow) for another 5 seconds. If the overload condition has been removed, the instrument will resume normal operation.

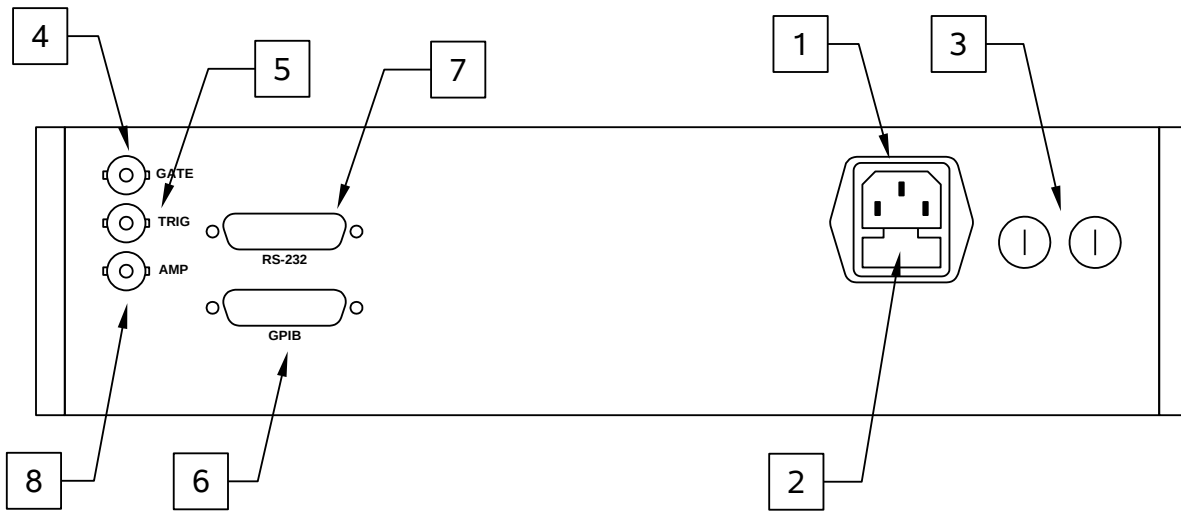
This overload indicator may flash yellow briefly at start-up. This is not a cause for concern.

3. PULSE OUT CONNECTOR. This BNC connector provides the pulse output signal to the output module. This output should be connected to the corresponding input on the output module using the supplied BNC-to-BNC coaxial cable.
4. VDC CONNECTOR. This SMA connector provides the DC offset signal to the output module. This output should be connected to the corresponding input on the output module using the supplied SMA-to-SMA coaxial cable.
5. SYNC OUT. This connector supplies a SYNC output that can be used to trigger other equipment, particularly oscilloscopes. This signal leads (or lags) the main output by a duration set by the "DELAY" controls and has an approximate amplitude of +3 Volts to  $R_L > 50\Omega$  with a pulse width of approximately 100 ns.

6. LIQUID CRYSTAL DISPLAY (LCD). This LCD is used in conjunction with the keypad to change the instrument settings. Normally, the main menu is displayed, which lists the key adjustable parameters and their current values. The “OP1B Interface Programming Manual” describes the menus and submenus in detail.
7. KEYPAD.

Control Name	Function
MOVE	This moves the arrow pointer on the display.
CHANGE	This is used to enter the submenu, or to select the operating mode, pointed to by the arrow pointer.
×10	If one of the adjustable numeric parameters is displayed, this increases the setting by a factor of ten.
÷10	If one of the adjustable numeric parameters is displayed, this decreases the setting by a factor of ten.
+/-	If one of the adjustable numeric parameters is displayed, and this parameter can be both positive or negative, this changes the sign of the parameter.
EXTRA FINE	This changes the step size of the ADJUST knob. In the extra-fine mode, the step size is twenty times finer than in the normal mode. This button switches between the two step sizes.
ADJUST	This large knob adjusts the value of any displayed numeric adjustable values, such as frequency, pulse width, etc. The adjust step size is set by the "EXTRA FINE" button.  When the main menu is displayed, this knob can be used to move the arrow pointer.

## REAR PANEL CONTROLS



1. AC POWER INPUT. An IEC-320 C14 three-pronged recessed male socket is provided on the back panel for AC power connection to the instrument. One end of the detachable power cord that is supplied with the instrument plugs into this socket.
2. AC FUSE DRAWER. The two fuses that protect the AC input are located in this drawer. Please see the “FUSES” section of this manual for more information.
3. DC FUSES. These two fuses protect the internal DC power supplies. Please see the “FUSES” sections of this manual for more information.
4. GATE. This TTL-level (0 and +5V) logic input can be used to gate the triggering of the instrument. This input can be either active high or active low, depending on the front panel settings or programming commands. (The instrument triggers normally when this input is unconnected). When set to active high mode, this input is pulled-down to ground by a 1 k $\Omega$  resistor. When set to active low mode, this input is pulled-up to +5V by a 1 k $\Omega$  resistor.
5. TRIG. This TTL-level (0 and +5V) logic input can be used to trigger the instrument, if the instrument is set to triggering externally. The instrument triggers on the rising edge of this input. The input impedance of this input is 1 k $\Omega$ . (Depending on the length of cable attached to this input, and the source driving it, it may be desirable to add a coaxial 50 Ohm terminator to this input to provide a proper transmission line termination. The Pasternack ([www.pasternack.com](http://www.pasternack.com)) PE6008-50 BNC feed-thru 50 Ohm terminator is suggested for this purpose.)

When triggering externally, the instrument can be set such that the output pulse width tracks the pulse width on this input, or the output pulse width can be set independently.



6. GPIB Connector. A standard GPIB cable can be attached to this connector to allow the instrument to be computer-controlled. See the “Programming Manual for -B Instruments” for more details on GPIB control.
7. RS-232 Connector. A standard serial cable with a 25-pin male connector can be attached to this connector to allow the instrument to be computer-controlled. See the “Programming Manual for -B Instruments” for more details on RS-232 control.
8. AMP Connector. This connector is not used.

## TIMING CONTROL

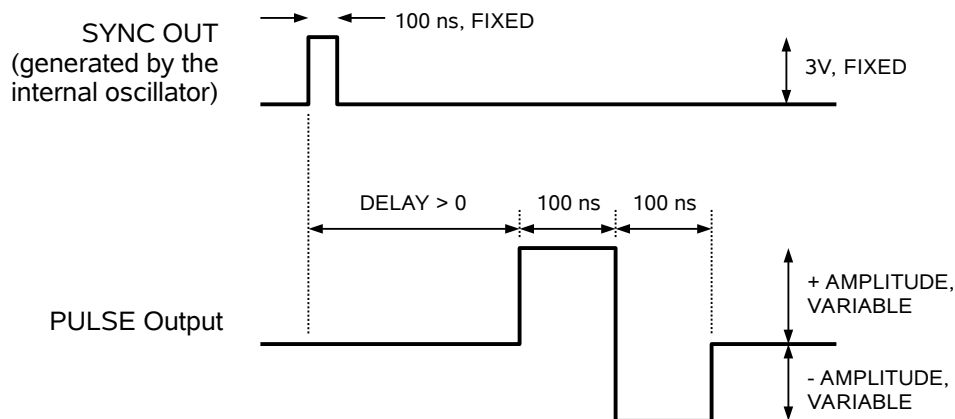
### BASIC TIMING CONTROL

This instrument can be triggered by its own internal clock or by an external TTL trigger signal. In either case, two output channels respond to the trigger: PULSE and SYNC.

The PULSE output is a bipolar signal that may either drive a 50 Ohm load, or the test jig described later. The positive and negative amplitudes are adjustable. The pulse widths are fixed at 100 ns.

The SYNC pulse is a fixed-width TTL-level reference pulse used to trigger oscilloscopes or other measurement systems. When the delay is set to a positive value the SYNC pulse precedes the PULSE output. When the delay is set to a negative value the SYNC pulse follows the PULSE output.

These pulses are illustrated below, assuming internal triggering and a positive delay:



*Figure A*

If the delay is negative, the order of the SYNC and PULSE outputs is reversed:

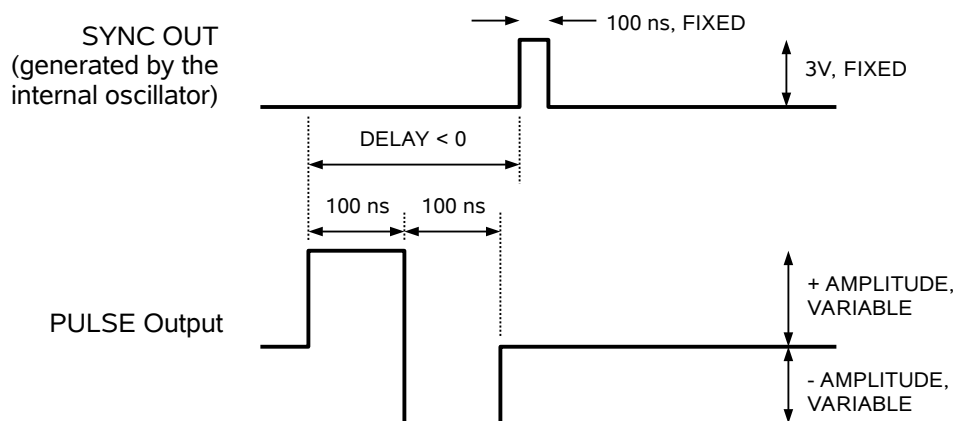


Figure B

The next figure illustrates the relationship between the signal when an external TTL-level trigger is used:

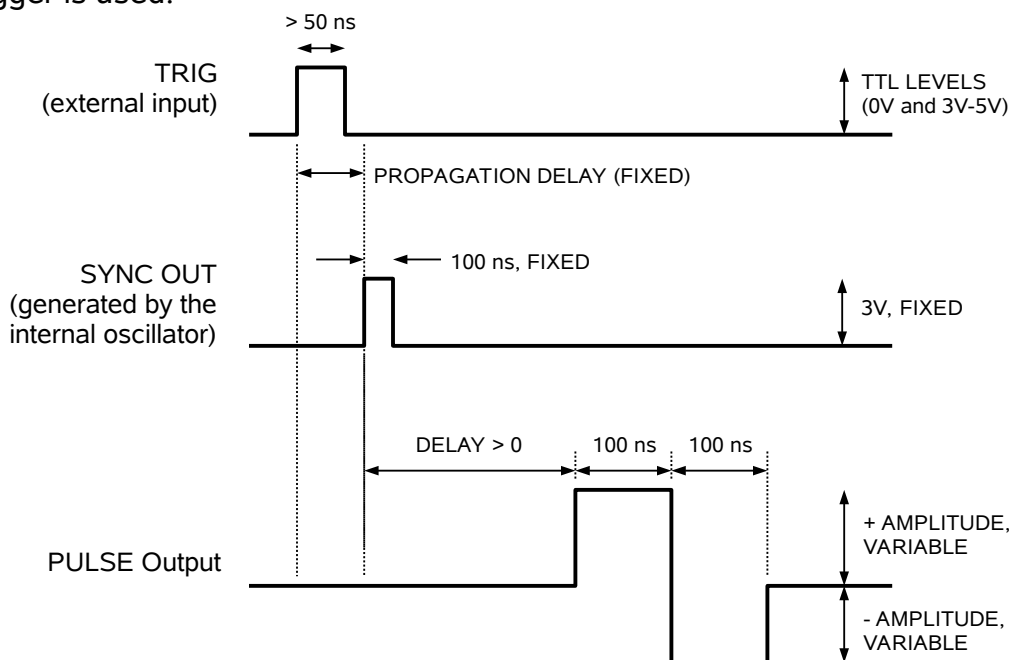


Figure C

As before, if the delay is negative, the order of the SYNC and PULSE outputs is reversed.

The delay and frequency (when in the internal mode) of the PULSE output can be varied with front panel controls or via the GPIB or RS-232 computer interfaces.

## TRIGGER MODES

This instrument has four trigger modes:

- Internal Trigger: the instrument controls the trigger frequency, and generates the clock internally.
- External Trigger: the instrument is triggered by an external TTL-level clock on the back-panel TRIG connector.
- Manual Trigger: the instrument is triggered by the front-panel “SINGLE PULSE” pushbutton.
- Hold Trigger: the instrument is set to not trigger at all.

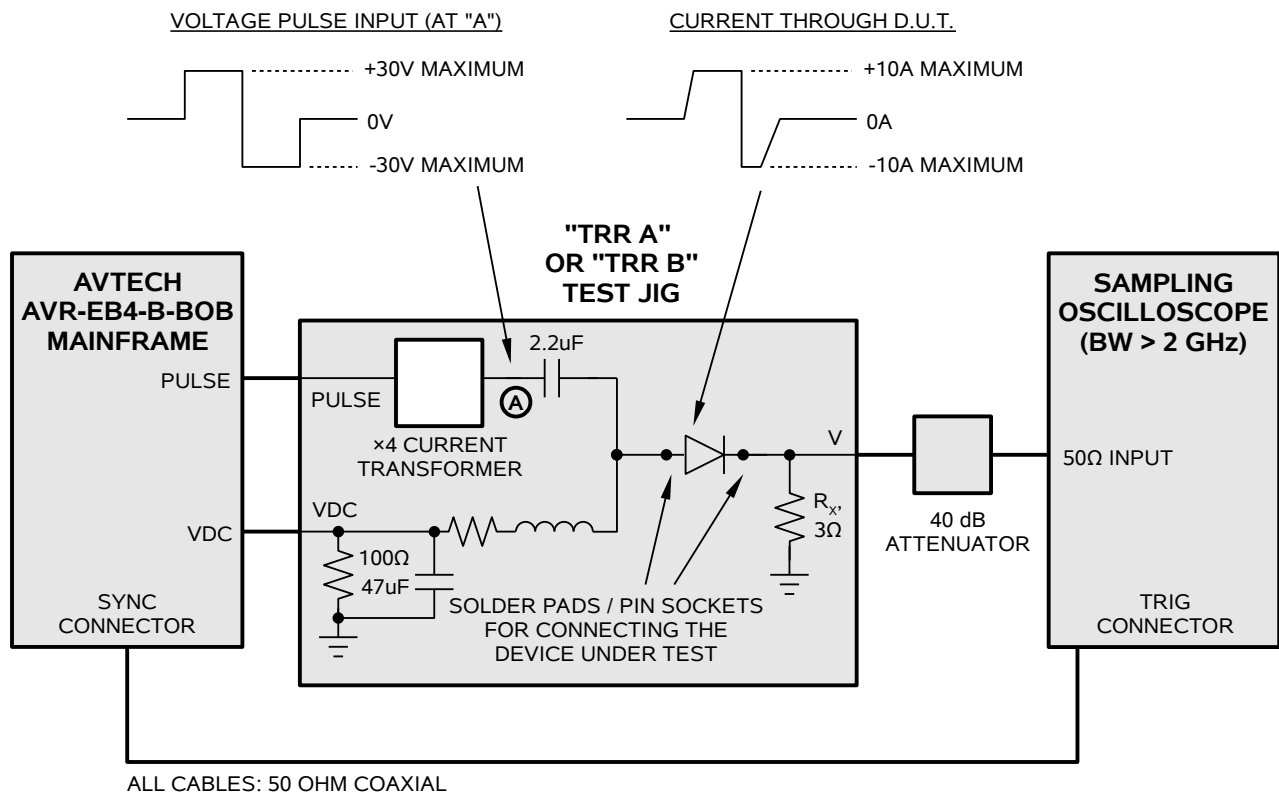
These modes can be selected using the front panel trigger menu, or by using the appropriate programming commands. (See the “Programming Manual for -B Instruments” for more details.)

## GATING MODES

Triggering can be suppressed by a TTL-level signal on the rear-panel GATE connector. The instrument can be set to stop triggering when this input high or low, using the front-panel gate menu or the appropriate programming commands. When gated, the output will complete the full pulse width if the output is high, and then stop triggering. Pulses are not truncated.

## BASIC AMPLITUDE CONTROL

The basic test arrangement for the AVR-EB4-B-BOB is shown in the figure below. The PULSE output on the instrument mainframe is connected to the PULSE input on the test jig (part number "TRR A" or "TRR B") using the supplied BNC-to-BNC coaxial cable, and the VDC output is connected to the VDC input using the supplied SMA-to-SMA coaxial cable. (If the DC offset feature not required, the BNC-to-BNC cable connecting the "VDC" connector on the mainframe to the "VDC" connector on the test jig may be left unconnected.)



The instrument mainframe generates a high-voltage (up to  $\pm 150\text{V}$  approximately), low-current bipolar pulse. This pulse is supplied to the test jig, where a current-quadrupling transformer boosts the current to  $\pm 10\text{A}$  levels (and reduces the voltages to  $\pm 30\text{V}$ , approximately).

The current through the diode is observed by connecting a high-speed oscilloscope to the "V" output terminal on the test jig. (Most high-speed sampling oscilloscopes will require the use of an attenuator on the input to ensure that the input voltage to the scope remains within safe limits - typically  $\pm 1\text{V}$ .) The voltage on the "V" output is directly related to the diode current, by the relation:

$$I_{\text{DIODE}} = V / R_{\text{SENSE}}$$

where  $R_{\text{SENSE}}$  is the effective resistance formed by the parallel combination of the internal sensing resistance ( $R_x = 3.0 \Omega \pm 5\%$ ) and the input impedance of the oscilloscope / attenuator combination ( $R_{\text{SCOPE}}$ , normally 50 Ohms, for a sampling oscilloscope). That is,

$$R_{\text{SENSE}} = 1 / (1/R_x + 1/R_{\text{SCOPE}})$$

The positive portion of the PULSE signal forward biases the device under test (DUT) for 100 ns. The negative portion that immediately follows the positive portion forces the DUT into reverse bias. The switching time from forward to negative bias is < 2 ns. The negative PULSE portion is 100 ns in duration.

When the DUT is switched into reverse bias, it will conduct for a short time due to the presence of stored charge and parasitic capacitance. The duration of this period of conduction is the reverse recovery time. The exact definition of the reverse recovery time depends on the the particular method or figure of merit that the user has adopted. A typical definition of reverse recovery time would be the time it takes for the reverse current transient to decay from 80% to 20% of its peak value.

### SETTING THE AMPLITUDE LEVELS

The amplitude of the positive and negative portions of the PULSE waveform may be set from the front panel of the instrument, or by computer command.

These settings are expressed in terms of the voltage present after the current transformer inside the test jig - point "A" in the figure above.

The positive voltage ("AMP1" on the front panel display) is related to the forward diode current by:

$$I_{\text{FORWARD}} \approx (\text{AMP1} - V_F) / (R_{\text{SENSE}} + R_{\text{DIODE-FORWARD}})$$

where  $V_F$  is the forward voltage drop of the diode (typically 0.7V for the classic silicon PN junction diode, and usually somewhat lower for a Schottky diode), and  $R_{\text{DIODE-FORWARD}}$  is the effective resistance of the diode under forward bias.

The negative voltage ("AMP2" on the front panel display) is related to the reverse diode current by:

$$I_{\text{REVERSE}} \approx \text{AMP2} / (R_{\text{SENSE}} + R_{\text{DIODE-REVERSE}}).$$

Where  $R_{\text{DIODE-REVERSE}}$  is the effective resistance of the diode under reverse bias.

It is important to note that  $R_{\text{DIODE-FORWARD}}$  and  $R_{\text{DIODE-REVERSE}}$  are not the same, and that they may change during the transient. Furthermore, depending on the design of the diode under test, it is possible that  $R_{\text{DIODE-REVERSE}}$  may be so high that it is impossible to

achieve the full 10 Amps of reverse current. (The ideal diode would of course have  $R_{\text{DIODE-REVERSE}} = \infty$ ).

Most test procedures for measuring recovery time will use a particular ratio of forward to reverse currents - for example,  $I_{\text{FORWARD}} / I_{\text{REVERSE}} = 1$ .

Some Schottky diodes have negligible amounts of stored charge resulting from the forward bias, compared to non-Schottky devices. For these Schottky diodes, the reverse transient will be governed by the capacitance of the device, and the reverse transient may be largely unaffected by the amplitude of the forward transient. (In other words, the  $I_{\text{FORWARD}} / I_{\text{REVERSE}}$  ratio is irrelevant). The capacitance may be so small that it becomes impossible to obtain the full -10 Amps of reverse current.

Normally, the forward and reverse amplitudes should be set near the maximum values ( $\pm 30\text{V}$ ). Performance may degrade if the amplitudes are set lower than  $\pm 5\text{V}$ .

### AMPLITUDE ACCURACY

Due to the variations in  $V_F$  and  $R_{\text{DIODE-FORWARD}}$  and  $R_{\text{DIODE-REVERSE}}$  as a function of operating conditions, the AMP1 and AMP2 settings *should not be relied upon for any degree of accuracy*. Instead the voltage at the "V" output terminal on the test jig should be monitored with a calibrated oscilloscope. As mentioned above,  $I_{\text{DIODE}} = V / R_{\text{SENSE}}$ .

$R_X$  can be measured directly (to determine  $R_{\text{SENSE}}$ ) for calibration purposes. To do so:

- 1) Disconnect all cables from the test jig, and remove any installed DUTs.
- 2) Use a four-wire resistance measurement system, such as the Keithley 2400. Connect the "INPUT / OUTPUT HI" ohmmeter terminal (as it is marked on the Keithley 2400) to the cathode pin socket or pad on the test jig.
- 3) Connect the "INPUT / OUTPUT LO" ohmmeter terminal to the outer conductor (the ground shield) of the "PULSE" connector on the test jig.
- 4) Connect the "SENSE HI" ohmmeter terminal to the center conductor of the "V" connector on the test jig.
- 5) Lastly, connect the "SENSE LO" ohmmeter terminal to the outer conductor (the ground shield) of the "V" connector on the test jig.
- 6) Measure the resistance. It should be 3.0 Ohms, approximately.

### DC OFFSET

A "VDC" DC offset output is provided on the instrument mainframe, in addition to the PULSE output. Normally this offset is simply set at zero, but it can be used to introduce

a negative (reverse bias) DC offset in the range of 0 to -12 Volts, if desired. Adding a slightly reverse bias may improve the "squareness" of the observed waveforms. This offset is essentially a "tweaking" adjustment, allowing an additional degree of freedom for obtaining the best possible waveforms.

If a DC offset of  $V_{DC}$  is used, the equations for the forward and reverse current are modified to:

$$I_{FORWARD} \approx (AMP1 + V_{DC} - V_F) / (R_{SENSE} + R_{DIODE})$$

and

$$I_{REVERSE} \approx (AMP2 + V_{DC}) / (R_{SENSE} + R_{DIODE}).$$

In these equations, AMP1 is positive, and AMP2 and  $V_{DC}$  are negative.

If the DC offset feature not required, the BNC-to-BNC cable connecting the "VDC" connector on the mainframe to the "VDC" connector on the test jig may be left unconnected.

### INCORRECT ORIENTATION

The instrument and the DUT will not be damaged if the diode is installed with the incorrect orientation (i.e., with the anode and cathode reversed). However, incorrect waveforms will be generated,

### ACCESSIBLE VOLTAGES

When a DUT is installed properly in the test jig, the maximum accessible voltage on the test jig (on the anode pins / pads / post) will be  $\pm 45V$ , with a duration of  $< 100$  ns, and a repetition rate  $\leq 1$  kHz.

When no DUT is installed in the test jig, the maximum accessible voltage on the test jig (on the anode pins / pads / post) will be  $\pm 120V$ , with pulse widths of  $< 100$  ns.

For safety purposes, the output should be set to "off" from the front panel menu (or by using the "output off" command) before touching the test jigs.



## TEST JIG MECHANICAL ASPECTS

Two test jigs (TRR A and TRR B) are supplied with the mainframe.

### TRR A TEST JIG

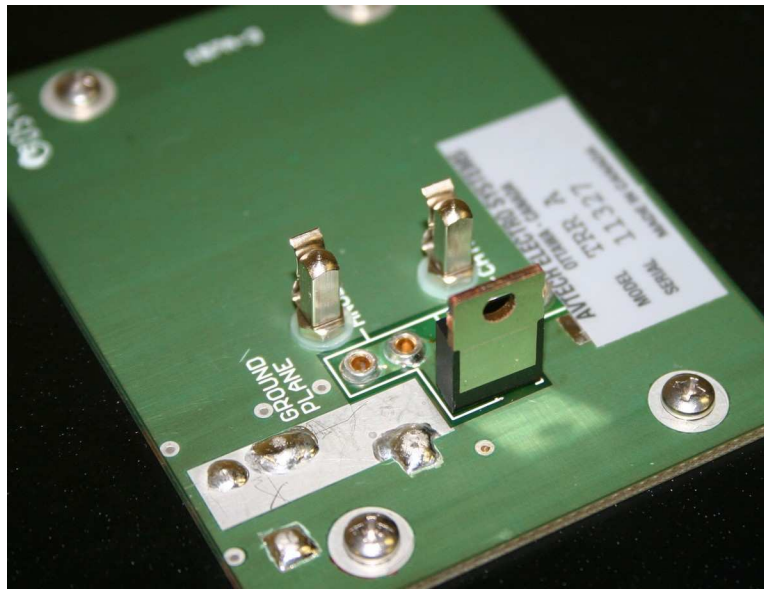
The TRR A test jig accepts a range of through-hole and axial devices, using pin sockets and spring-clip posts. It is intended for use with diodes in TO-220 or DO-204AR or similar packages. A photo of the pad/post arrangement is shown below. Pins 1-4 are connected together, and one of them should be connected to the anode of the device. Pins 5-8 are connected together, and should be connected to the cathode of the device.

The instrument and the DUT will not be damaged if the diode is installed with the incorrect orientation (i.e., with the anode and cathode reversed). However, incorrect waveforms will be generated.

Best results will be obtained using the pins closest to pins 1 and 5, because this results in the path of least inductance.

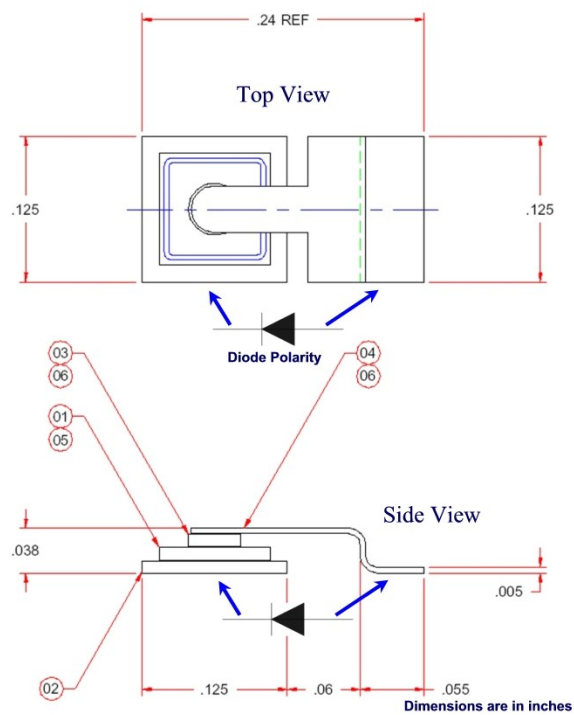


The photo below shows a Cree CSD10120 Silicon Carbide Schottky diode installed using pin sockets 1 and 5.



### TRR B TEST JIG

The TRR B test jig is specifically designed for testing diodes in the package shown in the user-supplied drawing below:



Photos of the TRR B test jig are shown below.



*Hinged portion up*



*Hinged portion down*

The gold pads on the lower circuit board are the active connection points for the device. The DUT should rest upon these two pads. (There is a hole with a nominal diameter of 0.032" in the center of each pad. It is possible to insert an axial-leaded through-hole diode into these holes by bending the leads appropriately. This is only suggested for testing purposes when the SMT DUT is unavailable or inconvenient, and it is not appropriate for production testing.)

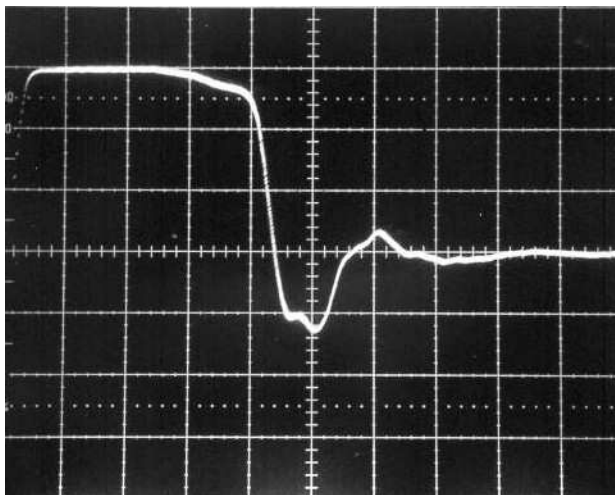
The upper circuit board is hinged and supports two spring-loaded probes that mechanically "pin down" the DUT. When the upper circuit board is lowered into position, a magnetic lock is engaged to secure it in position. To release the DUT, simply lift the upper circuit board up and out of the way.

## TYPICAL RESULTS

Obtaining meaningful results with the AVR-EB4-B-BOB requires care, experience, and an understanding of diode transient behavior and the impact of inductive and capacitive parasitics. To assist the user, typical results for commercially available diodes are provided below. The user should be able to reliably duplicate these results.

### CREE CSD10120

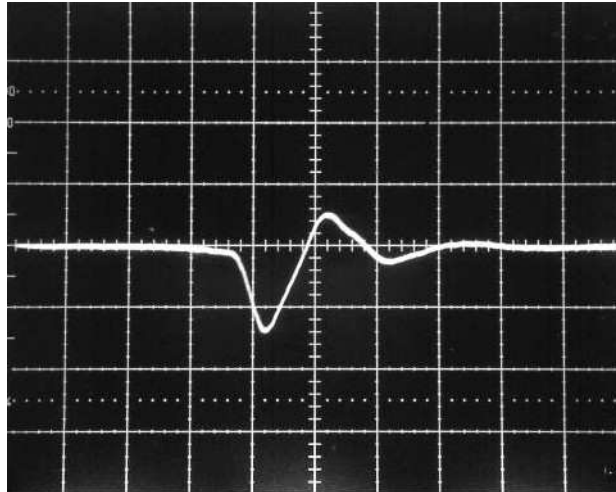
The Cree CSD10120 is a state-of-the-art 1200 Volt, 10 Amp TO-220-packaged Silicon Carbide Schottky diode, promoted as a "Zero Recovery Rectifier". (The client indicated that this diode is the commercially available diode most similar to the chip diode that will be tested with the TRR B test jig.) The waveform below shows the results obtained with the CSD10120 diode installed in the TRR A test jig. (See the "TEST JIG MECHANICAL ASPECTS" section for an actual photo of the device installed in the test jig.)



10 V/div (= 3.5A/div), 5 ns/div.

The waveform above shows the end of the forward pulse, followed by the rapid (< 2 ns) switched to reverse bias. The forward amplitude is set at +30V, and the reverse amplitude is set to -30V, which should generate currents of +10A and -10A, respectively. In fact, diode is not capable of supporting a -10A reverse current - a reverse current of -4 A lasting for a duration of 5 ns is observed.

The next waveform shows what happens to the reverse transient when the forward bias amplitude is zero:



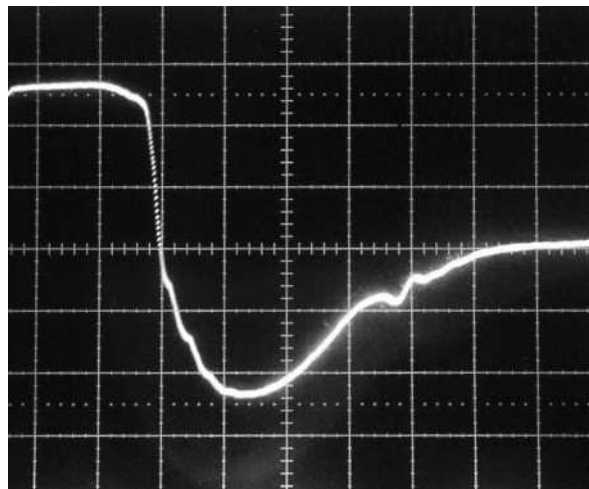
10 V/div (= 3.5A/div), 5 ns/div.

The forward transient is completely gone, but the amplitude and duration of the negative transient are largely unchanged! (The shape of the waveform is more "triangular", however.) This strongly suggests that the reverse transient is due to the device capacitance, rather than minority carrier charge storage. In fact, the CSD10120 datasheet indicates that the device has a capacitance of 1000 pF typically (for a bias of zero). The RC time constant of  $R_{\text{SENSE}} \times C_{\text{DIODE}} = 3 \Omega \times 1000 \text{ pF} = 3 \text{ ns}$ , which largely explains the nature of the capacitive reverse transient seen above.

The CSD10120 datasheet says "this is a majority carrier diode, so there is no reverse recovery charge", and the results above largely support this.

#### IR HFA16PB120 HEXFRED

The waveform below shows results for the International Rectifier HFA16PB120 1200 Volt, 16 Amp TO-247AC-packaged "Hexfred Ultrafast Soft Recovery Rectifier":

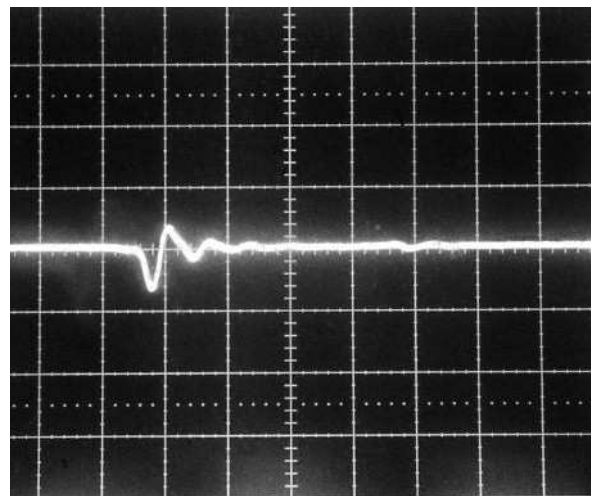


10 V/div (= 3.5A/div), 10 ns/div.

The reverse recovery time is considerably longer than the CSD10120. (The reverse transient is approximately 50 ns in duration). Also, the package inductance (approximately 8 nH, according to the datasheet) tends to degrade the forward-to-reverse switching time. (The inductive time constant is given by  $\tau = L / R_{\text{SENSE}}$ . Allowing 4 nH of inductance in the test jig, the inductive time constant will be  $\tau = (4 \text{ nH} + 8 \text{ nH}) / 3 \Omega = 4 \text{ ns}$ , which agrees well with the "rounding" seen above.)

The reverse transient decays smoothly to zero, in an exponential-like decay. This shows that the device has been optimized to produce "soft" reverse recovery transients. (See the results below for the FR803 for an example of a hard-switching transient.)

The next waveform shows the reverse transient obtained when the forward bias is zero:

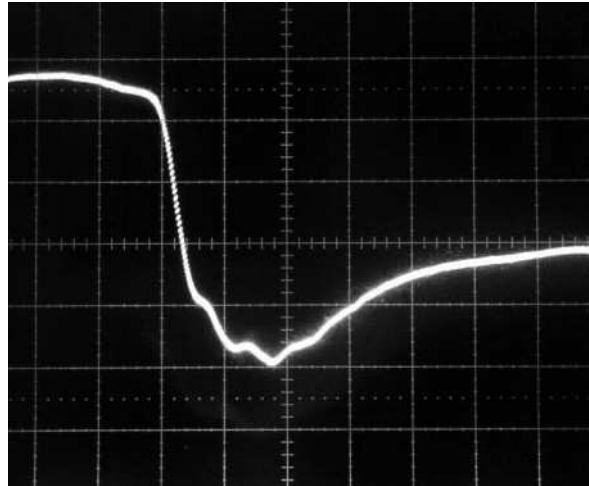


10 V/div (= 3.5A/div), 10 ns/div.

The large difference between the +10A and 0A forward bias results shows that the HFA16PB120 reverse transient behaviour is dominated by stored minority carrier charge, rather than device capacitance, unlike the CSD10120. This isn't surprising, since the HFA16PB120 is not a Schottky diode. The amplitude of the reverse transient for zero forward bias is smaller for the HFA16PB120 than the CSD10120, due to the lower capacitance of the HFA16PB120 (approximately 300 pF, versus 1000 pF, at zero bias).

### ADVANCED POWER APT15S20K

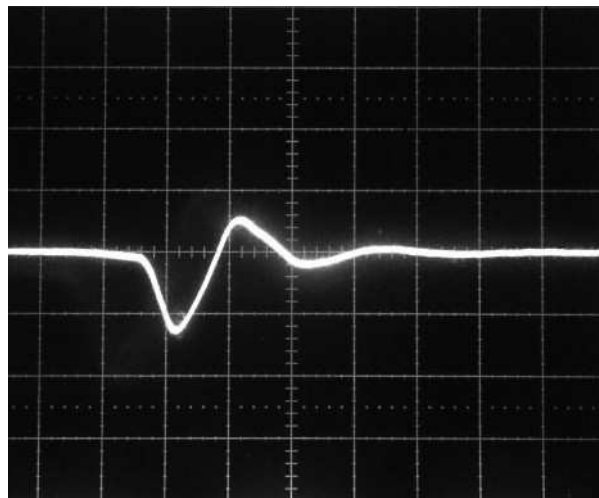
The Advanced Power APT15S20K is a 200 Volt, 25 Amp Schottky diode in a TO-220 package. The waveform for  $\pm 30\text{V}$  forward/reverse bias is shown below:



10 V/div (= 3.5A/div), 5 ns/div.

This Schottky diode has a considerably longer reverse recovery time than the CSD10120, but it is faster than the non-Schottky 1000V HFA16PB120.

The next waveform shows the reverse transient obtained when the forward bias is zero:

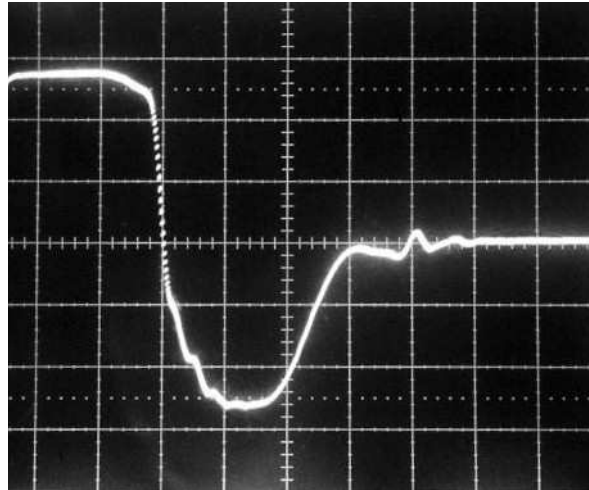


10 V/div (= 3.5A/div), 5 ns/div.

The zero-bias transient is very similar to the CSD10120, which is not surprising, since they have similar capacitances (1000 pF at zero bias, approximately).

### DIODES INC. FR803

The Diodes Inc. FR803 is a 200V, 8A fast-recovery rectifier (non-Schottky) in a TO-220A package. The waveform for  $\pm 30V$  forward/reverse bias is shown below:



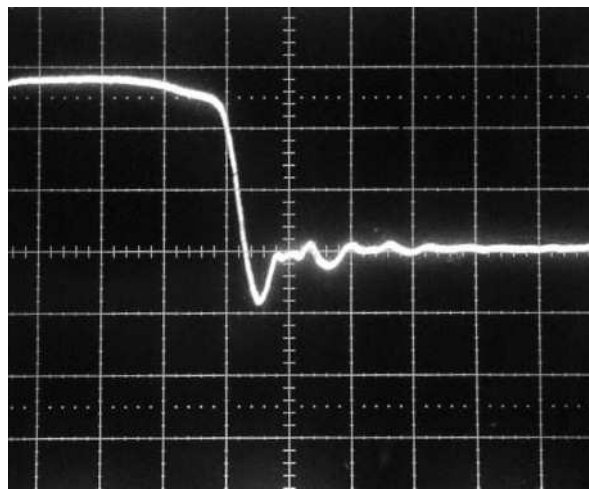
10 V/div (= 3.5A/div), 10 ns/div.

Compared to the HFA16PB120, the FR803 maintains its peak reverse current and then switches "off" more sharply. This is a "hard" reverse recovery transient.

Again, the inductive time constant degrades the forward-to-reverse switching time slightly.

#### DIODES INC. 1N5819

The 1N5819 is a Schottky diode, like the CSD10120, but intended for operation at much lower voltages and currents (40V, 1A). The waveform for  $\pm 30V$  forward/reverse bias is shown below:



10 V/div (= 3.5A/div), 5 ns/div.

The 1N5819 has almost no reverse transient - it lasts less than 2 ns! The Schottky design and the lower current design (which provides a low zero-bias capacitance of 250 pF) contribute to the achievement of the near-ideal reverse transient.

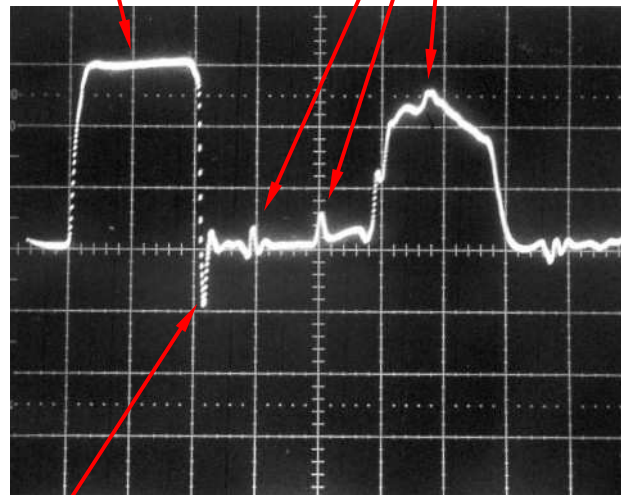


## TRANSIENT REFLECTIONS

The AVR-EB4-B-BOB relies on a transmission line system to obtain high-speed waveforms. When the diode DUT is forward biased or in the initial (conducting) phase of the reverse bias transient it acts as a low resistance, completing the transmission line circuit. When the diode enters the low-current, high-resistance phase of the reverse transient, the diode appears as an open circuit. This causes large reflections to occur on the output transmission line circuits, as expected from basic transmission line theory. Since these reflections occur after the forward-to-reverse switching transient, they can be ignored. An example of such a reflection is shown below, for a Cree CSD10120 DUT:

Forward bias pulse  
(100 ns in duration)

Reflections that  
can be ignored



10 V/div (= 3.5A/div), 50 ns/div.

Reverse transient of interest  
(see the "CREE CSD10120"  
section for a view of this  
transient at 5 ns/div)

## PROGRAMMING YOUR PULSE GENERATOR

### KEY PROGRAMMING COMMANDS

The “OP1B Interface Programming Manual” describes in detail how to connect the pulse generator to your computer, and the programming commands themselves. A large number of commands are available; however, normally you will only need a few of these. Here is a basic sample sequence of commands that might be sent to the instrument after power-up:

*rst	(resets the instrument)
trigger:source internal	(selects internal triggering)
frequency 1000 Hz	(sets the frequency to 1000 Hz)
pulse:delay 1 us	(sets the inter-channel delay to 1 us)
volt:ampl1 +30	(sets the positive pulse amplitude to +30 V)
volt:ampl2 -30	(sets the negative pulse amplitude to -30 V)
volt:low 0	(sets the DC offset to zero)
output on	(turns on the output)

For triggering a single event, this sequence would be more appropriate:

*rst	(resets the instrument)
trigger:source hold	(turns off all triggering)
pulse:delay 1 us	(sets the inter-channel delay to 1 us)
output on	(turns on the output)
volt:ampl1 +30	(sets the positive pulse amplitude to +30 V)
volt:ampl2 -30	(sets the negative pulse amplitude to -30 V)
volt:low 0	(sets the DC offset to zero)
trigger:source immediate	(generates a single non-repetitive trigger event)
trigger:source hold	(turns off all triggering)
output off	(turns off the output)

To set the instrument to trigger from an external TTL signal applied to the rear-panel TRlg connector, use:

*rst	(resets the instrument)
trigger:source external	(selects external triggering)
pulse:delay 1 us	(sets the inter-channel delay to 1 us)
volt:ampl1 +30	(sets the positive pulse amplitude to +30 V)
volt:ampl2 -30	(sets the negative pulse amplitude to -30 V)
volt:low 0	(sets the DC offset to zero)
output on	(turns on the output)

These commands will satisfy 90% of your programming needs.

## ALL PROGRAMMING COMMANDS

For more advanced programmers, a complete list of the available commands is given below. These commands are described in detail in the “OP1B Interface Programming Manual”. (Note: this manual also includes some commands that are not implemented in this instrument. They can be ignored.)


<u>Keyword</u>	<u>Parameter</u>	<u>Notes</u>
LOCAL		
OUTPut:		
:[STATe]	<boolean value>	
:PROTection		
:TRIPped?		[query only]
REMOTE		
[SOURce]:		
:FREQuency		
[:CW   FIXed]	<numeric value>	
[SOURce]:		
:PULSe		
:PERiod	<numeric value>	
:DELAy	<numeric value>	
:GATE		
:LEVel	High   Low	
[SOURce]:		
:VOLTAge		
[:LEVel]		
[:IMMediate]		
[:AMPLitude]	<numeric value>	
:LOW	<numeric value>   EXTeRnal	
:PROTection		
:TRIPped?		[query only]
STATUS:		
:OPERation		
:[EVENT]?		[query only, always returns "0"]
:CONDition?		[query only, always returns "0"]
:ENABle	<numeric value>	[implemented but not useful]
:QUEStionable		
:[EVENT]?		[query only, always returns "0"]
:CONDition?		[query only, always returns "0"]
:ENABle	<numeric value>	[implemented but not useful]
SYSTEM:		
:COMMunicate		
:GPIB		
:ADDReSS	<numeric value>	
:SERial		
:CONTRol		
:RTS	ON   IBFull   RFR	
:[RECeive]		
:BAUD	1200   2400   4800   9600	
:BITS	7   8	
:ECHO	<boolean value>	
:PARity		
:[TYPE]	EVEN   ODD   NONE	

	:SBITS	1   2	
:ERRor			
:[NEXT]?			[query only]
:COUNT?			[query only]
:VERSion?			[query only]
TRIGger:			
:SOURce		INTernal   EXTernal   MANual   HOLD   IMMEDIATE	
*CLS			[no query form]
*ESE		<numeric value>	
*ESR?			[query only]
*IDN?			[query only]
*OPC			
*SAV		0   1   2   3	[no query form]
*RCL		0   1   2   3	[no query form]
*RST			[no query form]
*SRE		<numeric value>	
*STB?			[query only]
*TST?			[query only]
*WAI			[no query form]


## MECHANICAL INFORMATION

### TOP COVER REMOVAL

If necessary, the interior of the instrument may be accessed by removing the four Phillips screws on the top panel. With the four screws removed, the top cover may be slid back (and off).

 Always disconnect the power cord and allow the instrument to sit unpowered for 10 minutes before opening the instrument. This will allow any internal stored charge to discharge.

There are no user-adjustable internal circuits. For repairs other than fuse replacement, please contact Avtech (info@avtechpulse.com) to arrange for the instrument to be returned to the factory for repair. Service is to be performed solely by qualified service personnel.

 Caution: High voltages are present inside the instrument during normal operation. Do not operate the instrument with the cover removed.

### RACK MOUNTING

A rack mounting kit is available. The -R5 rack mount kit may be installed after first removing the one Phillips screw on the side panel adjacent to the front handle.

### ELECTROMAGNETIC INTERFERENCE

To prevent electromagnetic interference with other equipment, all used outputs should be connected to shielded loads using shielded coaxial cables. Unused outputs should be terminated with shielded coaxial terminators or with shielded coaxial dust caps, to prevent unintentional electromagnetic radiation. All cords and cables should be less than 3m in length.

## MAINTENANCE

### REGULAR MAINTENANCE

This instrument does not require any regular maintenance.

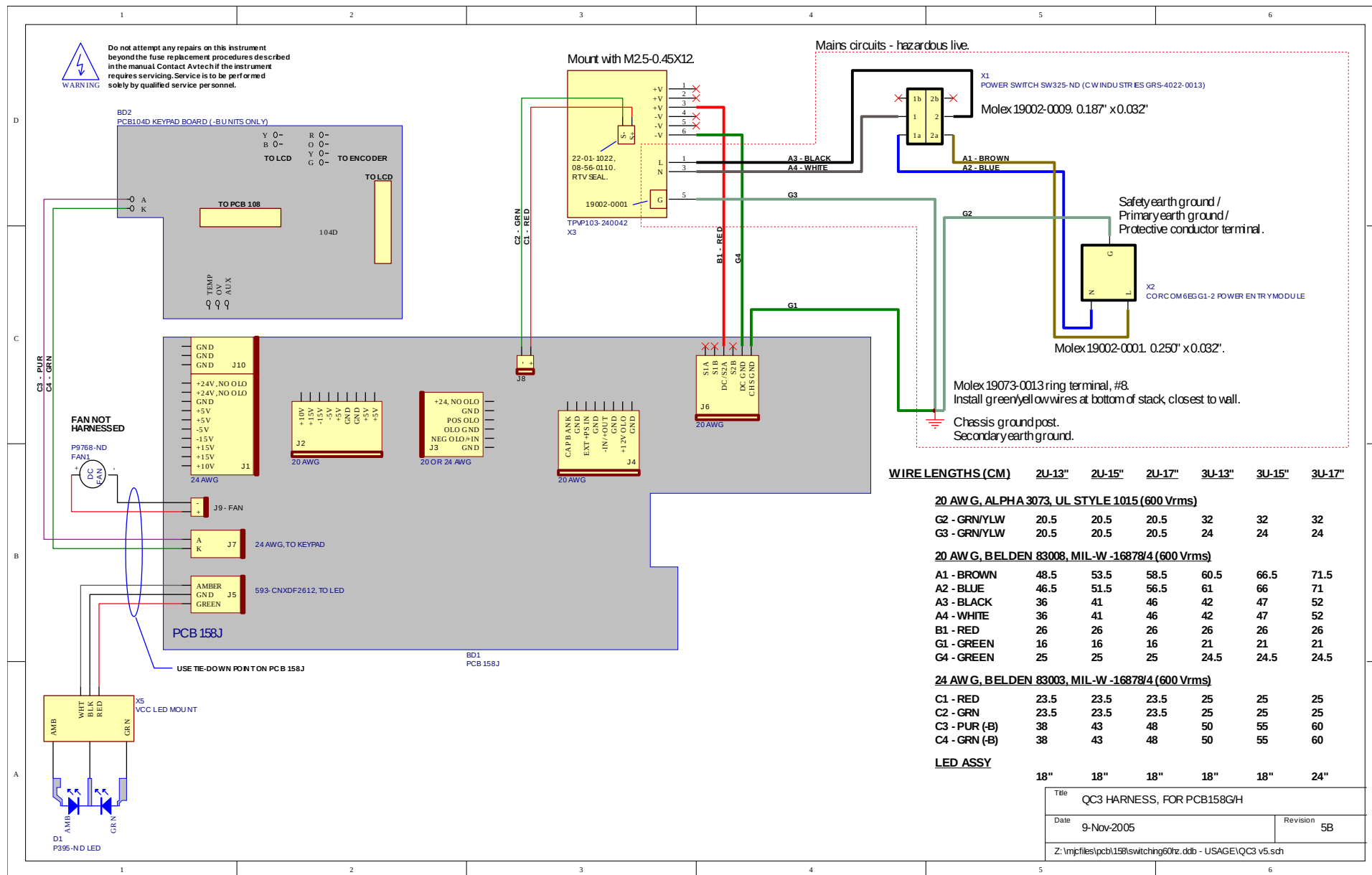
On occasion, one or more of the four rear-panel fuses may require replacement. All fuses can be accessed from the rear panel. See the “FUSES” section for details.

### CLEANING

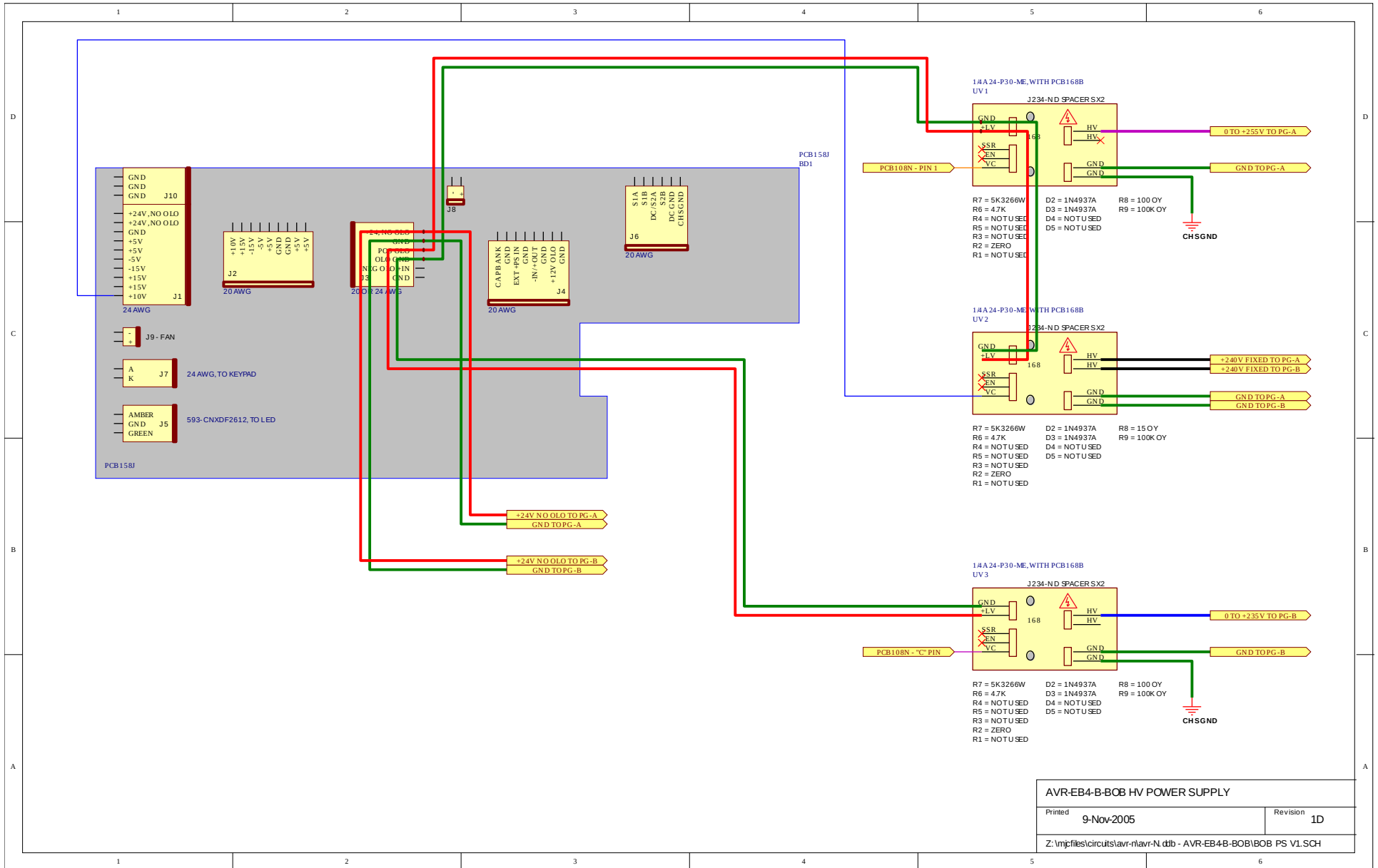
If desired, the interior of the instrument may be cleaned using compressed air to dislodge any accumulated dust. (See the “TOP COVER REMOVAL” section for instructions on accessing the interior.) No other cleaning is recommended.

# WIRING DIAGRAMS

## WIRING OF AC POWER, 1/2



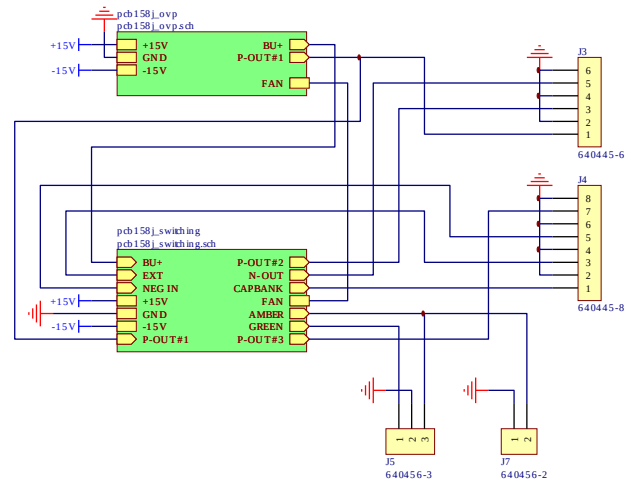
# WIRING OF AC POWER, 2/2



AVR-EB4-B-BOB HV POWER SUPPLY	
Printed 9-Nov-2005	Revision 1D
Z:\mpjfiles\circuits\avr-nlavr-n.dtb - AVR-EB4-B-BOB\BOB PS V1.SCH	

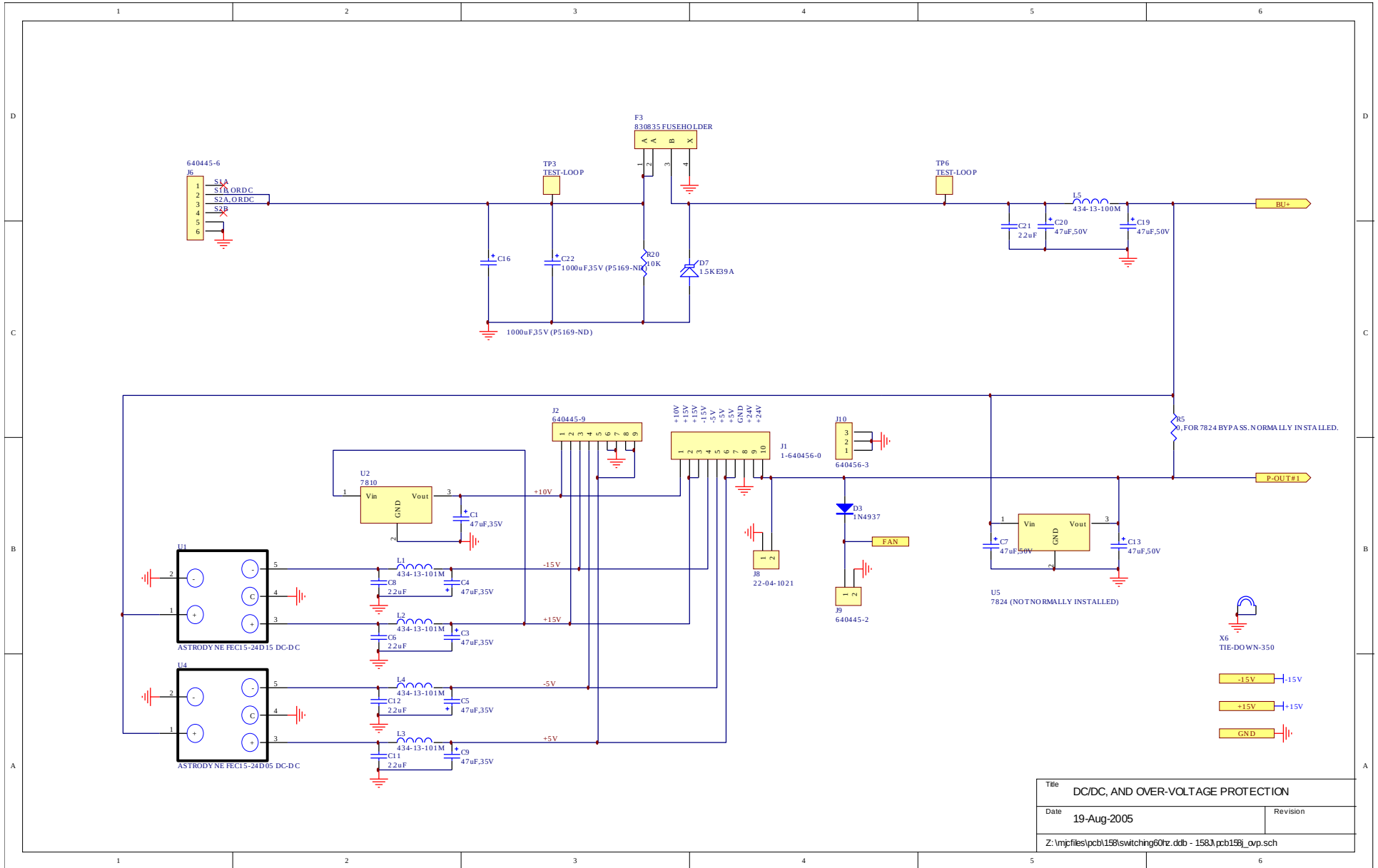


# PCB 158J - LOW VOLTAGE DC POWER SUPPLY, 1/3

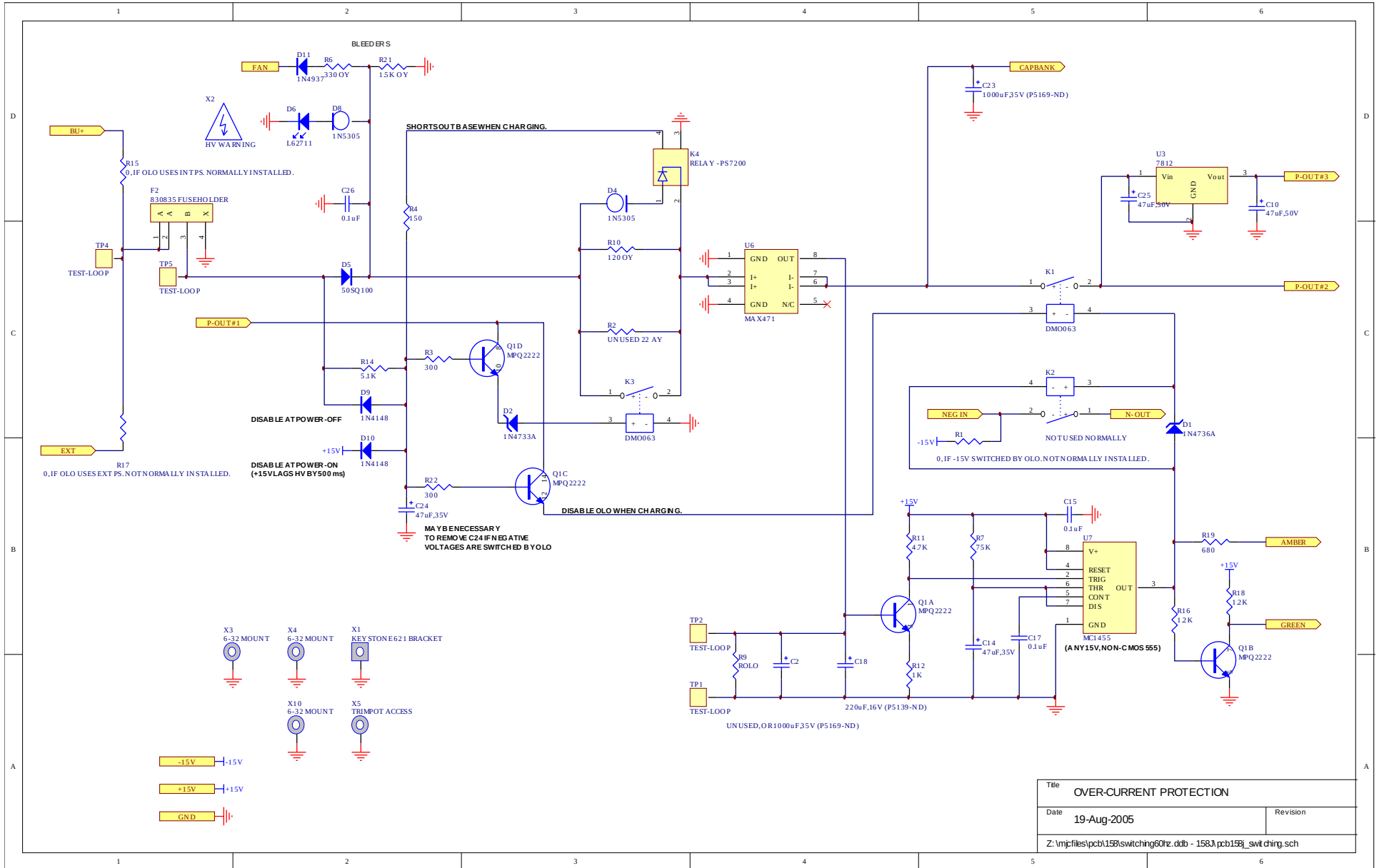


Title		LOW VOLTAGE DC/DC POWER SUPPLY
Date	19-Aug-2005	Revision
Z:\mpjfiles\pcb158\switching01rz.ddb - 158J.pcb158j.sch		

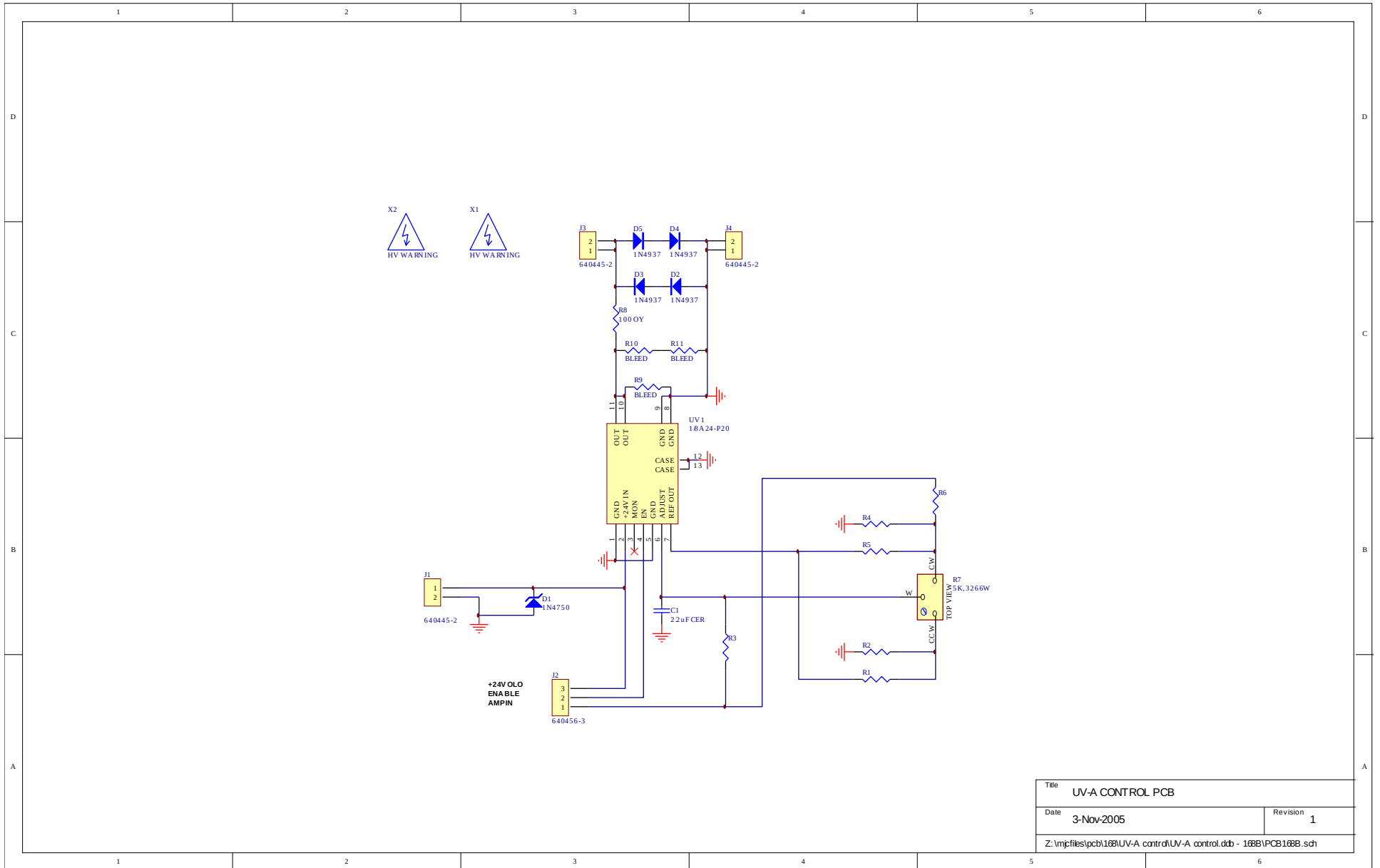
# PCB 158J - LOW VOLTAGE DC POWER SUPPLY, 2/3



# PCB 158J - LOW VOLTAGE DC POWER SUPPLY, 3/3



# PCB 168B - HIGH VOLTAGE DC POWER SUPPLY



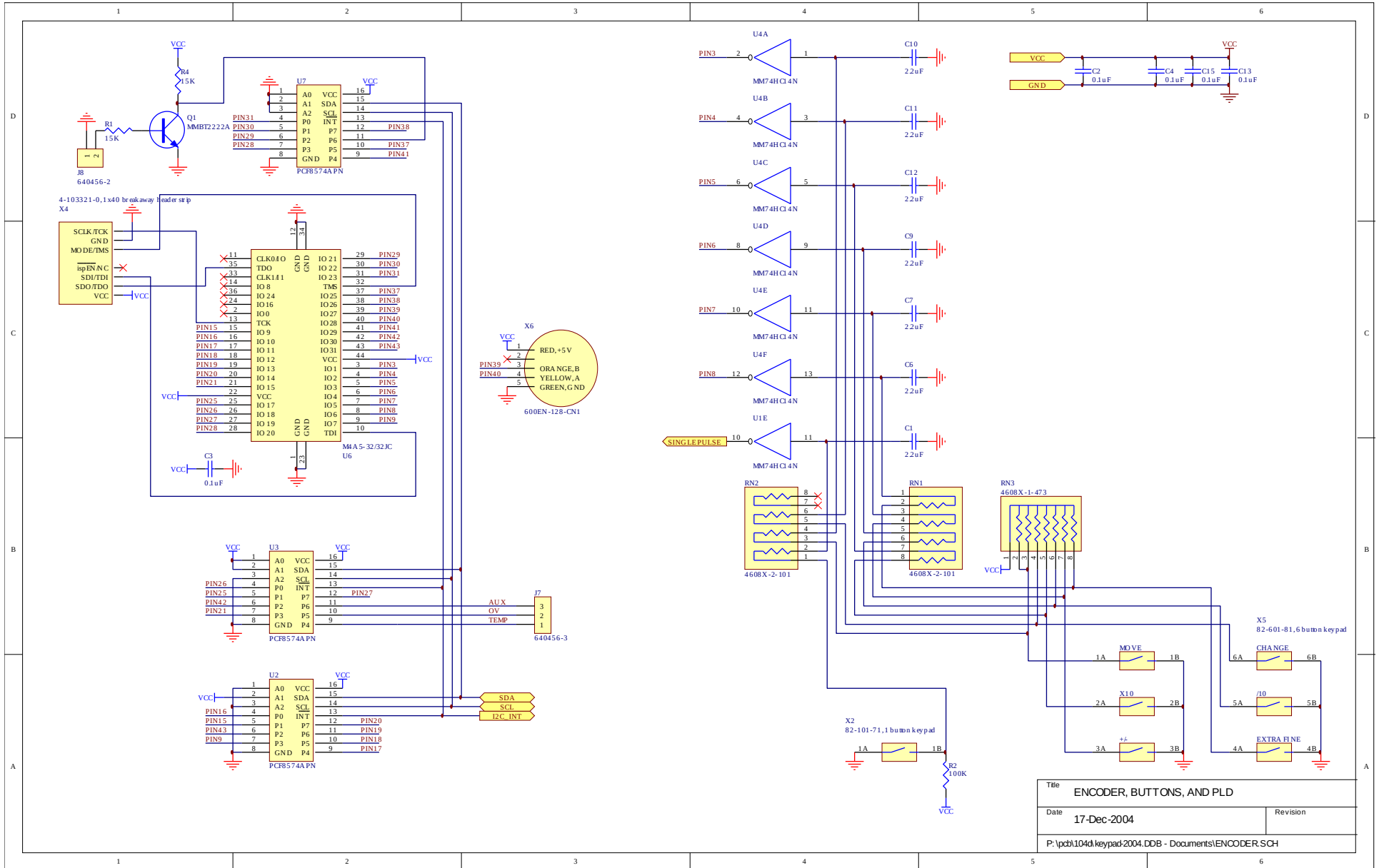
Title UV-A CONTROL PCB	
Date 3-Nov-2005	Revision 1
Z:\mpjfiles\pcb168\UV-A control\UV-A control.ddb - 168B\PCB168B.sch	

# PCB 104D - KEYPAD / DISPLAY BOARD, 1/3

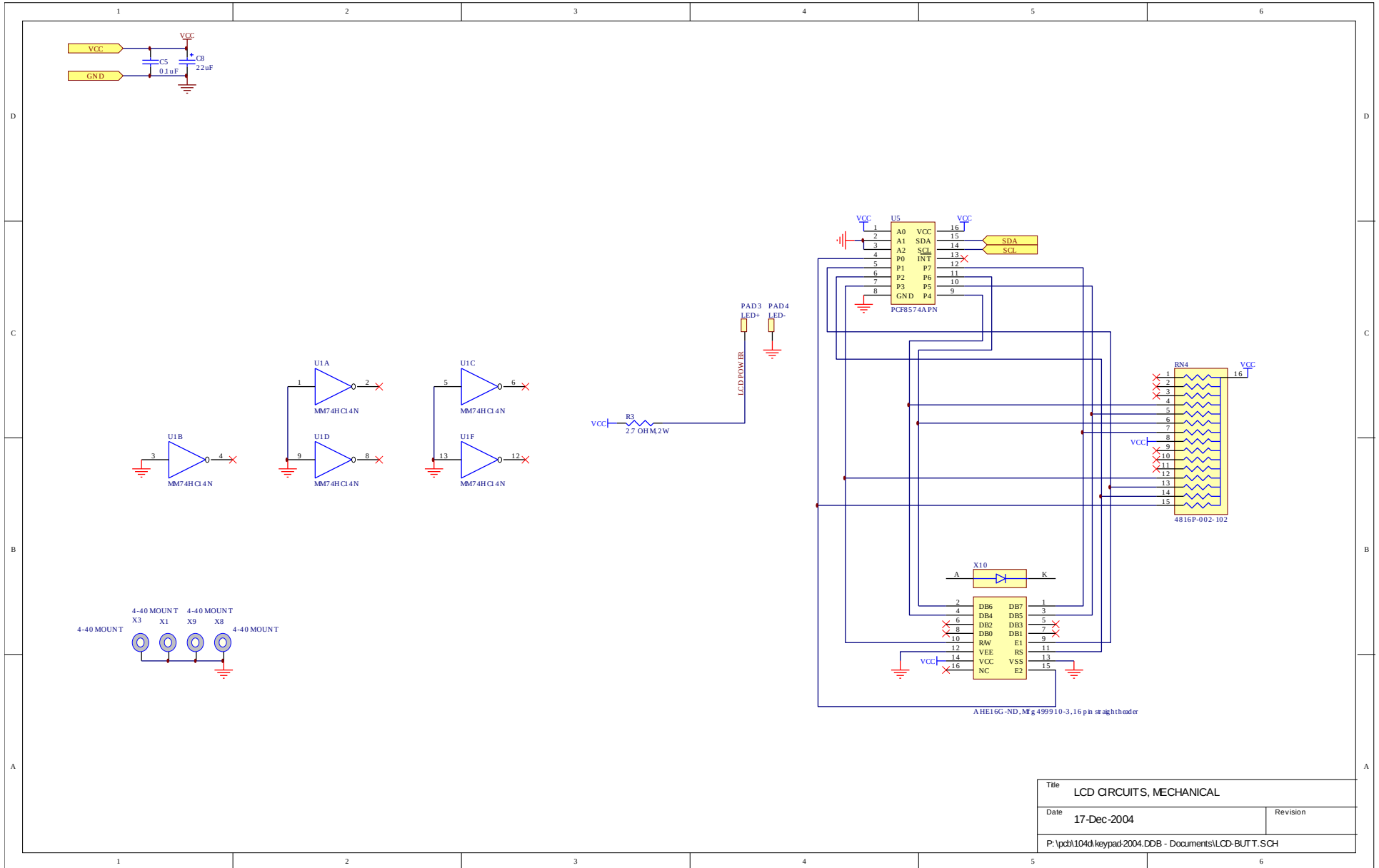


Title	PANEL TOP-LEVEL SCHEMATIC	
Date	17-Dec-2004	Revision
P:\pcb\104d\keypad\2004.DDB - Documents\Panelbrd.prj		

# PCB 104D - KEYPAD / DISPLAY BOARD, 2/3

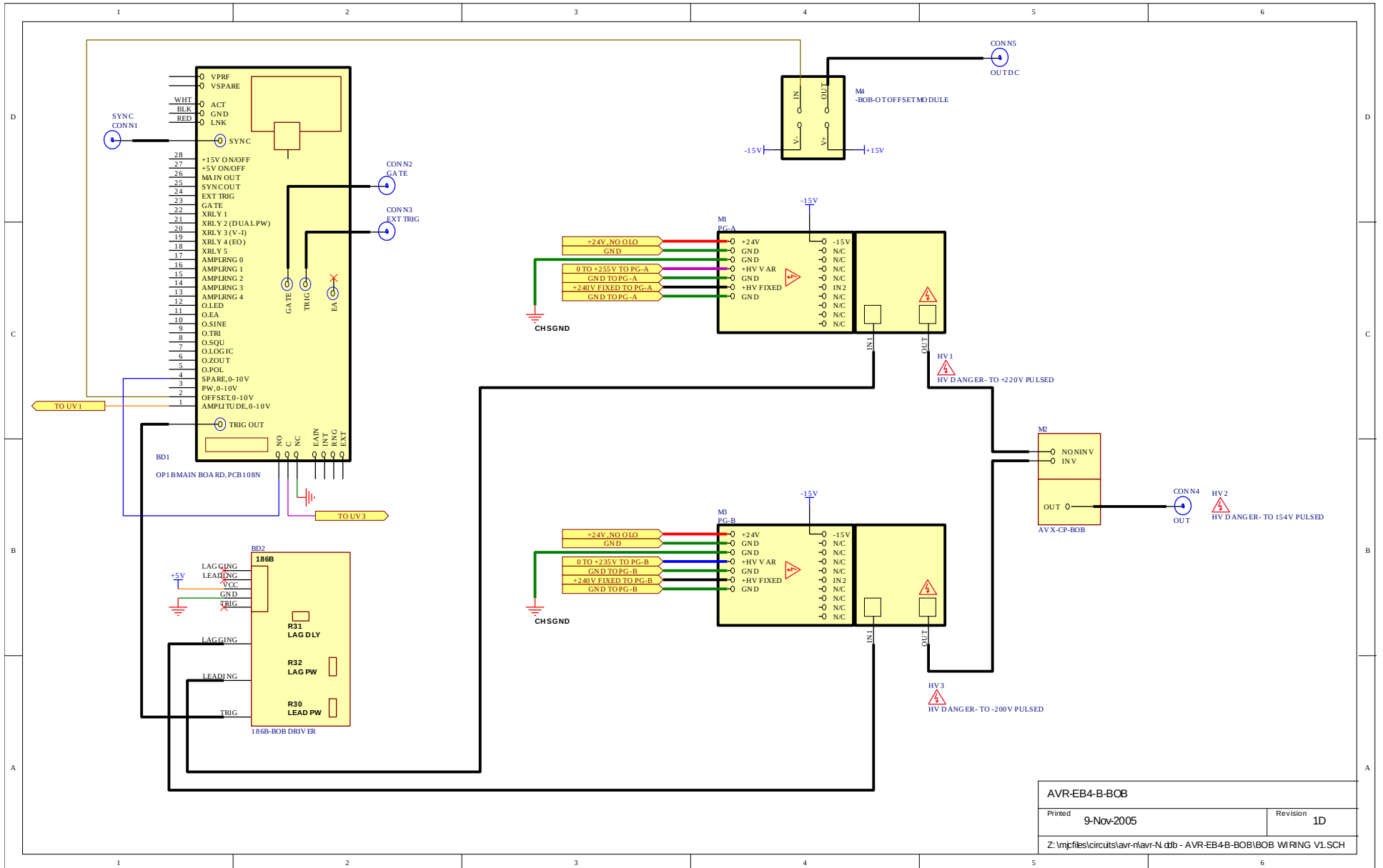


# PCB 104D - KEYPAD / DISPLAY BOARD, 3/3



Title		LCD CIRCUITS, MECHANICAL	
Date	17-Dec-2004	Revision	
P:\pcb\104d\keypad\2004.DDB - Documents\LCD-BUTT.SCH			

# MAIN WIRING



AVR-EB4-B-BOB		
Printed	9-Nov-2005	Revision 1D
Z:\mpjfiles\circuits\avr-nlavr-N.dtb - AVR-EB4-B-BOB\BOB WIRING V1.SCH		





PERFORMANCE CHECK SHEET