INSTRUCTION MANUAL

FOR

ISOLATED PULSE STIMULATOR

MODEL 2100

Serial #_____

Date_____

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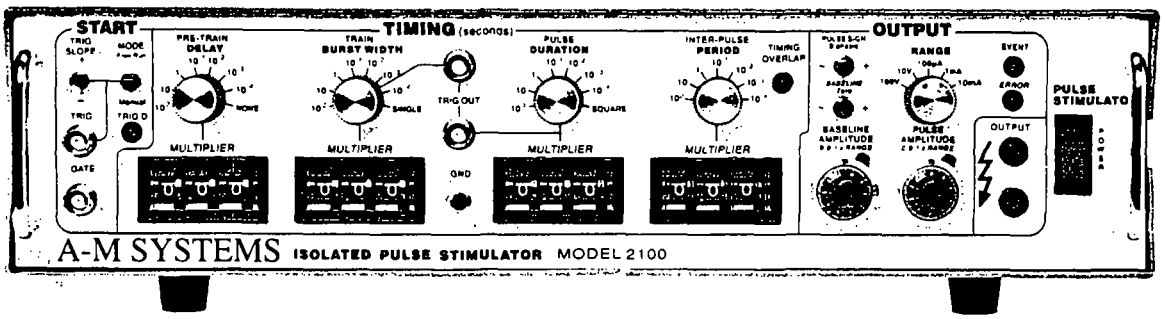
Each Isolated Pulse Stimulator is delivered complete with:

Rack Mount Hardware
Instructions & Maintenance Manual

NOTE

This instrument is not intended for clinical measurements using human subjects. A-M Systems, Inc. does not assume responsibility for injury or damage due to the misuse of this instrument.

General Description



Instrument Features

The *Isolated Pulse Stimulator Model 2100* is designed for a wide variety of applications. It is highly flexible, being capable of delivering single pulses, biphasic pairs, or bursts of pulses. Pulses may be started manually or upon receiving a trigger signal from another instrument or computer. Two non-isolated trigger outputs are available for triggering other instruments.

Four sets of timing controls provide comprehensive control over all aspects of pulse generation. Three digit accuracy is available over a 7 decade range for each timing function, using lever wheel switches. Pulse widths can be set over more than a 9 decade range, from 0.5 μs to 999 seconds. Timing accuracy is assured through the use of a 10 MHz base rate crystal-controlled clock, digitally divided to provide accurate timing over the entire range. A timing overlap indicator will light if the timing controls are set inconsistently.

The output may be conveniently switched between current and voltage modes. Pulse and baseline amplitudes are independently presettable with lockable dials. An error indicator will light if the *Model 2100* cannot deliver the desired signal.

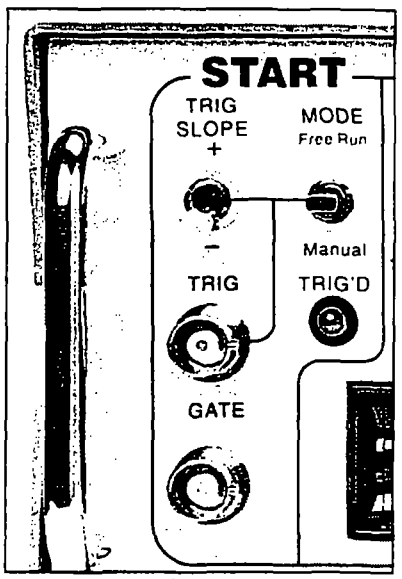
WARNING

The Model 2100 *can produce potentially dangerous voltages up to 100 V at the output connectors. The isolated output is not connected internally to safety (earth) ground in any way. Some part of the external circuit should be connected to safety ground. Use caution in handling any wires, connectors, or electrodes which may be directly or indirectly attached to the* Model 2100 *output. Some kinds of connectors such as BNC connectors have exposed metal parts which may float at dangerous potentials unless externally connected to safety ground.* ***For greatest safety, turn the* Model 2100 *off before making any connections to the instrument.***

Controls and Connectors

The controls for the *Model 2100* are grouped in three sections: **START**, controlling when a *pulse or burst of pulses begins*; ***TIMING***, *controlling the on/off timing of one or more pulses*; and **OUTPUT**, controlling the amplitude of the output signal.

Start



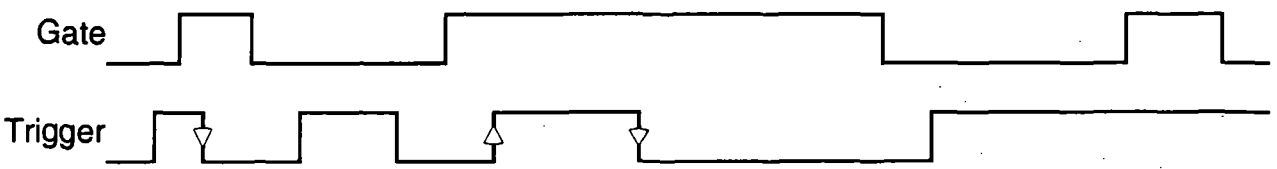
TRIG SLOPE: This switch determines whether valid triggers occur at positive or negative edges in the trigger signal.

MODE: This switch controls how waveforms are initiated. When set to **FREE RUN** one timing cycle immediately follows the last. When held in the **MANUAL** position, a timing cycle starts immediately. When the switch is in the center position, timing cycles start when valid triggering events occur.

TRIG'D: This LED lights up when a timing cycle is in process, and continues until the burst is completed.

TRIG: This BNC connector allows a signal from an external source to initiate timing cycles. It is set for standard TTL levels.

GATE: This BNC connector allows a signal from an external source to restrict the final output signal. This input must be at a logical high (or open-circuited) in order for the *Model 2100* to recognize either manual or automatic trigger events.

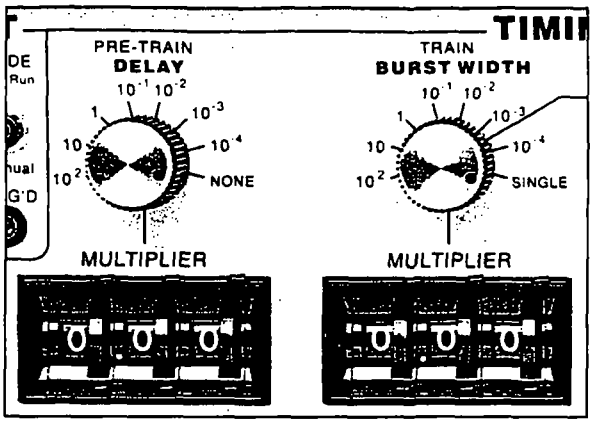


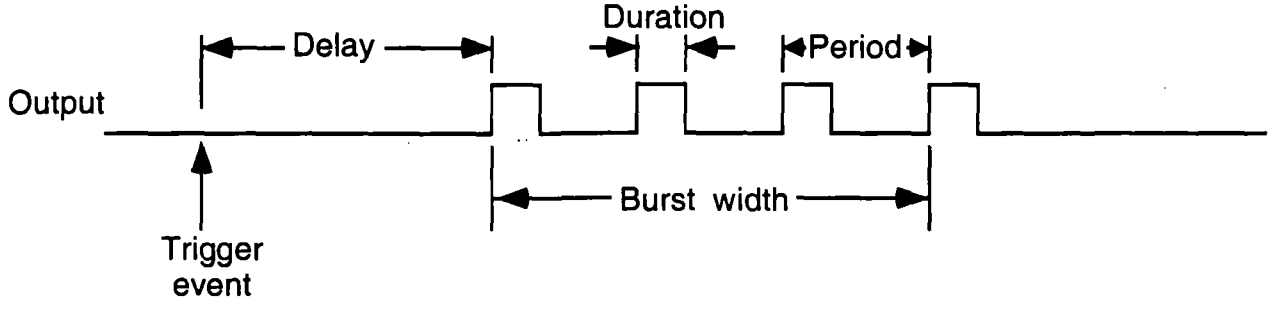
Valid triggers are represented by the arrows in the figure. Note that the up arrow would apply only if **TRIG SLOPE** is set to **+**; the down arrows would apply only if **TRIG SLOPE** is set to **-**.

NOTE: *Triggers have no effect if the system has not completed its response to a previous trigger.*

Timing

Four sets of controls govern the timing of pulse generation. Each set contains two values which are multiplied together to determine the actual timing value. The rotary knob (rate selector) provides the approximate timing value and the lever wheel switch bank (**MULTIPLIER**) provides a time resolution of three decimal digits. The following diagram shows most of the important relationships.

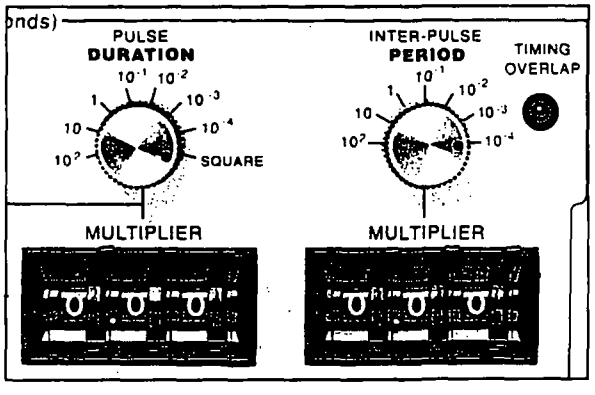




DELAY: These controls set the time between the initiating trigger event and the beginning of the pulse burst. If this rate selector is set to **NONE** or the multiplier is set to **0.00** there is no delay.

BURST WIDTH: These controls set the time period in which one or more pulses may be delivered. Once started a pulse may outlast the burst width. If this rate selector is set to **SINGLE**, or to any time shorter than the pulse duration, only a single pulse will occur. If the **BURST WIDTH** is longer than the period, pulses will be emitted at the **PERIOD** rate until the burst time ends. Pulses are never truncated by a short **BURST WIDTH**.

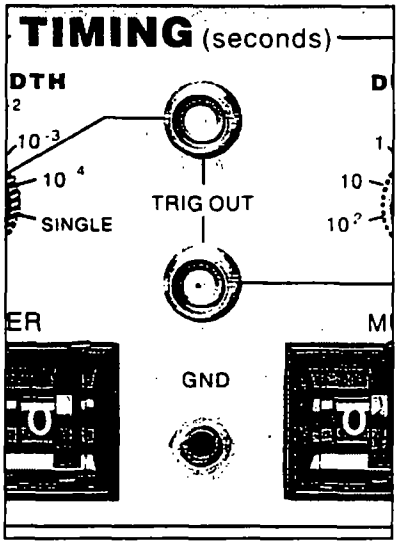
DURATION: These controls set the length of each pulse. If this rate selector is set to **SQUARE**, the duration is set to half of the period, regardless of the **MULTIPLIER** setting.



PERIOD: These controls set the period of time between adjacent pulse events within the burst. It also forces a minimum "dead time" between recognized input triggers following a burst of one or more pulses. This can be used to prevent over stimulation of a tissue without requiring excessive delay between the triggering event and the stimulating pulse.

NOTE: *If any of these timing controls are changed while a timing cycle is in operation, the results are undefined until the current cycle finishes.*

TIMING OVERLAP: This LED will light to indicate an inconsistency in the timing cycle settings. There are several ways to introduce such errors. The most common way is to set the inter-pulse **PERIOD** to be less than the pulse **DURATION.**



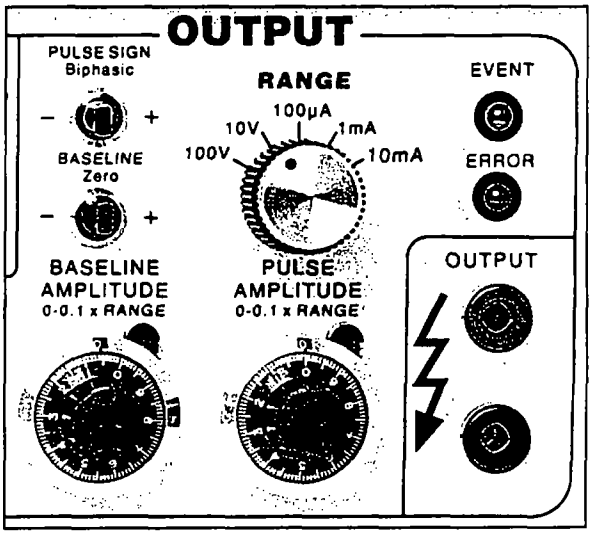
TRIG OUT (UPPER): This BNC connector provides a signal which is coincident with the internal Burst timing signal (default). This means the signal starts at the end of the Delay time, and persists until the Burst time expires. This output may also be set to represent the delay time-out by setting the internal jumper J510 to the right two pins instead of the left two pins (Please see the Calibration section in this manual for jumper location; Directions are given as viewed from the front of the instrument).

TRIG OUT (LOWER): This BNC connector provides a signal which is coincident with the Duration timing signal which controls pulse output.

NOTE: *Both trigger output signals slightly lead the isolated output signal.*

Output

PULSE SIGN: This switch sets the sign for the pulses to be generated. It also allows generation of biphasic pulses, thereby doubling the effective total period. ***Warning:*** *the first pulse generated after changing the* **PULSE SIGN** *switch may have the wrong polarity.*



BASELINE: This switch sets the sign for the baseline signal.

RANGE: This rotary switch allows one of three current or two voltage ranges to be selected for the output signal.

BASELINE AMPLITUDE: This value is independently set using a ten-turn counting dial. The maximum baseline amplitude is one tenth the value shown on the range amplitude switch.

PULSE AMPLITUDE: This value is independently set using a ten-turn counting dial. The maximum pulse amplitude is the value shown on the range amplitude switch.

EVENT: This LED indicates when a pulse is ongoing.

ERROR: This LED indicates when the internal output amplifier cannot output the pulse as desired. This is usually due to a short circuit while trying to output a voltage, or an open circuit while trying to output a current.

The *Pulse Sign* control in the *Output* section directly affects waveform timing. When set to the *Biphasic* mode, a positive-going pulse is immediately followed by a negative-going pulse. This effectively doubles the pulse "duration". If a burst of biphasic pulses is being produced the period must be at least twice the single pulse duration. In the *Square* wave mode, the baseline disappears as long as the burst persists.

Operating Instructions

Examples

Simple setup (and minimal instrument test)

Connect the output of the Model 2100 to an oscilloscope. Before connecting the instrument, it is safest to turn its power off.

Set the *Output* controls:

Range:	10V
Pulse Sign:	+
Baseline:	Zero
Pulse Amplitude:	2.00

Setting The Timing Controls:

Delay:	none
Burst Width:	single
Duration:	$1.50 * 10^{-2}$
Period:	$5.00 * 10^{-2}$

Setting The Start Controls:

Mode:	Free Run

Disconnect any cables to the TRIG or GATE inputs.

Note that the green *Trig* and *Event* indicators turn on as Free Run is turned on (and turn off otherwise). You should observe a 15ms duration, 20Hz rate pulse. of 2.00V above a 0V baseline on the oscilloscope.

Demonstration of Burst Mode

Connect the output of the Model 2100 to an oscilloscope. Before connecting the instrument, it is safest to turn its power off.

Set the *Output* controls:

Range:	10V
Pulse Sign:	+
Baseline:	-
Pulse Amplitude:	2.00
Baseline Amplitude	1.00

Setting The Timing Controls:

Delay:	$8.80 * 10^{-2}$
Burst Width:	$1.20 * 10^{-2}$
Duration:	$1.50 * 10^{-2}$
Period:	$5.00 * 10^{-2}$

Set the START controls as follows:

Mode:	Free Run

Disconnect any cables to the TRIG or GATE inputs.

Trigger the oscilloscope from the *Burst* trigger out (upper *Trig Out* connector) for a stable display. In each burst (occurring every l00ms), you should observe a trio of 15ms duration starting 50ms apart. Try switching the *Start/Mode* from Free Run to the center (normal) position. The pulses will no longer be produced, and the *Trig* and *Event* indicators will turn off. Pressing this switch once (to Manual) will cause a single burst to occur.

Problem Solving

If the instrument appears to be not working properly, check all of the control settings and connections. Be sure to wait at least 5- 10 seconds after turning the instrument off before turning it on again. The following summary of typical problems for the user (along with the most common solutions) may help:

Problem	Cause/Solution
EVENT indicator never lights, even in FREE RUN mode.	• Replace fuse, check power connection •Set DELAY or PERIOD to a shorter interval. • Power-on too soon after power-off.
OVERLAP indicator is on.	• Set DURATION >0.00. • DURATION is set to SQUARE, but PERIOD is 0.00. Increase PERIOD or set DURATION independantly. • BURST and WIDTH are > DURATION increase PERIOD or decrease DURATION. • BIPHASIC pulse output is on and PERIOD is not longer than twice the DURATION. Increase PERIOD or decrease DURATION. • Free-run is on and BURST is < PERIOD (BURST off), DELAY is 0 and PERIOD is < DURATION. Add, delay or modify PERIOD. • Free-run is on and BURST is > DURATION (BURST ON), and PERIOD is < DURATION. Increase PERIOD.
ERROR indicator is on.	• For VOLTAGE outputs: the output is trying to drive too low a resistance or capacitance (e.g. a short circuit). Check by disconnecting the output. It is possible (and normal) that for the fastest cycles and largest amplitudes (close to 100 V and 1μs) that the ERROR indicator might always come on during repetitive pulses. Fix output load or decrease amplitude as required.
Time appears to be excessive	• Changed control in mid-cycle, (resets current status).

Can't seem to get a full signal out	• Load is not properly connected, repair wiring. • Too low a load impedance (VOLTAGE modes) or too high a load impedance (CURRENT mode).
Incoming triggers not accepted frequently enough	• PERIOD is set too long, (enforces "dead time") followd by BURST set to SIGNAL. Reduce PERIOD time.

Table 1.0 Problem Solving

If you suspect that the Model 2100 may have completely failed, we recommend checking the basic level of functionality. If this fails, your instrument is defective and must be repaired. If this passes, either your experimental setup is incompatible or inconsistent; or there is a more subtle flaw in your Model 2100.

If the Model 2100 appears to be malfunctioning, contact A-M Systems, Inc., or your dealer. We will first attempt to solve the problem over the telephone, so have an exact description of your problem available when you call. You do not need to be within the warranty period to obtain over-the-phone assistance.

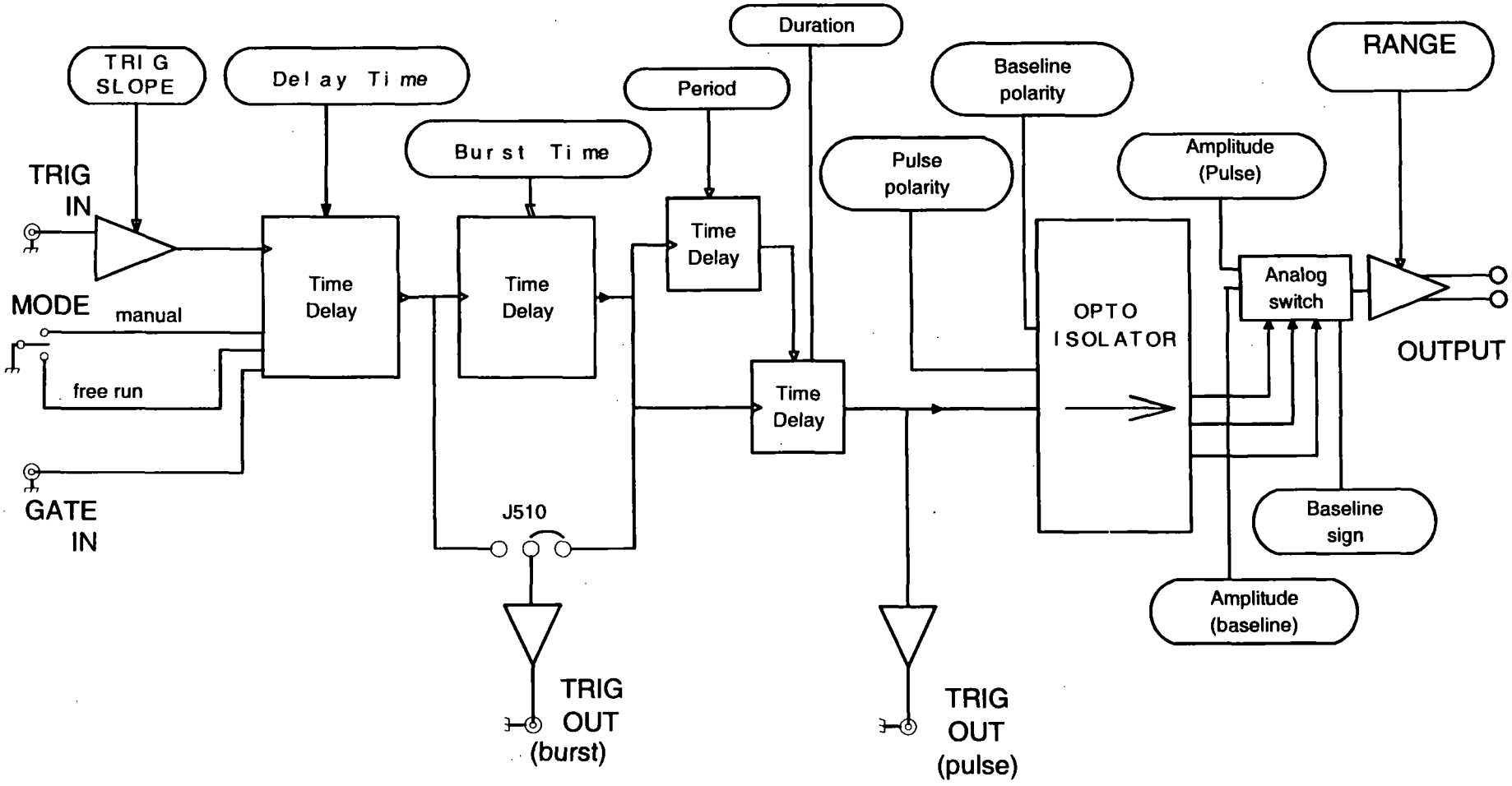
Theory of Operation

The operation of the Model 2100 is summarized in the block diagram (see the figure on Page 11). Not shown are all of the interconnections with the microcontroller. The internal microcontroler plays an important role in setting the signal path, but does not directly contribute to the dynamic characteristics. It scans the front panel switches, and sets the control values for the logic arrays. It programs the internal counters, which along with the other hardware achieve the necessary sub-microsecond speeds.

All action starts either from an input trigger signal (from Trig In), or from an internal signal (in free Run mode. only). A Delay timer counts the 10MHz clock until its count value is exhausted. At this point, the Burst timer starts. Both Period and Duration timers are started at this time: If the Burst timer has not expired by the end of the Period, the Period and Duration timers are restarted. If the Biphasic mode has been set, the Duration timer is restarted at the end of the initial Duration, and the sign of the output pulse is reversed, doubling the total duration.

The system state (pulse on, pulse sip, baseline sign [+/0/-]) is transmitted to the isolated section via optoisolator. The baseline and pulse amplitudes are selected by an analog switch. The resulting signal is amplified by a variable-power-supply discrete operational amplifier. The amplifier connections and gain is modified to provide two voltage and three current ranges.

Timing overlap errors are detected by a logical decision computation rather than by testing for counter collisions. This provides instant feedback, rather than waiting up to an hour for such a collision to occur. Output errors are measured by sensing the output amplifier's differential input voltage. Under normal conditions, this is a negligible voltage. If the amplifier fails to deliver the requested signal the window comparator testing this voltage sends this message (via optoisolator) to the logic section, turning on a warning LED.



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Calibration Procedures

The calibration interval is the lesser of 1000 hours of operation or 6 months. Somewhat greater drift can be expected in the first 100 hours of operation as the semiconductors age. Adjustments should only be made after the instrument has been fully warmed up for at least 15 minutes.

Full instrument calibration requires the following test equipment:

digital multimeter (± 0.1%), able to measure resistance to at least 100MΩ
oscilloscope with at least 50MHz bandwidth
true-rms voltmeter with 4MHz bandwidth
universal counter (± 0.01%), able to measure single pulse widths and periods
resistors (all ± 0.1%): 2kΩ, 10kΩ 1 watt, 20kΩ, 200kΩ
alligator clip lead sets, banana plugs and BNC adapters

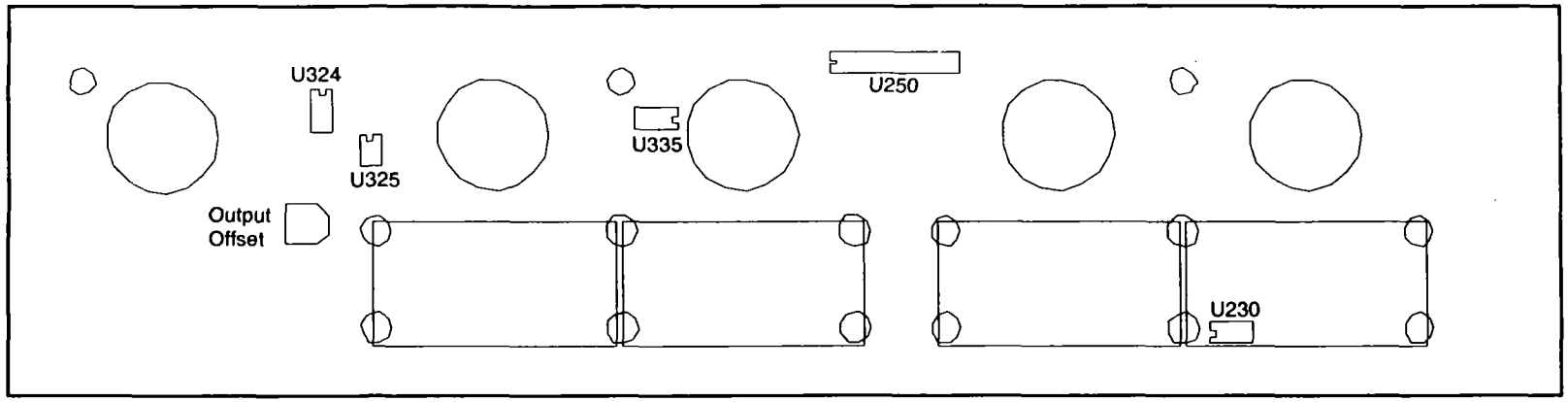
Adjustment, integrated circuit, and test point locations are shown in the following figures. All adjustments are on the timing board unless otherwise noted.

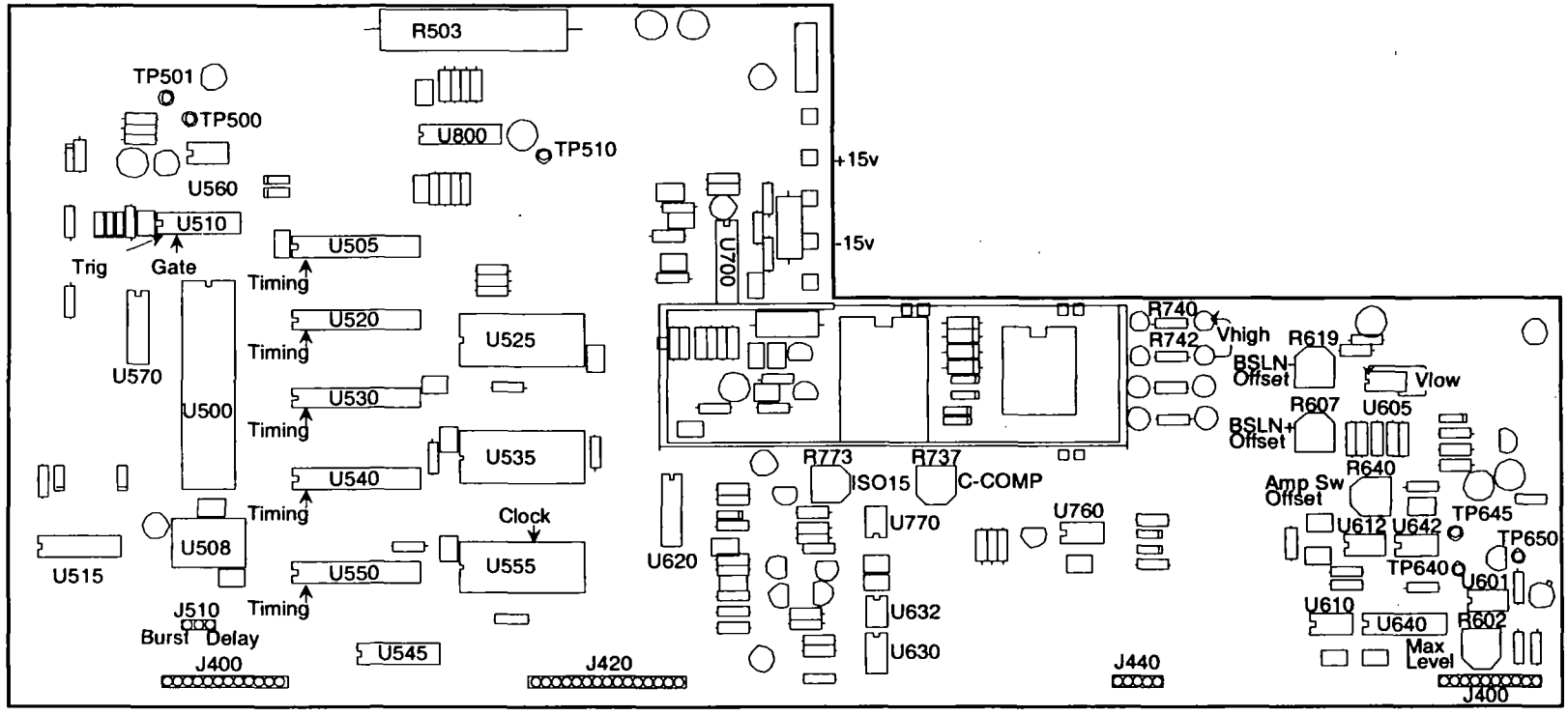
All voltages in the non-isolated section should be measured with respect to ground at TP510 unless otherwise stated. Some voltages are measured with respect to an internal "isolated ground" at TP650, or across the two output terminals. Occasionally the voltage at an IC pin must be measured; in these cases the reference designator is given, with the pin number in parentheses: e.g. U602(16). When it states within this procedure that a voltage is to be minimized, this means that the adjustment should be made such that the measured voltage is as close to zero volts as possible. Refer to the Specifications Section of this manual for acceptable tolerances.

The sequence of this procedure is important. If any adjustment is made, all adjustments which follow must be made to ensure that the specifications will be met. These procedures require that all controls remain as set in previous steps unless otherwise indicated.

WARNING

The *Model 2100* has dangerous voltages throughout the instrument, even with the power is off. Servicing the *Model 2100* should only be done by qualified service personnel. Use caution in handling any wires, connectors, or electrodes which may be directly or indirectly attached to the instrument. Do not touch exposed connections or components. Disconnect power by unplugging the power cord from the receptacle.





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Power supply and bias voltages

Power supply

Controls	Inputs / Observations	Adjust / Check
POWER: ON	Observe voltage at P703 power supply wire, top of main board	Check for +15 ± 0.50 V
	Observe voltage at P701 power supply wire, top of main board	Check for -15 ± 0.50 V
	Observe voltage at U505(24)	Check for +5 ± 0.25 V

Isolated supply voltage

Controls	Inputs / Observations	Adjust / Check
RANGE: 10 V **TRIG:** open circuit **MODE:** center position	Alternately observe V_{high} from R742 to R740, and V_{low} from the U605(4) to U605(8)	Adjust R773 so that $110\ V < V_{high} < 120\ V$ and $28\ V < V_{low} < 34\ V$

Capacitance balance

Controls	Inputs / Observations	Adjust / Check
	Connect a x10 oscilloscope probe to TP650 and ground the	Adjust R737 for minimum high frequency signal

Inputs

Gate function

Controls	Inputs / Observations	Adjust / Check
	Apply a 1 kHz, 0 - 5 V triangle wave to **GATE** Observe voltage at U510(3) with an oscilloscope	Verify that the voltage switches states at the proper input levels

Trigger slope

Controls	Inputs / Observations	Adjust / Check
	Apply a 1 kHz, 0 - 5 V triangle wave to **TRIG** Observe voltage at U510(1) with an oscilloscope	Verify that the voltage switches states at the proper input levels
TRIG SLOPE: +		Verify voltage is 180º out of phase
TRIG SLOPE: -		Verify voltage is in phase

Trigger and gate function

Controls	Inputs / Observations	Adjust / Check
DELAY: NONE **BURSTWIDTH:** SINGLE **DURATION:** SQUARE **PERIOD:** 1.00 X 10-3	Apply a 1 kHz, 0 - 5 V triangle wave to **TRIG** Observe **TRIG'D** and **EVENT** LEDs	
TRIG: disconnect all	Short the **GATE** connector to **GND**	Verify LEDs extinguish
MODE: press to **MANUAL**		Verify LEDs flash once

Timing

System clock frequency

Controls	Inputs / Observations	Adjust / Check
	Observe the frequency of the wave at U555(17)	Verify 1.000 MHz ± 0.01%

Multipliers (Wheel Switches)

Controls	Inputs / Observations	Adjust / Check
PULSE SIGN: + **MODE:** FREE RUN **TRIG:** disconnect all **TIMING MULTIPLIERS:** all wheels set to zero except the one being tested **TIMING OVERLAP:** ignore	Observe the pulse width with the counter at the location specified below	Verify pulse width is correct for each wheel as it is tested independently

For each wheel of each **MULTIPLIER**, test each position to verify that the pulse width is correct. Observe the signal at the following locations: **DELAY:** U520(2); **BURSTWIDTH:** U530(2); **PERIOD:** U540(2); **DURATION:** U550(2)

Rates (Rotary Switches)

Controls	Inputs / Observations	Adjust / Check
TIMING MULTIPLIERS: 0.01 **TIMING RATES:** all rotary switches set to 10-4 except the one being tested	Observe the pulse width with the counter at the location specified below	Verify pulse width is correct for each rotary switch as it is tested independently

For each of the four rotary switches in **TIMING**, test each position to verify that the pulse width is correct. Observe the signal at the following locations: **DELAY:** U520(2); **BURSTWIDTH:** U530(2); **PERIOD:** U540(2); **DURATION:** U550(2)

Trigger outputs

Controls	Inputs / Observations	Adjust / Check
Range: 10V Pulse Amplitude: 5.00 Delay: 1.00 x 10^{-2} Burst: 1.00 x 10^{-2} Duration: 1.00 x 10^{-3} Period: 4.00 x 10^{-3} Pulse sign: + Trig Mode: Free run Trig in: open	Trigger the oscilloscope to the Burst Trig Out. Observe it, the Pulse Trig Out, and the isolated output.	Verify that the waveform consists of a burst of three 1ms-on/3ms-off pulses. The burst trigger should be synchronous with the burst; the pulse trigger coincident with each pulse.

Output Calibration

Isolation Resistance (check)

Controls	Inputs / Observations	Adjust / Check
Trig Mode: center position Trig In: open	Measure the resistance between ground banana jack (front panel) and black banana jack of output with DMM	Resistance read > 100MΩ

Amplitude Switch Offset (R640)

Controls	Inputs/Observations	Adjust/Check
Baseline: Zero Trig Mode: center position Trig In: Open	Measure the voltage at TP645 vs. TP650 with the DMM.	Adjust R640 (Ampl Sw Offset) for minimum voltage.

Output Offset (R332: front panel board)

Controls	Inputs/Observations	Adjust/Check
Baseline: Zero Range: 10V Trig Mode: center position Trig In: Open	Measure the voltage across the output with the DMM.	Adjust R332 (Output offset) for minimum voltage.

Positive Baseline Offset (R607)

Controls	Inputs/Observations	Adjust/Check
Baseline Sign: + Baseline Amplitude: fully CCW (0.00) Range: 10V Trig In: open Trig Mode: center position	Measure the voltage across the output with the DMM.	Adjust R602 (BSLN + offset) for minimum voltage.

Negative Baseline Offset (R619)

Controls	Inputs/Observations	Adjust/Check
Baseline Sign: - Baseline Amplitude: fully CCW (0.00) Range: 10V Trig In: open Trig Mode: center position	Measure the voltage across the output with the DMM.	Adjust R619 (BSLN + offset) for minimum voltage.

Pulse Amplitude Adjust (R602)

Controls	Inputs/Observations	Adjust/Check
Trig Mode: Free Mode Pulse Amplitude: 10.00 Timing: Delay =none; Burst =single; Duration =1.00*1; Period =0.01*10-4 Pulse Sign: - Trig In: open Range: 10V	Measure the voltage across the output with the DMM.	The Overlap indicator should be on. Adjust R602 (Max Level) for -10.00V out.

Pulse Sign Gain (check)

Controls	Inputs/Observations	Adjust/Check
Trig Mode: Free Mode Pulse Amplitude: 10.00 Timing: Delay =none; Burst =single; Duration =1.00*1s; Period =0.01*10-4s Trig In: open Range: 10V	Measure the voltage at the output with the DMM for the Pulse Sign at + and - positions	The absolute values of the voltages should differ by less than 100mV.

Baseline Amplitudes (check)

Controls	Inputs/Observations	Adjust/Check
Range: 100mA *Trig Mode*: center position *Baseline Amplitude*: fully CW (10.00) *Trig In*: open	Measure the voltage at the output with the *DMM with Baseline Sign in +, Zero, and - positions.*	Gain the matching of current levels at = and - positions; and offset current in Zero position..

Output Range Amplitude and Drive (check)

Controls	Inputs/Observations	Adjust/Check
Pulse Amplitude: 10.00 Pulse Sign: + Trig Mode: Free Run Timing: Delay =none; Burst =single; Duration =1.00*1; Period =100*10-4 Trig In: open	Load the output with a 10KV 1W 0.1% resistor. Measure the voltage at the output with DMM.	Verify that full scale output is within specification: Scale: Range: 100V 100V 10V 10V 100mA 1V 1mA 10V 10mA 100V

Pulse Sign and Short Circuit Protection (check)

Controls	Inputs/Observations	Adjust/Check
Timing: Delay =none; Burst =single: Duration =2.00*;10-4 Period =0.01*10-3 Baseline: Zero Pulse Amplitude: 2.5 Range: 10V Trig Mode: Free Run Trig In: open	Measure the voltage at the output with the oscilloscope. Check for Pulse Sign set to each of: +, -, biphasic. Watch for Error indicator when shorting the output.	Verify that pulses of approx. 2.5V amplitude (62.5V for biphasic mode) of the correct sign are produced every 10ms. Short output in biphasic mode. Output should return when opened.

Output Transient Response (check)

Controls	Inputs/Observations	Adjust/Check
Pulse Sign: + Timing: Delay =none; Burst: =single; Duration =2.00*10-4; Period =0.01*10-3 Pulse Amplitude: 2.50 Baseline: Zero Trig Mode: Free Mode Trig In: open	Connect the oscilloscope to the output with a 310 attenuator probe. Test both 10V and 100V ranges.	Verify that overshoot and risetime meet specifications.

Specifications

There are three classes of specifications. Class A specifications tested in all units, and are guaranteed. Class B specifications are inherent in the design; they are indirectly tested, and are guaranteed. Class C specifications are typical operating values which are occasionally tested-, these are typical values, given for your information but not guaranteed. The class for each specification is noted in the center column of the following sections.

Inputs

Switching level	A	1.6 V (± 0.2 V)
Hysteresis	C	approx. 50 mV
Input equivalent circuit	C	100K Ω to +5 in parallel with no more than 35pF
Minimum duration (TTL-level signal)	C	> 50 ns.
Open circuit condition	B	defaults to high/on level

Timing and rate accuracy

Rate selector steps	B	100μs to 100s in 7 steps
Timing multiplier steps	B	1% of rate selector step size. Maximum value is 9.99 x the rate selector step size
Resolution	B	approx. 0.1% of the maximum value
Timing error (second and later pulses after resetting controls)	B	< 0.02% of rate selector value + 0.15 μs
Timing error (first pulse after readjusting timing controls)	C	an additional 0.25 μs error may occur
Timing repeatability	C	< 0.01% setting + 20 ns (monophasic)

TRIG IN to OUTPUT delay (DELAY set to 0), output set to 2 V	C	approx. 0.5 μs for a load of no more than 10 KΩ in parallel with 50 pF
Timing jitter from TRIG IN to OUTPUT (for TTL trigger input with risetime <10 ns)	C	< 125 ns (all rates except 100s) < 1.25 μs (100s rate)
Timing jitter from TRIG OUT (either BURST or PULSE) and OUTPUT	C	Less than 20 ns (all rates)
Trigger output to pulse output delay	C	approx. 350 ns
Output characteristics		
Pulse level error (voltage mode: open circuit; current mode: short circuit	A	< 0.3% of setting + 0.5% of r range (plus an additional 0.5 μA in 100 μA range)
Biphasic level difference | V + + V- | /2	C	< 0.3% of range (voltage modes: into open circuit; current modes :into short circuit)
Baseline level error (voltage mode: open circuit; current mode: short circuit)	A	< 0.3% of setting of setting + 0.1% of range (plus an additional 0.5 μA in 100μA range)
Risetime (2.5 V out)	A	≈ 200 ns into less than 30 pF
Risetime (25 V out)	A	≈ 1.5 μs into less than 30 pF
Transient response	A	< 8% overshoot into less than 30 pF for pulse voltages different than baseline voltage by at least 10% of range
Output impedance (voltage mode)	C	≈ 50 ohms
Output impedance (current mode)	C	>>10 GΩ (typically 200 GΩ)
Isolation resistance	A	>>100 MΩ
Isolation capacitance	C	≈ 60 pF at 100 Hz

Noise (differential mode)	C	≈ 1 mV rms (10 V scale; 10 Hz - 4 MHz)
Noise (common mode: earth to isolated ground) with no signal output	C	≈ 8 mV rms (10 Hz - 4 MHz); ≈ 100 mV p-p (200 Hz - 10 MHz), measured with a 10 MΩ, 15 pF oscilloscope probe
Overload error indicator (low frequency, short circuited voltage mode)	C	Turns on for set amplitude at or greater than approx. ±1 V (10 V range); or ±2 V (100 V range)
Overload error indicator low frequency, open circuited current mode)	C	Turns on for set amplitude at or above approx. 2% of range
Overload error response time	C	Flat to approx. 30 μs duration Decreasing sensitivity for shorter pulses

Miscellaneous

Power	approx. 11 watts
Fuse	1 amp 3 AG
Operating temperature range	10 - 30° C
Storage temperature range	0 - 50° C
Operating humidity	5 - 80% RH
Dimensions	17 x 4.75 x 11.25 (inches) 43.2 x 12.1 x 28.6 cm
Weight	20 lbs (9 kg)

Warranty and Service

What does this warranty cover?

A-M Systems, Inc. warrants to the Purchaser that the Instrument, excluding cables, Headstage Probes and any other accessories shipped with the Instrument, (hereafter the "hardware") is free from defects in workmanship or material under normal use and service for the period of one (1) year. This warranty commences on the date of delivery of the hardware to the Purchaser.

What are the obligations of A-M Systems, Inc. under this warranty?

During the warranty period, A-M Systems, Inc. agrees to repair or replace, at its sole option, without charge to the Purchaser, any defective component part of the hardware. To obtain warranty service, the Purchaser must return the hardware to A-M Systems, Inc. or an authorized A-M Systems, Inc. distributor in an adequate shipping container. Any postage, shipping and insurance charges incurred in shipping the hardware to A-M Systems, Inc. must be prepaid by the Purchaser and all risk for the hardware shall remain with purchaser until such time as A-M Systems, Inc. takes receipt of the hardware. Upon receipt, A-M Systems, Inc. will promptly repair or replace the defective unit, and then return the hardware to the Purchaser, postage, shipping, and insurance prepaid. A-M Systems, Inc. may use reconditioned or like new parts or units at its sole option, when repairing any hardware. Repaired products shall carry the same amount of outstanding warranty as from original purchase, or ninety (90) days which ever is greater. Any claim under the warranty must include a dated proof of purchase of the hardware covered by this warranty. In any event, A-M Systems, Inc. liability for defective hardware is limited to repairing or replacing the hardware.

What is not covered by this warranty?

This warranty is contingent upon proper use and maintenance of the hardware by the Purchaser and does not cover batteries. Neglect, misuse whether intentional or otherwise, tampering with or altering the hardware, damage caused by accident, damage caused by unusual physical, electrical, chemical, or electromechanical stress, damage caused by failure of electrical power, or damage caused during transportation are not covered by this warranty. **Products may not be returned to A-M Systems, Inc. for service, whether under warranty or otherwise, which are contaminated by infectious agents, radioactive compounds or other materials constituting a health hazard to employees of A-M Systems, Inc.**

What are the limits of liability for A-M Systems, Inc. under this warranty?

A-M Systems, Inc. shall not be liable for loss of data, profits or savings, or any special, incidental, consequential, indirect or other similar damages arising from breach of contract, negligence, or other legal action even if the company or its agent has been advised of the possibility of such damages, or for any claim brought against you by another party. **THIS EQUIPMENT IS NOT INTENDED FOR CLINICAL MEASUREMENTS USING HUMAN SUBJECTS. A-M SYSTEMS, INC. DOES NOT ASSUME RESPONSIBILITY FOR INJURY OR DAMAGE DUE TO MISUSE OF THIS EQUIPMENT.** Jurisdictions vary with regard to the enforceability of provisions excluding or limiting liability for incidental or consequential damages. Check the provision of your local jurisdiction to find out whether the above exclusion applies to you.

This warranty allocates risks of product failure between the Purchaser and A-M Systems, Inc. A-M Systems, Inc. hardware pricing reflects this allocation of risk and the limitations of liability contained in this warranty. The warranty set forth above is in lieu of all other express warranties, whether oral or written. The agents, employees, distributors, and dealers of A-M Systems, Inc. are not authorized to make modifications to this warranty, or additional warranties binding on the company. Accordingly, additional statements such as dealer advertising or presentations, whether oral or written, do not constitute warranties by A-M Systems, Inc. and should not be relied upon. This warranty gives you specific legal rights. You may also have other rights which vary from one jurisdiction to another.

2100

Isolated Pulse Stimulator

INSTRUCTION MANUAL

FOR

ISOLATED PULSE STIMULATOR

MODEL 2100

Serial #_____

Date_____

A-M Systems, Inc.
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Version 5.0
May 1998

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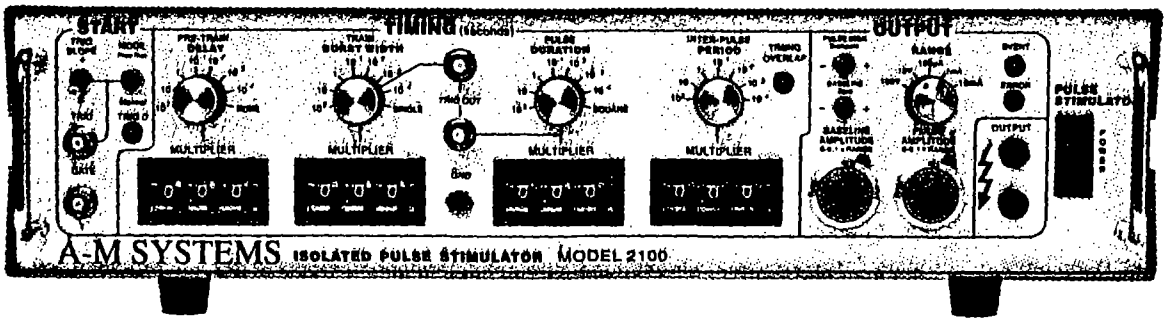
Each Isolated Pulse Stimulator is delivered complete with:

Rack Mount Hardware
Instructions & Maintenance Manual

NOTE

This instrument is not intended for clinical measurements using human subjects. A-M Systems, Inc. does not assume responsibility for injury or damage due to the misuse of this instrument.

General Description



Instrument Features

The *Isolated Pulse Stimulator Model 2100* is designed for a wide variety of applications. It is highly flexible, being capable of delivering single pulses, biphasic pairs, or bursts of pulses. Pulses may be started manually or upon receiving a trigger signal from another instrument or computer. Two non-isolated trigger outputs are available for triggering other instruments.

Four sets of timing controls provide comprehensive control over all aspects of pulse generation. Three digit accuracy is available over a 7 decade range for each timing function, using lever wheel switches. Pulse widths can be set over more than a 9 decade range, from 0.5 µs to 999 seconds. Timing accuracy is assured through the use of a 10 MHz base rate crystal-controlled clock, digitally divided to provide accurate timing over the entire range. A timing overlap indicator will light if the timing controls are set inconsistently.

The output may be conveniently switched between current and voltage modes. Pulse and baseline amplitudes are independently presettable with lockable dials. An error indicator will light if the *Model 2100* cannot deliver the desired signal.

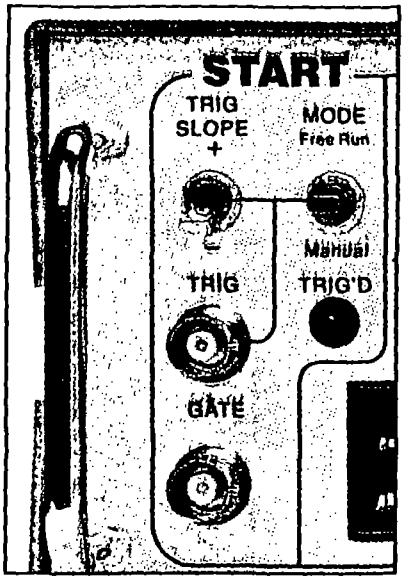
WARNING

The Model 2100 *can produce potentially dangerous voltages up to 100 V at the output connectors. The isolated output is not connected internally to safety (earth) ground in any way. Some part of the external circuit should be connected to safety ground. Use caution in handling any wires, connectors, or electrodes which may be directly or indirectly attached to the* Model 2100 *output. Some kinds of connectors such as BNC connectors have exposed metal parts which may float at dangerous potentials unless externally connected to safety ground.* ***For greatest safety, turn the* Model 2100 *off before making any connections to the instrument.***

Controls and Connectors

The controls for the *Model 2100* are grouped in three sections: **START**, controlling when a pulse or burst of pulses begins; **TIMING**, controlling the on/off timing of one or more pulses; and **OUTPUT**, controlling the amplitude of the output signal.

Start



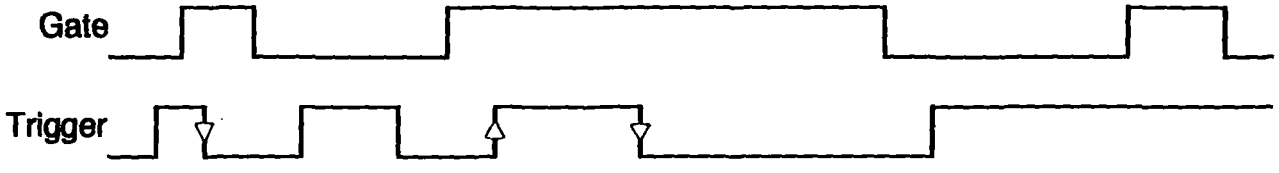
TRIG SLOPE: This switch determines whether valid triggers occur at positive or negative edges in the trigger signal.

MODE: This switch controls how waveforms are initiated. When set to **FREE RUN** one timing cycle immediately follows the last. When held in the **MANUAL** position, a timing cycle starts immediately. When the switch is in the center position, timing cycles start when valid triggering events occur.

TRIG'D: This LED lights up when a timing cycle is in process, and continues until the burst is completed.

TRIG: This BNC connector allows a signal from an external source to initiate timing cycles. It is set for standard TTL levels.

GATE: This BNC connector allows a signal from an external source to restrict the final output signal. This input must be at a logical high (or open-circuited) in order for the *Model 2100* to recognize either manual or automatic trigger events.

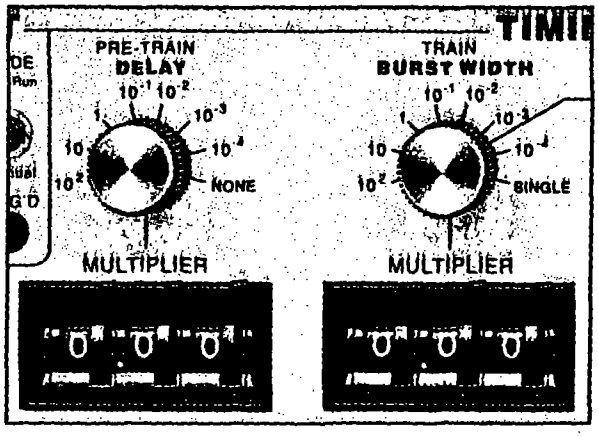


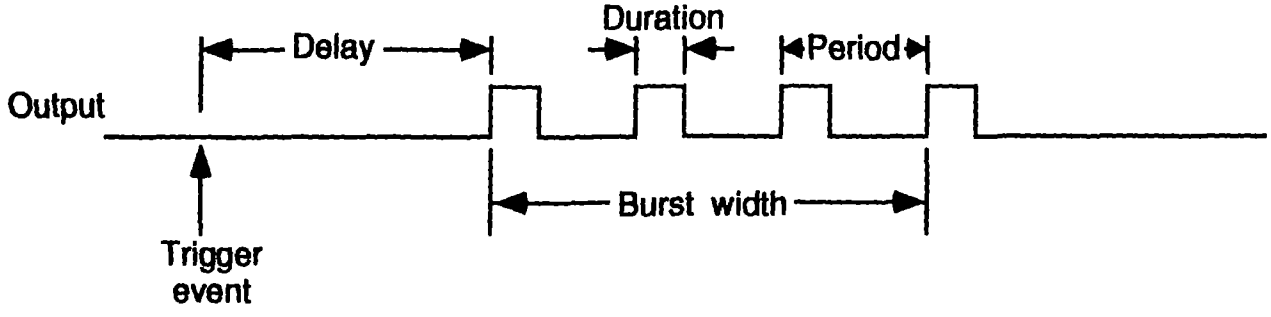
Valid triggers are represented by the arrows in the figure. Note that the up arrow would apply only if **TRIG SLOPE** is set to **+**; the down arrows would apply only if **TRIG SLOPE** is set to **-**.

NOTE: *Triggers have no effect if the system has not completed its response to a previous trigger.*

Timing

Four sets of controls govern the timing of pulse generation. Each set contains two values which are multiplied together to determine the actual timing value. The rotary knob (rate selector) provides the approximate timing value and the lever wheel switch bank (**MULTIPLIER**) provides a time resolution of three decimal digits. The following diagram shows most of the important relationships.

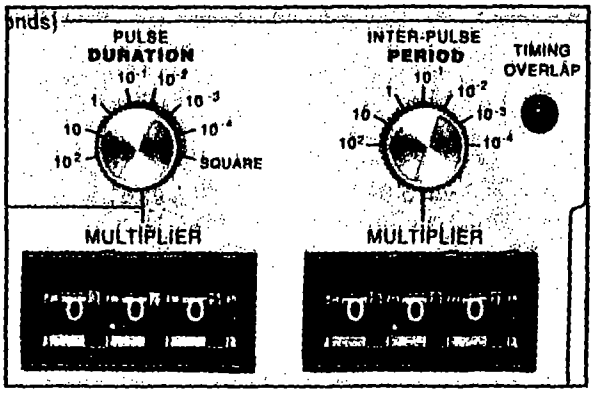




DELAY: These controls set the time between the initiating trigger event and the beginning of the pulse burst. If this rate selector is set to **NONE** or the multiplier is set to **0.00** there is no delay.

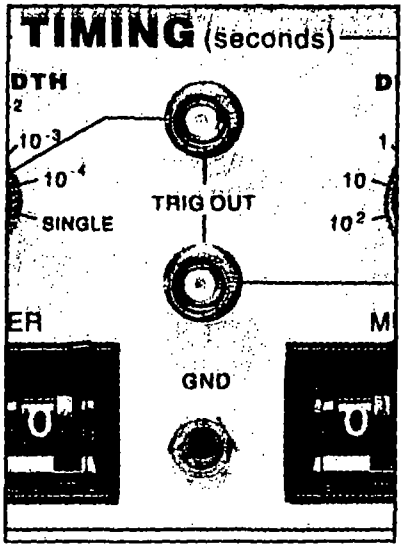
BURST WIDTH: These controls set the time period in which one or more pulses may be delivered. Once started a pulse may outlast the burst width. If this rate selector is set to **SINGLE**, or to any time shorter than the pulse duration, only a single pulse will occur. If the **BURST WIDTH** is longer than the period, pulses will be emitted at the **PERIOD** rate until the burst time ends. Pulses are never truncated by a short **BURST WIDTH**.

DURATION: These controls set the length of each pulse. If this rate selector is set to **SQUARE**, the duration is set to half of the period, regardless of the **MULTIPLIER** setting.



PERIOD: These controls set the period of time between adjacent pulse events within the burst. It also forces a minimum "dead time" between recognized input triggers following a burst of one or more pulses. This can be used to prevent over stimulation of a tissue without requiring excessive delay between the triggering event and the stimulating pulse.

NOTE: *If any of these timing controls are changed while a timing cycle is in operation, the results are undefined until the current cycle finishes.*



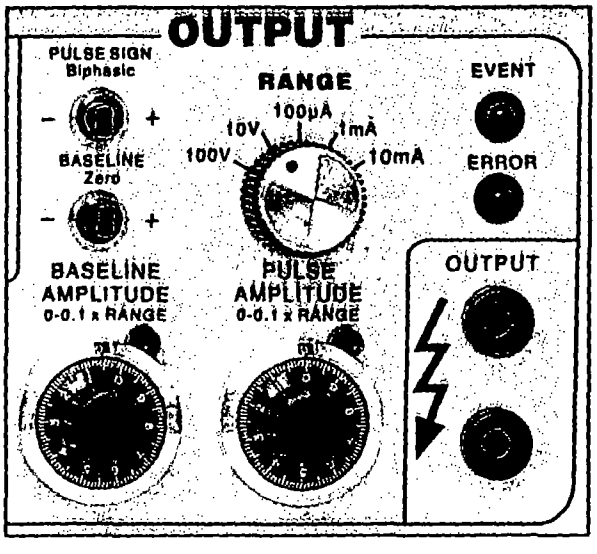
TIMING OVERLAP: This LED will light to indicate an inconsistency in the timing cycle settings. There are several ways to introduce such errors. The most common way is to set the inter-pulse **PERIOD** to be less than the pulse **DURATION**.

TRIG OUT (UPPER): This BNC connector provides a signal which is coincident with the internal Burst timing signal (default). This means the signal starts at the end of the Delay time, and persists until the Burst time expires. This output may also be set to represent the delay time-out by setting the internal jumper J510 to the left two pins instead of the right two pins (Please see the Calibration section in this manual for jumper location; Directions are given as viewed from the front of the instrument).

TRIG OUT (LOWER): This BNC connector provides a signal which is coincident with the Duration timing signal which controls pulse output.

NOTE: *Both trigger output signals slightly lead the isolated output signal.*

Output



PULSE SIGN: This switch sets the sign for the pulses to be generated. It also allows generation of biphasic pulses, thereby doubling the effective total period. ***Warning:*** *the first pulse generated after changing the* **PULSE SIGN** *switch may have the wrong polarity.*

BASELINE: This switch sets the sign for the baseline signal.

RANGE: This rotary switch allows one of three current or two voltage ranges to be selected for the output signal.

BASELINE AMPLITUDE: This counting dial are independently set using ten-minute counting dials, with the baseline having one tenth the range of the pulse amplitude..

PULSE AMPLITUDE: This counting dial

EVENT: This LED indicates when a pulse is ongoing.

ERROR: This LED indicates when the internal output amplifier cannot output the pulse as desired. This is usually due to a short circuit while trying to output a voltage, or an open circuit while trying to output a current.

One control from the *Output* section directly affects waveform timing the *Pulse Sign* control When set to the *Biphasic* mode, a positive-going pulse is immediately followed by a negative-going pulse. This effectively doubles the pulse "duration". If a burst of biphasic pulses is being produced the period must be at least twice the single pulse duration. In the *Square* wave mode, the baseline disappears as long as the burst persists.

Operating Instructions

Examples

Simple setup (and minimal instrument test)

Connect the output of the Model 2100 to an oscilloscope. Before connecting the instrument, it is safest to turn its power off.

Set the *Output* controls:

Range:	10V
Pulse Sign:	+
Baseline:	Zero
Pulse Amplitude:	2.00

Setting The Timing Controls:

Delay:	none
Burst Width:	single
Duration:	$1.50 * 10^{-2}$
Period:	$5.00 * 10^{-2}$

Setting The Start Controls:

Mode:	Free Run

Disconnect any cables to the TRIG or GATE inputs.

Note that the green *Trig* and *Event* indicators turn on as Free Run is turned on (and turn off otherwise). You should observe a 15ms duration, 20Hz rate pulse. of 2.00V above a 0V baseline on the oscilloscope.

Demonstration of Burst Mode

Connect the output of the Model 2100 to an oscilloscope. Before connecting the instrument, it is safest to turn its power off.

Set the *Output* controls:

Range:	10V
Pulse Sign:	+
Baseline:	-
Pulse Amplitude:	2.00
Baseline Amplitude	1.00

Setting The Timing Controls:

Delay:	$8.80 * 10^{-2}$
Burst Width:	$1.20 * 10^{-2}$
Duration:	$1.50 * 10^{-2}$
Period:	$5.00 * 10^{-2}$

Set the START controls as follows:

Mode:	Free Run

Disconnect any cables to the TRIG or GATE inputs.

Trigger the oscilloscope from the *Burst* trigger out (upper *Trig Out* connector) for a stable display. In each burst (occurring every l00ms), you should observe a trio of 15ms duration starting 50ms apart. Try switching the *Start/Mode* from Free Run to the center (normal) position. The pulses will no longer be produced, and the *Trig* and *Event* indicators will turn off. Pressing this switch once (to Manual) will cause a single burst to occur.

Problem Solving

If the instrument appears to be not working properly, check all of the control settings and connections. Be sure to wait at least 5- 10 seconds after turning the instrument off before turning it on again. The following t6ef summary of typical problems for the user (along with the most common solutions) may help:

Problem	Cause/Solution
EVENT indicator never lights, even in FREE RUN mode.	• Replace fuse, check power connection •Set DELAY or PERIOD to a shorter interval. • Power-on too soon after power-off.
OVERLAP indicator is on.	• Set DURATION >0.00. • DURATION is set to SQUARE, but PERIOD is 0.00. Increase PERIOD or set DURATION independantly. • BURST and WIDTH are > DURATION increase PERIOD or decrease DURATION. • BIPHASIC pulse output is on and PERIOD is not longer than twice the DURATION. Increase PERIOD or decrease DURATION. • Free-run is on and BURST is < PERIOD (BURST off), DELAY is 0 and PERIOD is < DURATION. Add, delay or modify PERIOD. • Free-run is on and BURST is > DURATION (BURST ON), and PERIOD is < DURATION. Increase PERIOD.
ERROR indicator is on.	• For VOLTAGE outputs: the output is trying to drive too low a resistance or capacitance (e.g. a short circuit). Check by disconnecting the output. It is possible (and normal) that for the fastest cycles and largest amplitudes (close to 100 V and 1µs) that the ERROR indicator might always come on during repetitive pulses. Fix output load or decrease amplitude as required.
Time appears to be excessive	• Changed control in mid-cycle, (resets current status).

Can't seem to get a full signal out	• Load is not properly connected, repair wiring. • Too low a load impedance (VOLTAGE modes) or too high a load impedance (CURRENT mode).
Incoming triggers not accepted frequently enough	• PERIOD is set too long, (enforces "dead time") followd by BURST set to SIGNAL. Reduce PERIOD time.

Table 1.0 Problem Solving

If you suspect that the Model 2100 may have completely failed, we recommend checking the basic level of functionality. If this fails, your instrument is defective and must be repaired If this passes, either your experimental setup is incompatible or inconsistent; or there is a more subtle flaw in your Model 2100.

If the Model 2100 appears to be malfunctioning, contact A-M Systems, Inc., or your dealer. Telephone numbers for A-M Systems, Inc., listed on the front cover of this manual We will first attempt to solve the problem over the telephone, so have an exact description of your problem available when you call You do not need to be within the warranty period to obtain over-the-phone assistance.

Theory of Operation

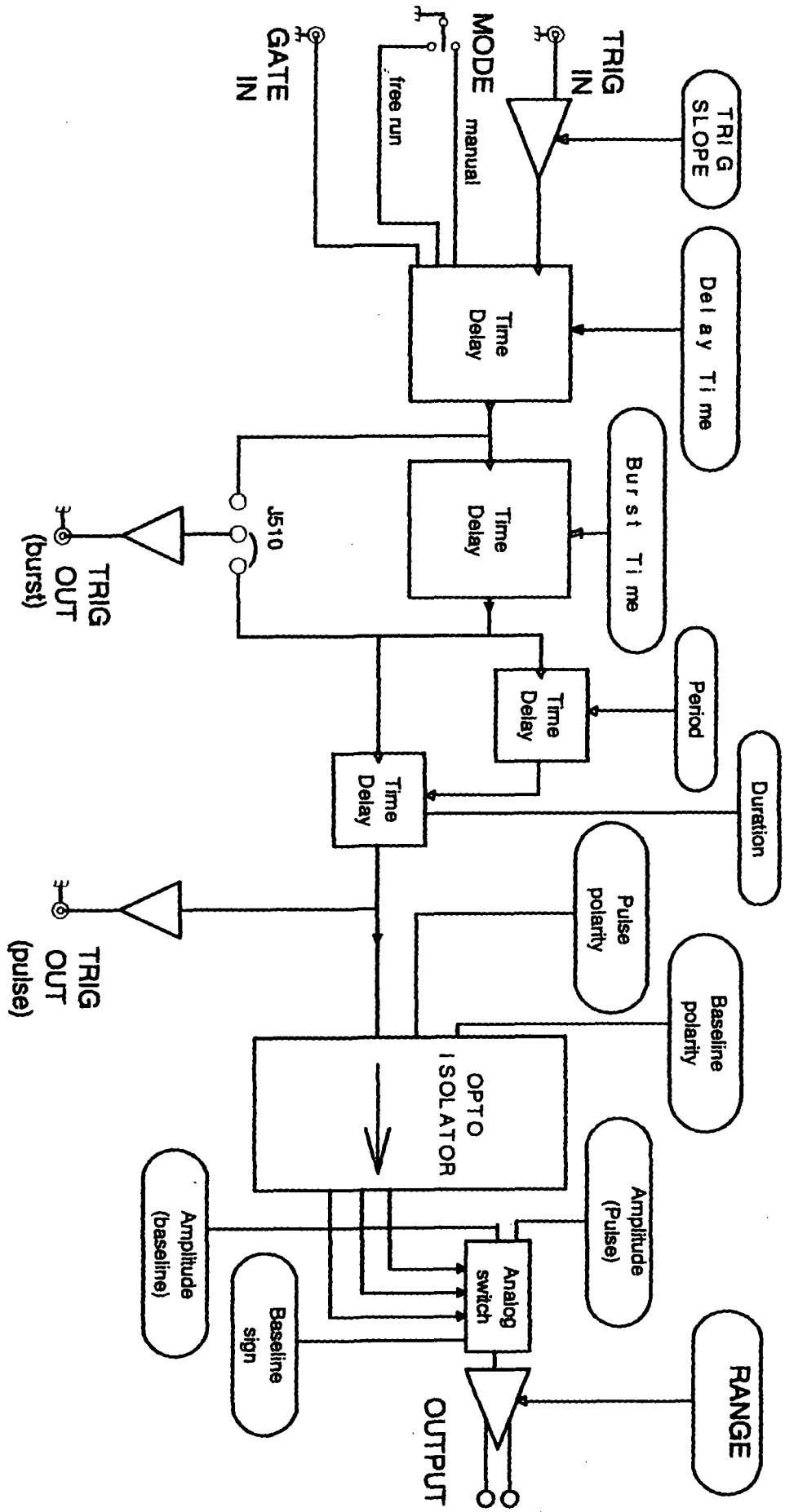
The operation of the Model 2100 is summarized in the block diagram (see Fig. 3). Not shown are all of the interconnections with the microcontroller. The internal microcontroler plays an important role in setting the signal path, but does not directly

contribute to the dynamic characteristics. It scans the front panel switches, and sets the control values for the logic arrays. It programs the internal counters, which along with the other hardware achieve the necessary sub-microsecond speeds.

All action starts either from an input trigger signal (from Trig In), or from an internal signal (in free Run mode. only). A Delay timer counts the 10MHz clock until its count value is exhausted. At this point, the Burst timer starts. Both Period and Duration timers are started at this time. If the Burst timer has not expired by the end of the Period, the Period and Duration timers are restarted. If the Biphasic mode has been set, the Duration timer is restarted at the end of the initial Duration, and the sign of the output pulse is reversed, doubling the total duration.

The system state (pulse on, pulse sip, baseline sign [+/0/-]) is transmitted to the isolated section via optoisolator. The baseline and pulse amplitudes are selected by an analog switch. The resulting signal is amplified by a variable-power-supply discrete operational amplifier. The amplifier connections and gain is modified to provide two voltage and three current ranges.

Timing overlap errors are detected by a logical decision computation rather than by testing for counter collisions. This provides instant feedback, rather than waiting up to an hour for such a collision to occur. Output errors are measured by sensing the output amplifier's differential input voltage. Under normal conditions, this is a negligible voltage. If the amplifier fails to deliver the requested signal the window comparator testing this voltage sends this message (via optoisolator) to the logic section, turning on a warning LED.



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Calibration Procedures

The calibration interval is the lesser of 1000 hours of operation or 6 months. Somewhat greater drift can be expected in the first 100 hours of operation as the semiconductors age. Adjustments should only be made after the instrument has been fully warmed up for at least 15 minutes.

Full instrument calibration requires the following test equipment:

digital multimeter (± 0.1%), able to measure resistance to at least 100MΩ
oscilloscope with at least 50MHz bandwidth
true-rms voltmeter with 4MHz bandwidth
universal counter (± 0.01%), able to measure single pulse widths and periods
resistors (all ± 0.1%): 2kΩ, 10kΩ 1 watt, 20kΩ, 200kΩ
alligator clip lead sets, banana plugs and BNC adapters

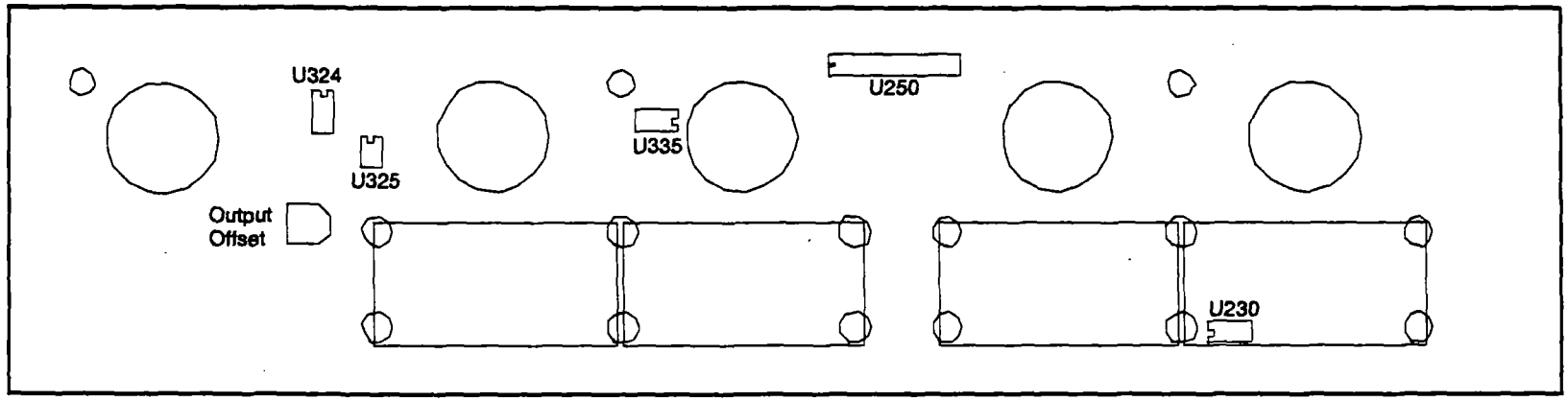
Adjustment, integrated circuit, and test point locations are shown in the following figures. All adjustments are on the timing board unless otherwise noted.

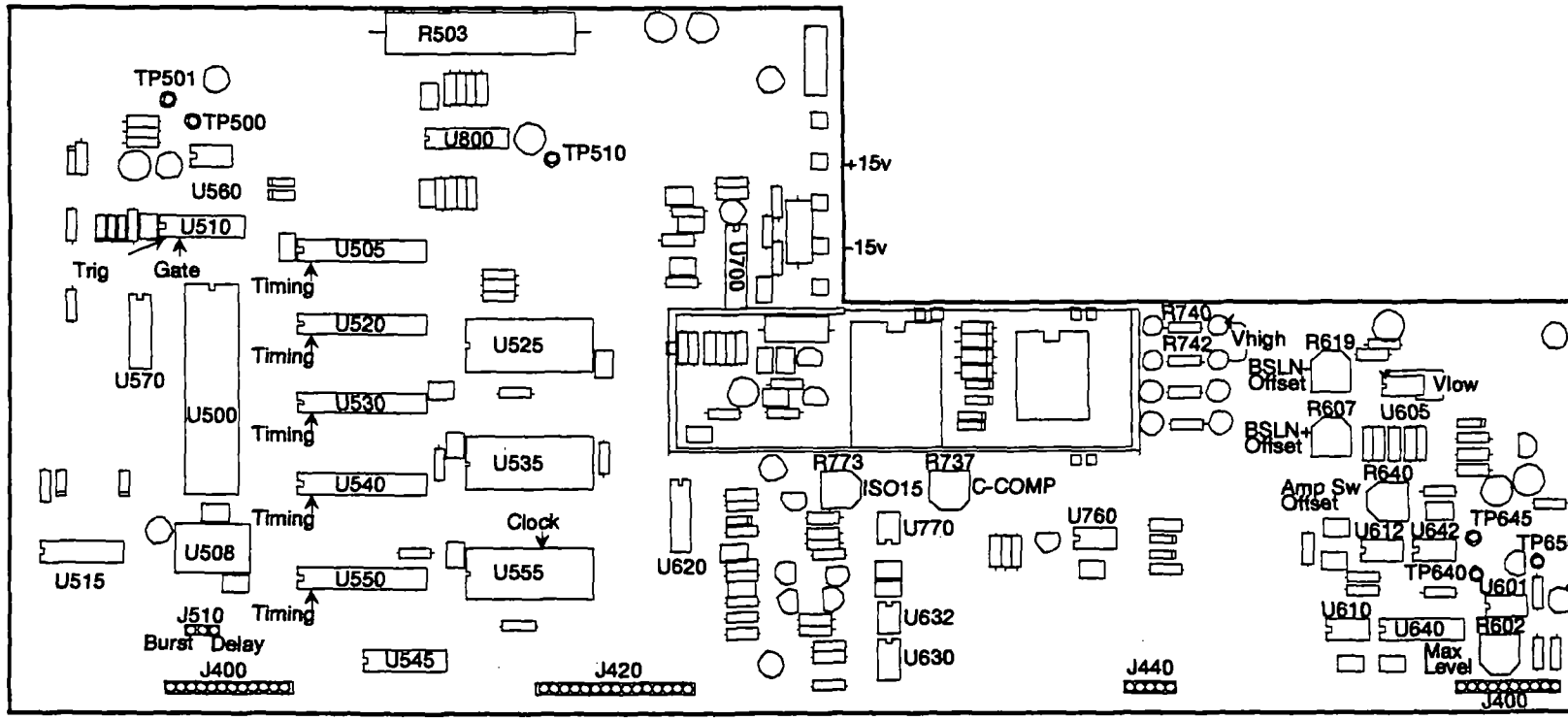
All voltages in the non-isolated section should be measured with respect to ground at TP510 unless otherwise stated. Some voltages are measured with respect to an internal "isolated ground" at TP650, or across the two output terminals. Occasionally the voltage at an IC pin must be measured; in these cases the reference designator is given, with the pin number in parentheses: e.g. U602(16). When it states within this procedure that a voltage is to be minimized, this means that the adjustment should be made such that the measured voltage is as close to zero volts as possible. Refer to the Specifications Section of this manual for acceptable tolerances.

The sequence of this procedure is important. If any adjustment is made, all adjustments which follow must be made to ensure that the specifications will be met. These procedures require that all controls remain as set in previous steps unless otherwise indicated.

WARNING

The *Model 2100* has dangerous voltages throughout the instrument, even with the power is off. Servicing the *Model 2100* should only be done by qualified service personnel. Use caution in handling any wires, connectors, or electrodes which may be directly or indirectly attached to the instrument. Do not touch exposed connections or components. Disconnect power by unplugging the power cord from the receptacle.





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Power supply and bias voltages

Power supply

Controls	Inputs / Observations	Adjust / Check
POWER: ON	Observe voltage at P703 power supply wire, top of main board	Check for +15 ± 0.50 V
	Observe voltage at P701 power supply wire, top of main board	Check for -15 ± 0.50 V
	Observe voltage at U505(24)	Check for +5 ± 0.25 V

Isolated supply voltage

Controls	Inputs / Observations	Adjust / Check
RANGE: 10 V **TRIG:** open circuit **MODE:** center position	Alternately observe V_{high} from R742 to R740, and V_{low} from the U605(4) to U605(8)	Adjust R773 so that 110 V < V_{high} < 120 V and 28 V < V_{low} < 34 V

Capacitance balance

Controls	Inputs / Observations	Adjust / Check
	Connect a x10 oscilloscope probe to TP650 and ground the	Adjust R737 for minimum high frequency signal

Inputs

Gate function

Controls	Inputs / Observations	Adjust / Check
	Apply a 1 kHz, 0 - 5 V triangle wave to **GATE** Observe voltage at U510(3) with an oscilloscope	Verify that the voltage switches states at the proper input levels

Trigger slope

Controls	Inputs / Observations	Adjust / Check
	Apply a 1 kHz, 0 - 5 V triangle wave to **TRIG** Observe voltage at U510(1) with an oscilloscope	Verify that the voltage switches states at the proper input levels
TRIG SLOPE: +		Verify voltage is 180° out of phase
TRIG SLOPE: -		Verify voltage is in phase

Trigger and gate function

Controls	Inputs / Observations	Adjust / Check
DELAY: NONE BURSTWIDTH: SINGLE DURATION: SQUARE PERIOD: 1.00 X 10-3	Apply a 1 kHz, 0 - 5 V triangle wave to TRIG Observe TRIG'D and EVENT LEDs	
TRIG: disconnect all	Short the GATE connector to GND	Verify LEDs extinguish
MODE: press to MANUAL		Verify LEDs flash once

Timing

System clock frequency

Controls	Inputs / Observations	Adjust / Check
	Observe the frequency of the wave at U555(17)	Verify 1.000 MHz ± 0.01%

Multipliers (Wheel Switches)

Controls	Inputs / Observations	Adjust / Check
PULSE SIGN: + MODE: FREE RUN TRIG: disconnect all TIMING MULTIPLIERS: all wheels set to zero except the one being tested TIMING OVERLAP: ignore	Observe the pulse width with the counter at the location specified below	Verify pulse width is correct for each wheel as it is tested independently

For each wheel of each MULTIPLIER, test each position to verify that the pulse width is correct. Observe the signal at the following locations: DELAY: U520(2); BURSTWIDTH: U530(2); PERIOD: U540(2); DURATION: U550(2)

Rates (Rotary Switches)

Controls	Inputs / Observations	Adjust / Check
TIMING MULTIPLIERS: 0.01 TIMING RATES: all rotary switches set to 10-4 except the one being tested	Observe the pulse width with the counter at the location specified below	Verify pulse width is correct for each rotary switch as it is tested independently

For each of the four rotary switches in TIMING, test each position to verify that the pulse width is correct. Observe the signal at the following locations: DELAY: U520(2); BURSTWIDTH: U530(2); PERIOD: U540(2); DURATION: U550(2)

Trigger outputs

Controls	Inputs / Observations	Adjust / Check
Range: 10V Pulse Amplitude: 5.00 Delay: 1.00 x 10^{-2} Burst: 1.00 x 10^{-2} Duration: 1.00 x 10^{-3} Period: 4.00 x 10^{-3} Pulse sign: + Trig Mode: Free run Trig in: open	Trigger the oscilloscope to the Burst Trig Out. Observe it, the Pulse Trig Out, and the isolated output.	Verify that the waveform consists of a burst of three 1ms-on/3ms-off pulses. The burst trigger should be synchronous with the burst; the pulse trigger coincident with each pulse.

Output Calibration

Isolation Resistance (check)

Controls	Inputs / Observations	Adjust / Check
Trig Mode: center position Trig In: open	Measure the resistance between ground banana jack (front panel) and black banana jack of output with DMM	Resistance read > 100MΩ

Amplitude Switch Offset (R640)

Controls	Inputs/Observations	Adjust/Check
Baseline: Zero Trig Mode: center position Trig In: Open	Measure the voltage at TP645 vs. TP650 with the DMM.	Adjust R640 (Ampl Sw Offset) for minimum voltage.

Output Offset (R332: front panel board)

Controls	Inputs/Observations	Adjust/Check
Baseline: Zero Range: 10V Trig Mode: center position Trig In: Open	Measure the voltage across the output with the DMM.	Adjust R332 (Output offset) for minimum voltage.

Positive Baseline Offset (R607)

Controls	Inputs/Observations	Adjust/Check
Baseline Sign: + Baseline Amplitude: fully CCW (0.00) Range: 10V Trig In: open Trig Mode: center position	Measure the voltage across the output with the DMM.	Adjust R602 (BSLN + offset) for minimum voltage.

Negative Baseline Offset (R619)

Controls	Inputs/Observations	Adjust/Check
Baseline Sign: - Baseline Amplitude: fully CCW (0.00) Range: 10V Trig In: open Trig Mode: center position	Measure the voltage across the output with the DMM.	Adjust R619 (BSLN + offset) for minimum voltage.

Pulse Amplitude Adjust (R602)

Controls	Inputs/Observations	Adjust/Check
Trig Mode: Free Mode Pulse Amplitude: 10.00 Timing: Delay =none; Burst =single; Duration =1.00*1; Period =0.01*10-4 Pulse Sign: - Trig In: open Range: 10V	Measure the voltage across the output with the DMM.	The Overlap indicator should be on. Adjust R602 (Max Level) for -10.00V out.

Pulse Sign Gain (check)

Controls	Inputs/Observations	Adjust/Check
Trig Mode: Free Mode Pulse Amplitude: 10.00 Timing: Delay =none; Burst =single; Duration =1.00*1s; Period =0.01*10-4s Trig In: open Range: 10V	Measure the voltage at the output with the DMM for the Pulse Sign at + and - positions	The absolute values of the voltages should differ by less than 100mV.

Baseline Amplitudes (check)

Controls	Inputs/Observations	Adjust/Check
Range: 100mA *Trig Mode*: center position *Baseline Amplitude*: fully CW (10.00) *Trig In*: open	Measure the voltage at the output with the *DMM with Baseline Sign in +, Zero, and - positions.*	Gain the matching of current levels at = and - positions; and offset current in Zero position..

Output Range Amplitude and Drive (check)

Controls	Inputs/Observations	Adjust/Check
Pulse Amplitude: 10.00 Pulse Sign: + Trig Mode: Free Run Timing: Delay =none; Burst =single; Duration =1.00*1; Period =100*10-4 Trig In: open	Load the output with a 10KV 1W 0.1% resistor. Measure the voltage at the output with DMM.	Verify that full scale output is within specification: Scale: Range: 100V 100V 10V 10V 100mA 1V 1mA 10V 10mA 100V

Pulse Sign and Short Circuit Protection (check)

Controls	Inputs/Observations	Adjust/Check
Timing: Delay =none; Burst =single: Duration =2.00*;10-4 Period =0.01*10-3 Baseline: Zero Pulse Amplitude: 2.5 Range: 10V Trig Mode: Free Run Trig In: open	Measure the voltage at the output with the oscilloscope. Check for Pulse Sign set to each of: +, -, biphasic. Watch for Error indicator when shorting the output.	Verify that pulses of approx. 2.5V amplitude (62.5V for biphasic mode) of the correct sign are produced every 10ms. Short output in biphasic mode. Output should return when opened.

Output Transient Response (check)

Controls	Inputs/Observations	Adjust/Check
Pulse Sign: + Timing: Delay =none; Burst: =single; Duration =2.00*10-4; Period =0.01*10-3 Pulse Amplitude: 2.50 Baseline: Zero Trig Mode: Free Mode Trig In: open	Connect the oscilloscope to the output with a 310 attenuator probe. Test both 10V and 100V ranges.	Verify that overshoot and risetime meet specifications.

Specifications

There are three classes of specifications. Class A specifications tested in all units, and are guaranteed. Class B specifications are inherent in the design; they are indirectly tested, and are guaranteed. Class C specifications are typical operating values which are occasionally tested-, these are typical values, given for your information but not guaranteed. The class for each specification is noted in the center column of the following sections.

Inputs

Switching level	A	1.6 V (± 0.2 V)
Hysteresis	C	approx. 50 mV
Input equivalent circuit	C	100K Ω to +5 in parallel with no more than 35pF
Minimum duration (TTL-level signal)	C	> 50 ns.
Open circuit condition	B	defaults to high/on level

Timing and rate accuracy

Rate selector steps	B	100µs to 100s in 7 steps
Timing multiplier steps	B	1% of rate selector step size. Maximum value is 9.99 x the rate selector step size
Resolution	B	approx. 0.1% of the maximum value
Timing error (second and later pulses after resetting controls)	B	< 0.02% of rate selector value + 0.15 µs
Timing error (first pulse after readjusting timing controls)	C	an additional 0.25 µs error may occur
Timing repeatability	C	< 0.01% setting + 20 ns (monophasic)

TRIG IN to OUTPUT delay (DELAY set to 0), output set to 2 V	C	approx. 0.5 µs for a load of no more than 10 KΩ in parallel with 50 pF
Timing jitter from TRIG IN to OUTPUT (for TTL trigger input with risetime <10 ns)	C	< 125 ns (all rates except 100s) < 1.25 µs (100s rate)
Timing jitter from TRIG OUT (either BURST or PULSE) and OUTPUT	C	Less than 20 ns (all rates)
Trigger output to pulse output delay	C	approx. 350 ns
Output characteristics		
Pulse level error (voltage mode: open circuit; current mode: short circuit	A	< 0.3% of setting + 0.5% of r range (plus an additional 0.5 µA in 100 µA range)
Biphasic level difference | V+ + V- | /2	C	< 0.3% of range (voltage modes: into open circuit; current modes :into short circuit)
Baseline level error (voltage mode: open circuit; current mode: short circuit)	A	< 0.3% of setting of setting + 0.1% of range (plus an additional 0.5 µA in 100µA range)
Risetime (2.5 V out)	A	≈ 200 ns into less than 30 pF
Risetime (25 V out)	A	≈ 1.5 µs into less than 30 pF
Transient response	A	< 8% overshoot into less than 30 pF for pulse voltages different than baseline voltage by at least 10% of range
Output impedance (voltage mode)	C	≈ 50 ohms
Output impedance (current mode)	C	>>10 GΩ (typically 200 GΩ)
Isolation resistance	A	>>100 MΩ
Isolation capacitance	C	≈ 60 pF at 100 Hz

Noise (differential mode)	C	≈ 1 mV rms (10 V scale; 10 Hz - 4 MHz)
Noise (common mode: earth to isolated ground) with no signal output	C	≈ 8 mV rms (10 Hz - 4 MHz); ≈ 100 mV p-p (200 Hz - 10 MHz), measured with a 10 MΩ, 15 pF oscilloscope probe
Overload error indicator (low frequency, short circuited voltage mode)	C	Turns on for set amplitude at or greater than approx. ±1 V (10 V range); or ±2 V (100 V range)
Overload error indicator low frequency, open circuited current mode)	C	Turns on for set amplitude at or above approx. 2% of range
Overload error response time	C	Flat to approx. 30 µs duration Decreasing sensitivity for shorter pulses

Miscellaneous

Power	approx. 11 watts
Fuse	1 amp 3 AG
Operating temperature range	10 - 30° C
Storage temperature range	0 - 50° C
Operating humidity	5 - 80% RH
Dimensions	17 x 4.75 x 11.25 (inches) 43.2 x 12.1 x 28.6 cm
Weight	20 lbs (9 kg)

Warranty and Service

What does this warranty cover?

A-M Systems, Inc. warrants to the Purchaser that the Instrument, excluding cables, Headstage Probes and any other accessories shipped with the Instrument, (hereafter the "hardware") is free from defects in workmanship or material under normal use and service for the period of one (1) year. This warranty commences on the date of delivery of the hardware to the Purchaser.

What are the obligations of A-M Systems, Inc. under this warranty?

During the warranty period, A-M Systems, Inc. agrees to repair or replace, at its sole option, without charge to the Purchaser, any defective component part of the hardware. To obtain warranty service, the Purchaser must return the hardware to A-M Systems, Inc. or an authorized A-M Systems, Inc. distributor in an adequate shipping container. Any postage, shipping and insurance charges incurred in shipping the hardware to A-M Systems, Inc. must be prepaid by the Purchaser and all risk for the hardware shall remain with purchaser until such time as A-M Systems, Inc. takes receipt of the hardware. Upon receipt, A-M Systems, Inc. will promptly repair or replace the defective unit, and then return the hardware to the Purchaser, postage, shipping, and insurance prepaid. A-M Systems, Inc. may use reconditioned or like new parts or units at its sole option, when repairing any hardware. Repaired products shall carry the same amount of outstanding warranty as from original purchase, or ninety (90) days which ever is greater. Any claim under the warranty must include a dated proof of purchase of the hardware covered by this warranty. In any event, A-M Systems, Inc. liability for defective hardware is limited to repairing or replacing the hardware.

What is not covered by this warranty?

This warranty is contingent upon proper use and maintenance of the hardware by the Purchaser and does not cover batteries. Neglect, misuse whether intentional or otherwise, tampering with or altering the hardware, damage caused by accident, damage caused by unusual physical, electrical, chemical, or electromechanical stress, damage caused by failure of electrical power, or damage caused during transportation are not covered by this warranty. **Products may not be returned to A-M Systems, Inc. for service, whether under warranty or otherwise, which are contaminated by infectious agents, radioactive compounds or other materials constituting a health hazard to employees of A-M Systems, Inc.**

What are the limits of liability for A-M Systems, Inc. under this warranty?

A-M Systems, Inc. shall not be liable for loss of data, profits or savings, or any special, incidental, consequential, indirect or other similar damages arising from breach of contract, negligence, or other legal action even if the company or its agent has been advised of the possibility of such damages, or for any claim brought against you by another party. **THIS EQUIPMENT IS NOT INTENDED FOR CLINICAL MEASUREMENTS USING HUMAN SUBJECTS. A-M SYSTEMS, INC. DOES NOT ASSUME RESPONSIBILITY FOR INJURY OR DAMAGE DUE TO MISUSE OF THIS EQUIPMENT**. Jurisdictions vary with regard to the enforceability of provisions excluding or limiting liability for incidental or consequential damages. Check the provision of your local jurisdiction to find out whether the above exclusion applies to you.

This warranty allocates risks of product failure between the Purchaser and A-M Systems, Inc. A-M Systems, Inc. hardware pricing reflects this allocation of risk and the limitations of liability contained in this warranty. The warranty set forth above is in lieu of all other express warranties, whether oral or written. The agents, employees, distributors, and dealers of A-M Systems, Inc. are not authorized to make modifications to this warranty, or additional warranties binding on the company. Accordingly, additional statements such as dealer advertising or presentations, whether oral or written, do not constitute warranties by A-M Systems, Inc. and should not be relied upon. This warranty gives you specific legal rights. You may also have other rights which vary from one jurisdiction to another.

2100

Isolated Pulse Stimulator

INSTRUCTION MANUAL

FOR

ISOLATED PULSE STIMULATOR

MODEL 2100

Serial #_____

Date_____

A-M Systems, Inc.
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U.S.A.
360-683-8300 ♦ 800-426-1306
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Version 7.0
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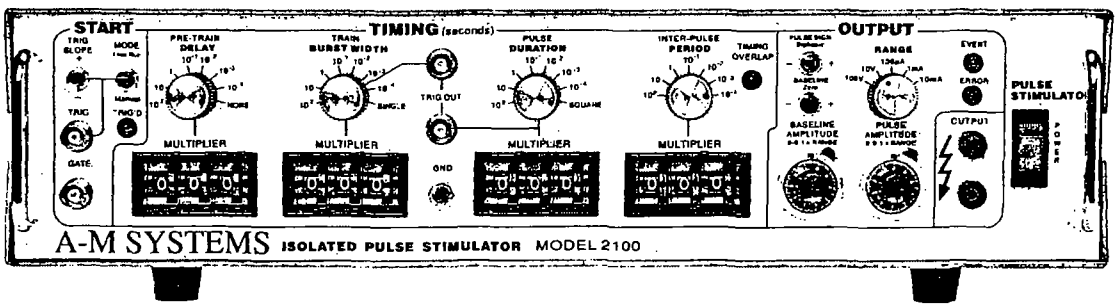
Each Isolated Pulse Stimulator is delivered complete with:

Rack Mount Hardware
Instructions & Maintenance Manual

NOTE

This instrument is not intended for clinical measurements using human subjects. A-M Systems, Inc. does not assume responsibility for injury or damage due to the misuse of this instrument.

General Description



Instrument Features

The *Isolated Pulse Stimulator Model 2100* is designed for a wide variety of applications. It is highly flexible, being capable of delivering single pulses, biphasic pairs, or bursts of pulses. Pulses may be started manually or upon receiving a trigger signal from another instrument or computer. Two non-isolated trigger outputs are available for triggering other instruments.

Four sets of timing controls provide comprehensive control over all aspects of pulse generation. Three digit accuracy is available over a 7 decade range for each timing function, using lever wheel switches. Pulse widths can be set over more than a 9 decade range, from 0.5 µs to 999 seconds. Timing accuracy is assured through the use of a 10 MHz base rate crystal-controlled clock, digitally divided to provide accurate timing over the entire range. A timing overlap indicator will light if the timing controls are set inconsistently.

The output may be conveniently switched between current and voltage modes. Pulse and baseline amplitudes are independently presettable with lockable dials. An error indicator will light if the *Model 2100* cannot deliver the desired signal.

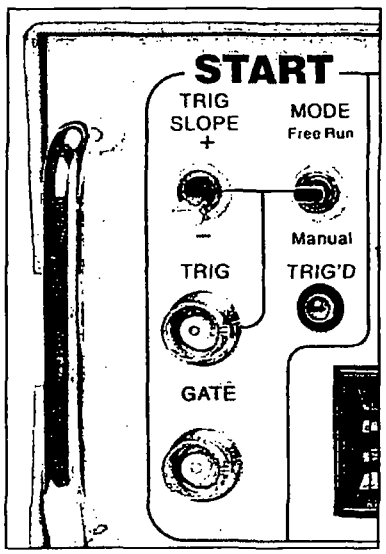
WARNING

The Model 2100 *can produce potentially dangerous voltages up to 100 V at the output connectors. The isolated output is not connected internally to safety (earth) ground in any way. Some part of the external circuit should be connected to safety ground. Use caution in handling any wires, connectors, or electrodes which may be directly or indirectly attached to the* Model 2100 *output. Some kinds of connectors such as BNC connectors have exposed metal parts which may float at dangerous potentials unless externally connected to safety ground.* ***For greatest safety, turn the* Model 2100 *off before making any connections to the instrument.***

Controls and Connectors

The controls for the *Model 2100* are grouped in three sections: **START**, which controls when a pulse or burst of pulses begins; **TIMING**, which controls the on/off timing of one or more pulses; and **OUTPUT**, which controls the amplitude of the output signal.

Start



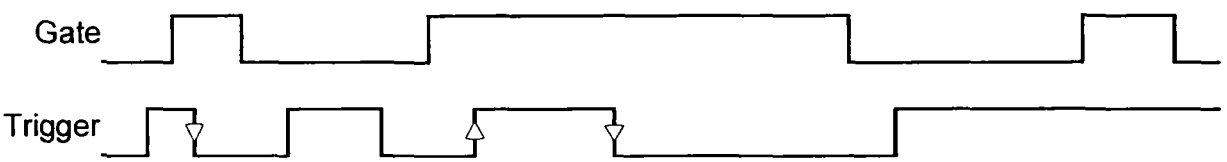
TRIG SLOPE: Determines the polarity of valid trigger pulses (positive or negative edges in the trigger signal).

MODE: Controls waveform initiation. When set to **FREE RUN**, one timing cycle immediately follows the last. When momentarily placed in the **MANUAL** position, a timing cycle starts immediately. When the switch is in the center position, timing cycles start when valid triggering events occur.

TRIG'D: This LED lights up when a timing cycle is in process, and continues until the burst is completed.

TRIG: This BNC connector allows a signal from an external source to initiate timing cycles. It is set for standard TTL levels.

GATE: This BNC connector allows a signal from an external source to restrict the final output signal. This input must be at a logical high (or open-circuited) in order for the *Model 2100* to recognize either manual or automatic trigger events.

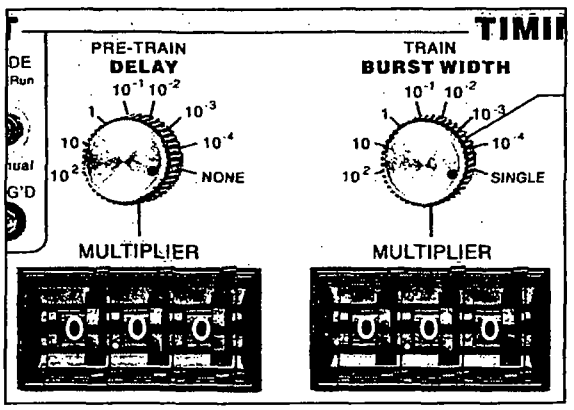


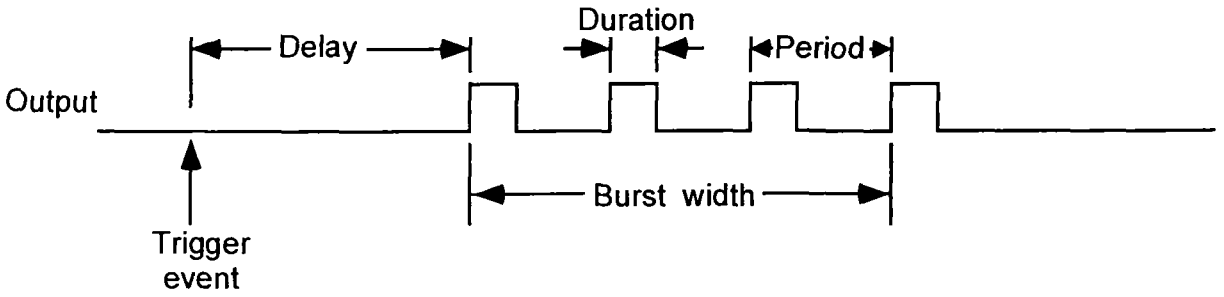
Valid triggers (represented by the arrows in the figure) can occur only when the gate is at logical high. Note that the up arrow would apply only if **TRIG SLOPE** is set to **+**; the down arrows would apply only if **TRIG SLOPE** is set to **-**.

NOTE: *Triggers have no effect if the system has not completed its response to a previous trigger.*

Timing

Four sets of controls govern the timing of pulse generation. Each set contains two values which are multiplied together to determine the actual timing value. The rotary knob (rate selector) provides the approximate timing value and the lever wheel switch bank (**MULTIPLIER**) provides a time resolution of three decimal digits. The following diagram shows most of the important relationships.

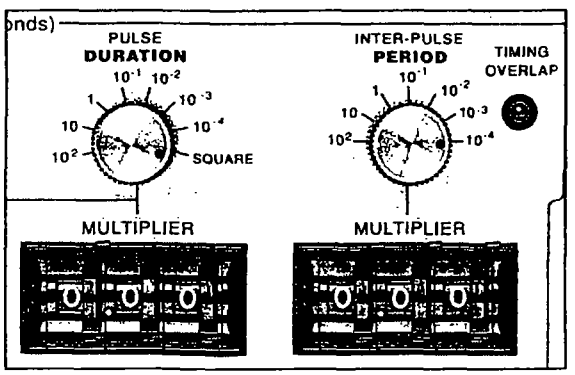




DELAY: These controls determine the time duration between the initiating trigger event and the beginning of the pulse burst. If this rate selector is set to **NONE** or the multiplier is set to **0.00** there is no delay.

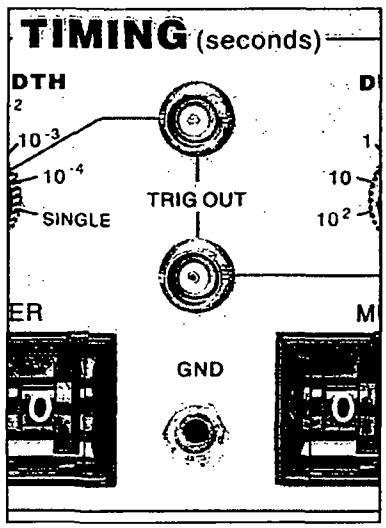
BURST WIDTH: These controls determine the time period in which one or more pulses may be delivered. Once started a pulse may outlast the burst width. If this rate selector is set to **SINGLE**, or to any time shorter than the pulse duration, only a single pulse will occur. If the **BURST WIDTH** is longer than the period, pulses will be emitted at the **PERIOD** rate until the burst time ends. Pulses are never truncated by a short **BURST WIDTH**.

DURATION: These controls determine the length of each pulse. If this rate selector is set to **SQUARE**, the duration is set to half of the period, regardless of the **MULTIPLIER** setting.



PERIOD: These controls set the period of time between adjacent pulse events within the burst. It also forces a minimum "dead time" between recognized input triggers following a burst of one or more pulses. This can be used to prevent over stimulation of a tissue without requiring excessive delay between the triggering event and the stimulating pulse.

NOTE: *If any of these timing controls are changed while a timing cycle is in operation, the results are undefined until the current cycle finishes.*



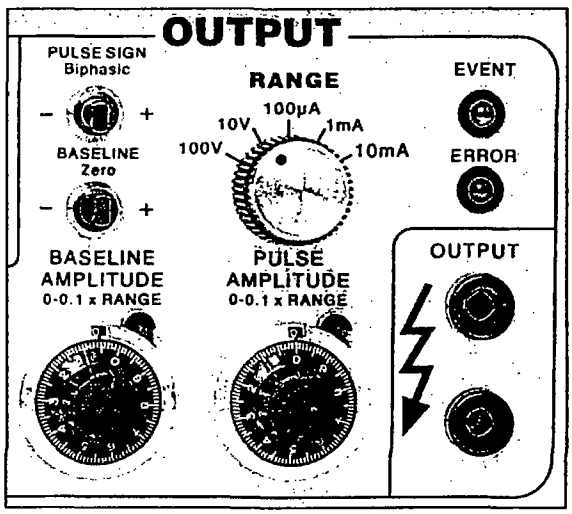
TIMING OVERLAP: This LED will light to indicate an inconsistency in the timing cycle settings. There are several ways to introduce such errors. The most common way is to set the inter-pulse **PERIOD** to be less than the pulse **DURATION**.

TRIG OUT (UPPER): This BNC connector provides a signal which is coincident with the internal Burst timing signal (default). This means the signal starts at the end of the Delay time, and persists until the Burst time expires. This output may also be set to represent the delay time-out by setting the internal jumper J510 to the right two pins instead of the left two pins (Please see the Calibration section in this manual for jumper location; Directions are given as viewed from the front of the instrument).

TRIG OUT (LOWER): This BNC connector provides a signal which is coincident with the Duration timing signal which controls pulse output.

NOTE: *Both trigger output signals slightly lead the isolated output signal.*

Output



PULSE SIGN: This switch determines the polarity of the pulses to be generated. It also allows generation of biphasic pulses, thereby doubling the effective total period. ***Warning:*** *the first pulse generated after changing the* **PULSE SIGN** *switch may have the wrong polarity.*

BASELINE: This switch determines the polarity of the baseline signal.

RANGE: This rotary switch determines if the output pulses will be constant current (3 ranges) or constant voltage (2 ranges).

BASELINE AMPLITUDE: This value is independently set using a ten-turn counting dial. The maximum baseline amplitude is one tenth the value shown on the range amplitude switch.

PULSE AMPLITUDE: This value is independently set using a ten-turn counting dial. The maximum pulse amplitude is the value shown on the range amplitude switch.

EVENT: This LED indicates when a pulse is ongoing.

ERROR: This LED indicates when the internal output amplifier cannot output the pulse as desired. This is usually due to a short circuit while trying to output a voltage, or an open circuit while trying to output a current.

NOTE: The *Pulse Sign* control in the *Output* section directly affects waveform timing. When set to the *Biphasic* mode, a positive-going pulse is immediately followed by a negative-going pulse. This effectively doubles the pulse "duration". If a burst of biphasic pulses is being produced the period must be at least twice the single pulse duration. In the *Square* wave mode, the baseline disappears as long as the burst persists.

Operating Instructions

Examples

Simple setup (and minimal instrument test)

Connect the output of the Model 2100 to an oscilloscope. Before connecting the Model 2100 to any other instrument, or the experimental preparation, it is safest to turn its power off.

Set the *Output* controls:

Range:	10V
Pulse Sign:	+
Baseline:	Zero
Pulse Amplitude:	2.00

Setting The Timing Controls:

Delay:	none
Burst Width:	single
Duration:	$1.50 * 10^{-2}$
Period:	$5.00 * 10^{-2}$

Setting The Start Controls:

Mode:	Free Run

Disconnect any cables to the TRIG or GATE inputs.

Note that the green *Trig* and *Event* indicators turn on as Free Run is turned on (and turn off otherwise). You should observe a 15ms duration, 20Hz rate pulse. of 2.00V above a 0V baseline on the oscilloscope.

Demonstration of Burst Mode

Connect the output of the Model 2100 to an oscilloscope. Before connecting the Model 2100 to any other instrument, or the experimental preparation, it is safest to turn its power off.

Set the *Output* controls:

Range:	10V
Pulse Sign:	+
Baseline:	-
Pulse Amplitude:	2.00
Baseline Amplitude	1.00

Setting The Timing Controls:

Delay:	$8.80 * 10^{-2}$
Burst Width:	$1.20 * 10^{-2}$
Duration:	$1.50 * 10^{-2}$
Period:	$5.00 * 10^{-2}$

Set the START controls as follows:

Mode:	Free Run

Disconnect any cables to the TRIG or GATE inputs.

Trigger the oscilloscope from the *Burst* trigger out (upper *Trig Out* connector) for a stable display. In each burst (occurring every l00ms), you should observe a trio of 15ms duration starting 50ms apart. Try switching the *Start/Mode* from Free Run to the center (normal) position. The pulses will no longer be produced, and the *Trig* and *Event* indicators will turn off. Pressing this switch once (to Manual) will cause a single burst to occur.

Problem Solving

If the instrument appears to be not working properly, check all of the control settings and connections. Be sure to wait at least 5- 10 seconds after turning the instrument off before turning it on again. The following summary of typical problems for the user (along with the most common solutions) may help:

Problem	Cause/Solution
EVENT indicator never lights, even in FREE RUN mode.	• Replace fuse, check power connection •Set DELAY or PERIOD to a shorter interval. • Power-on too soon after power-off.
OVERLAP indicator is on.	• Set DURATION >0.00. • DURATION is set to SQUARE, but PERIOD is 0.00. Increase PERIOD or set DURATION independantly. • BURST and WIDTH are > DURATION increase PERIOD or decrease DURATION. • BIPHASIC pulse output is on and PERIOD is not longer than twice the DURATION. Increase PERIOD or decrease DURATION. • Free-run is on and BURST is < PERIOD (BURST off), DELAY is 0 and PERIOD is < DURATION. Add, delay or modify PERIOD. • Free-run is on and BURST is > DURATION (BURST ON), and PERIOD is < DURATION. Increase PERIOD.
ERROR indicator is on.	• For VOLTAGE outputs: the output is trying to drive too low a resistance or capacitance (e.g. a short circuit). Check by disconnecting the output. It is possible (and normal) that for the fastest cycles and largest amplitudes (close to 100 V

	and 1µs) that the ERROR indicator might always come on during repetitive pulses. Fix output load or decrease amplitude as required.
Time appears to be excessive	• Changed control in mid-cycle, (resets current status).
Can't seem to get a full signal out	• Load is not properly connected, repair wiring. • Too low a load impedance (VOLTAGE modes) or too high a load impedance (CURRENT mode).
Incoming triggers not accepted frequently enough	• PERIOD is set too long, (enforces "dead time") followd by BURST set to SIGNAL. Reduce PERIOD time.

Table 1.0 Problem Solving

If you suspect that the Model 2100 may have completely failed, we recommend checking the basic level of functionality. If this fails, your instrument is defective and must be repaired. If this passes, either your experimental setup is incompatible or inconsistent; or there is a more subtle flaw in your Model 2100.

If the Model 2100 appears to be malfunctioning, contact A-M Systems, Inc., or your dealer. We will first attempt to solve the problem over the telephone, so have an exact description of your problem available when you call. You do not need to be within the warranty period to obtain over-the-phone assistance.

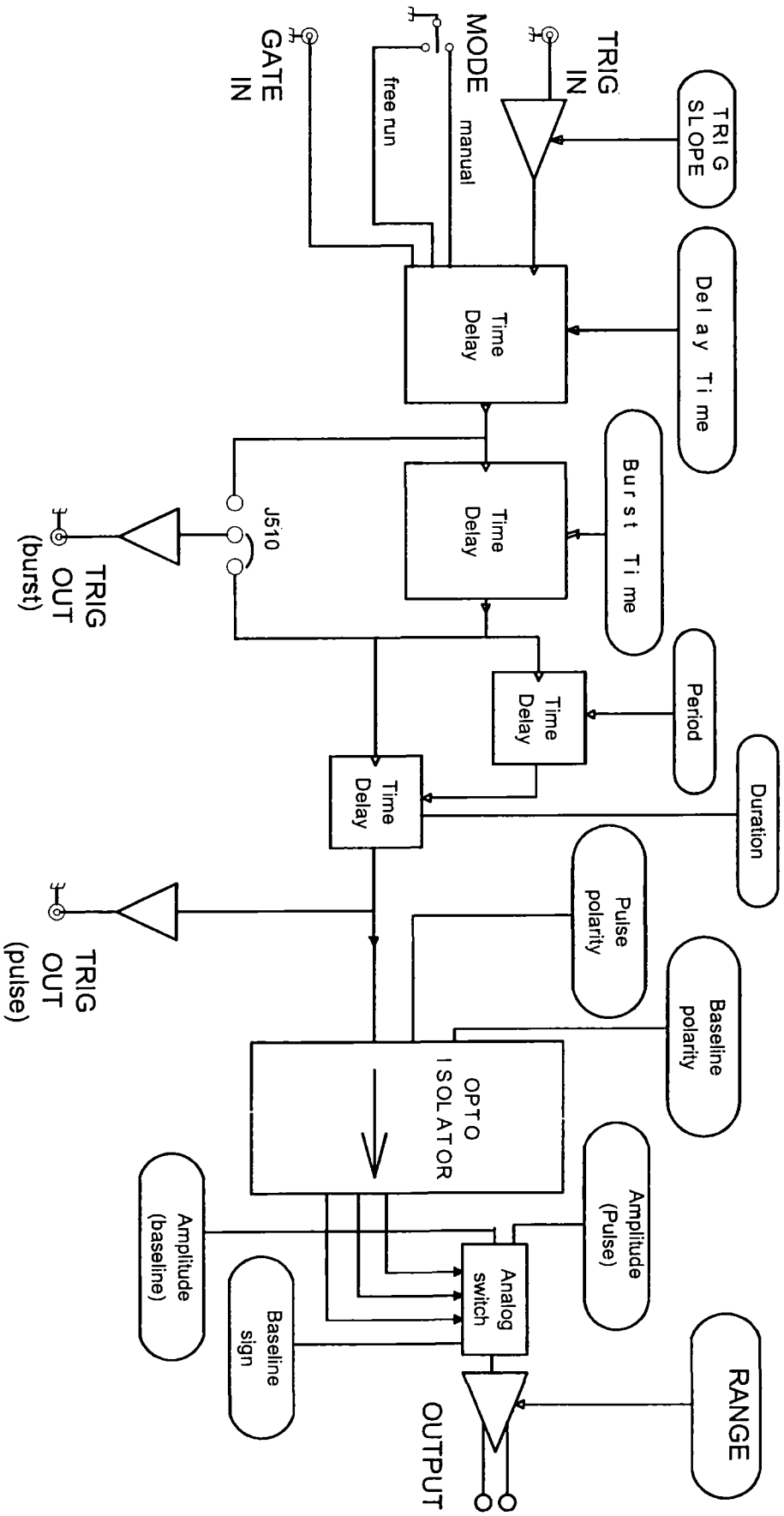
Theory of Operation

The operation of the Model 2100 is summarized in the block diagram (see the figure on Page 11). Not shown are all of the interconnections with the microcontroller. The internal microcontroler plays an important role in setting the signal path, but does not directly contribute to the dynamic characteristics. It scans the front panel switches, and sets the control values for the logic arrays. It programs the internal counters, which along with the other hardware achieve the necessary sub-microsecond speeds.

Pulse generation starts either from an input trigger signal (from Trig In), or an internally signal (Free Run mode). A Delay timer counts the 10MHz clock until its count value is exhausted. At this point, the Burst, Period, and Duration timers are started. If the Burst timer has not expired by the end of the Period, the Period and Duration timers are restarted. If the Biphasic mode has been set, the Duration timer is restarted at the end of the initial Duration, and the sign of the output pulse is reversed, doubling the total duration.

The system state (pulse on, pulse sign, baseline sign [+/0/-]) is transmitted to the isolated section via optoisolator. The baseline and pulse amplitudes are selected by an analog switch. The resulting signal is amplified by a variable-power-supply discrete operational amplifier. The amplifier connections and gain is modified to provide two voltage and three current ranges.

Timing overlap errors are detected by a logical decision computation rather than by testing for counter collisions. This provides instant feedback, rather than waiting up to an hour for such a collision to occur. Output errors are measured by sensing the output amplifier's differential input voltage. Under normal conditions, this is a negligible voltage. If the amplifier fails to deliver the requested signal the window comparator testing this voltage sends this message (via optoisolator) to the logic section, turning on a warning LED.



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Calibration Procedures

The calibration interval is the lesser of 1000 hours of operation or 6 months. Somewhat greater drift can be expected in the first 100 hours of operation as the semiconductors age. Adjustments should only be made after the instrument has been fully warmed up for at least 15 minutes.

Full instrument calibration requires the following test equipment:

digital multimeter (± 0.1%), able to measure resistance to at least 100MΩ
oscilloscope with at least 50MHz bandwidth
true-rms voltmeter with 4MHz bandwidth
universal counter (± 0.01%), able to measure single pulse widths and periods
resistors (all ± 0.1%): 2kΩ, 10kΩ 1 watt, 20kΩ, 200kΩ
alligator clip lead sets, banana plugs and BNC adapters

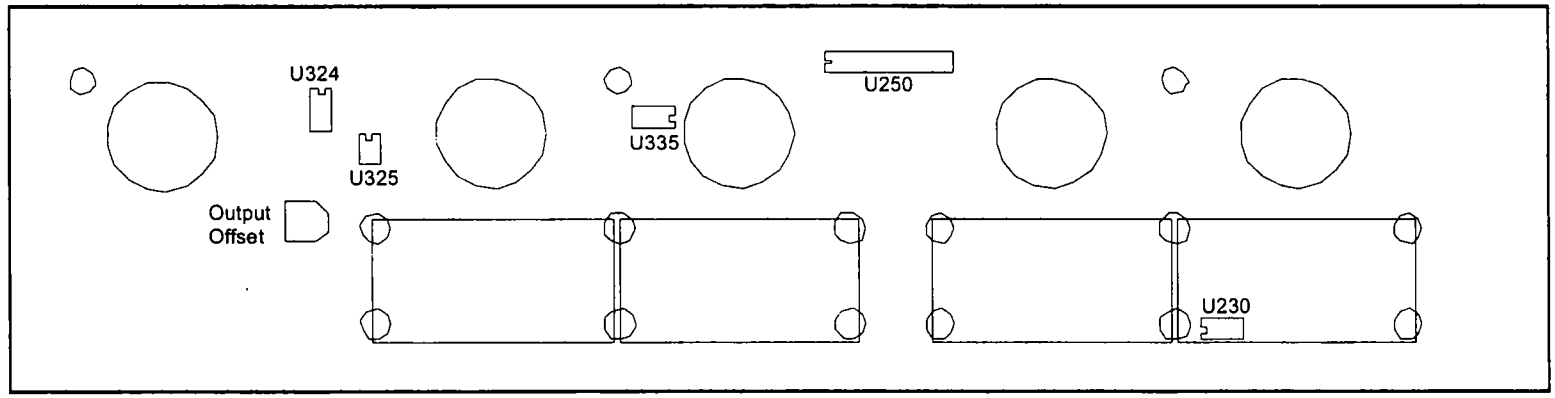
Adjustment, integrated circuit, and test point locations are shown in the following figures. All adjustments are on the timing board unless otherwise noted.

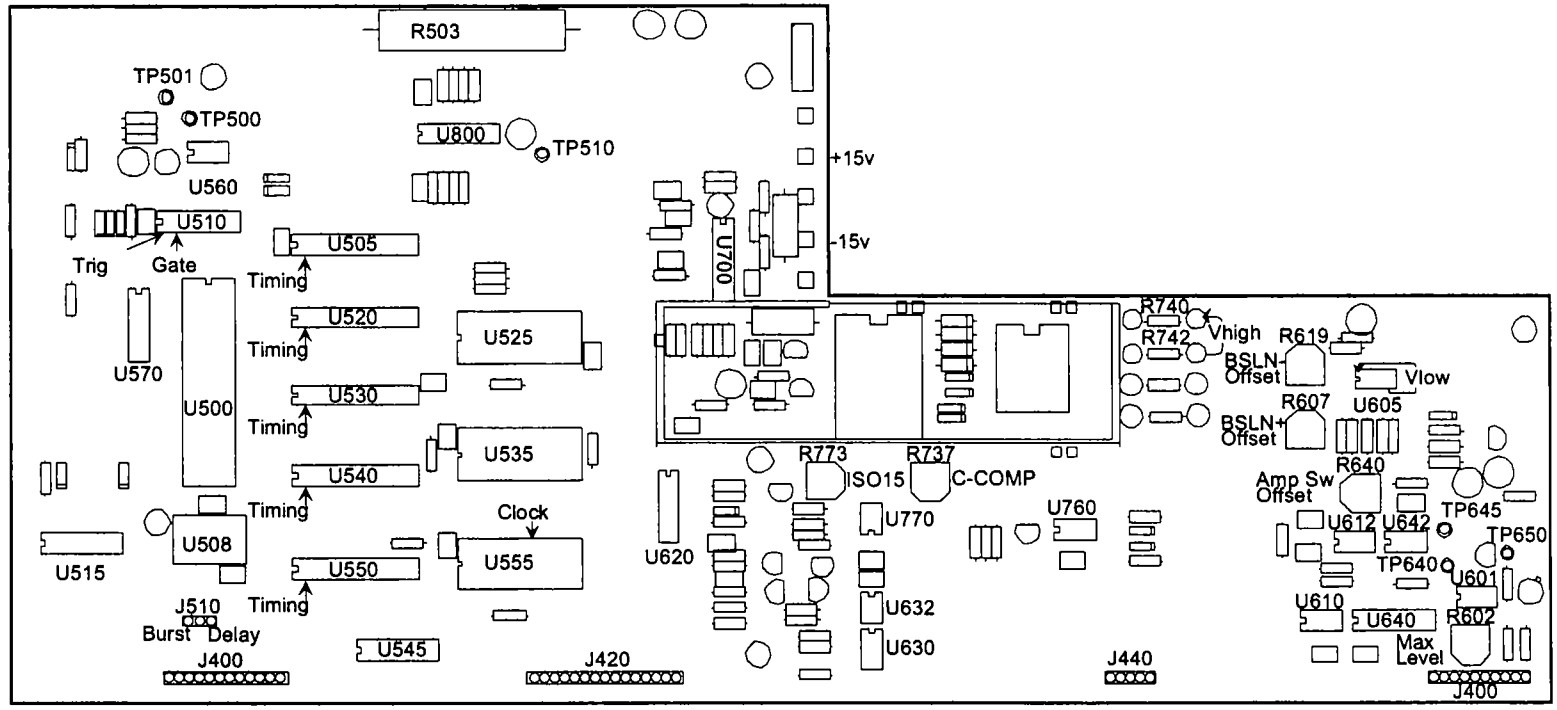
All voltages in the non-isolated section should be measured with respect to ground at TP510 unless otherwise stated. Some voltages are measured with respect to an internal "isolated ground" at TP650, or across the two output terminals. Occasionally the voltage at an IC pin must be measured; in these cases the reference designator is given, with the pin number in parentheses: e.g. U602(16). When it states within this procedure that a voltage is to be minimized, this means that the adjustment should be made such that the measured voltage is as close to zero volts as possible. Refer to the Specifications Section of this manual for acceptable tolerances.

The sequence of this procedure is important. If any adjustment is made, all adjustments which follow must be made to ensure that the specifications will be met. These procedures require that all controls remain as set in previous steps unless otherwise indicated.

WARNING

The *Model 2100* has dangerous voltages throughout the instrument, even with the power is off. Servicing the *Model 2100* should only be done by qualified service personnel. Use caution in handling any wires, connectors, or electrodes which may be directly or indirectly attached to the instrument. Do not touch exposed connections or components. Disconnect power by unplugging the power cord from the receptacle.





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Power supply and bias voltages

Power supply

Controls	Inputs / Observations	Adjust / Check
POWER: ON	Observe voltage at P703 power supply wire, top of main board	Check for +15 ± 0.50 V
	Observe voltage at P701 power supply wire, top of main board	Check for -15 ± 0.50 V
	Observe voltage at U505(24)	Check for +5 ± 0.25 V

Isolated supply voltage

Controls	Inputs / Observations	Adjust / Check
RANGE: 10 V **TRIG:** open circuit **MODE:** center position	Alternately observe V_{high} from R742 to R740, and V_{low} from the U605(4) to U605(8)	Adjust R773 so that 110 V < V_{high} < 120 V and 28 V < V_{low} < 34 V

Capacitance balance

Controls	Inputs / Observations	Adjust / Check
	Connect a x10 oscilloscope probe to TP650 and ground the	Adjust R737 for minimum high frequency signal

Inputs

Gate function

Controls	Inputs / Observations	Adjust / Check
	Apply a 1 kHz, 0 - 5 V triangle wave to **GATE** Observe voltage at U510(3) with an oscilloscope	Verify that the voltage switches states at the proper input levels

Trigger slope

Controls	Inputs / Observations	Adjust / Check
	Apply a 1 kHz, 0 - 5 V triangle wave to **TRIG** Observe voltage at U510(1) with an oscilloscope	Verify that the voltage switches states at the proper input levels
TRIG SLOPE: +		Verify voltage is 180° out of phase
TRIG SLOPE: -		Verify voltage is in phase

Trigger and gate function

Controls	Inputs / Observations	Adjust / Check
DELAY: NONE **BURSTWIDTH:** SINGLE **DURATION:** SQUARE **PERIOD:** 1.00 X 10-3	Apply a 1 kHz, 0 - 5 V triangle wave to **TRIG** Observe **TRIG'D** and **EVENT** LEDs	
TRIG: disconnect all	Short the **GATE** connector to **GND**	Verify LEDs extinguish
MODE: press to **MANUAL**		Verify LEDs flash once

Timing

System clock frequency

Controls	Inputs / Observations	Adjust / Check
	Observe the frequency of the wave at U555(17)	Verify 1.000 MHz ± 0.01%

Multipliers (Wheel Switches)

Controls	Inputs / Observations	Adjust / Check
PULSE SIGN: + **MODE:** FREE RUN **TRIG:** disconnect all **TIMING MULTIPLIERS:** all wheels set to zero except the one being tested **TIMING OVERLAP:** ignore	Observe the pulse width with the counter at the location specified below	Verify pulse width is correct for each wheel as it is tested independently

For each wheel of each **MULTIPLIER**, test each position to verify that the pulse width is correct. Observe the signal at the following locations: **DELAY:** U520(2); **BURSTWIDTH:** U530(2); **PERIOD:** U540(2); **DURATION:** U550(2)

Rates (Rotary Switches)

Controls	Inputs / Observations	Adjust / Check
TIMING MULTIPLIERS: 0.01 **TIMING RATES:** all rotary switches set to 10-4 except the one being tested	Observe the pulse width with the counter at the location specified below	Verify pulse width is correct for each rotary switch as it is tested independently

For each of the four rotary switches in **TIMING**, test each position to verify that the pulse width is correct. Observe the signal at the following locations: **DELAY:** U520(2); **BURSTWIDTH:** U530(2); **PERIOD:** U540(2); **DURATION:** U550(2)

Trigger outputs

Controls	Inputs / Observations	Adjust / Check
Range: 10V Pulse Amplitude: 5.00 Delay: 1.00 x 10^{-2} Burst: 1.00 x 10^{-2} Duration: 1.00 x 10^{-3} Period: 4.00 x 10^{-3} Pulse sign: + Trig Mode: Free run Trig in: open	Trigger the oscilloscope to the Burst Trig Out. Observe it, the Pulse Trig Out, and the isolated output.	Verify that the waveform consists of a burst of three 1ms-on/3ms-off pulses. The burst trigger should be synchronous with the burst; the pulse trigger coincident with each pulse.

Output Calibration

Isolation Resistance (check)

Controls	Inputs / Observations	Adjust / Check
Trig Mode: center position Trig In: open	Measure the resistance between ground banana jack (front panel) and black banana jack of output with DMM	Resistance read > 100MΩ

Amplitude Switch Offset (R640)

Controls	Inputs/Observations	Adjust/Check
Baseline: Zero Trig Mode: center position Trig In: Open	Measure the voltage at TP645 vs. TP650 with the DMM.	Adjust R640 (Ampl Sw Offset) for minimum voltage.

Output Offset (R332: front panel board)

Controls	Inputs/Observations	Adjust/Check
Baseline: Zero Range: 10V Trig Mode: center position Trig In: Open	Measure the voltage across the output with the DMM.	Adjust R332 (Output offset) for minimum voltage.

Positive Baseline Offset (R607)

Controls	Inputs/Observations	Adjust/Check
Baseline Sign: + Baseline Amplitude: fully CCW (0.00) Range: 10V Trig In: open Trig Mode: center position	Measure the voltage across the output with the DMM.	Adjust R602 (BSLN + offset) for minimum voltage.

Negative Baseline Offset (R619)

Controls	Inputs/Observations	Adjust/Check
Baseline Sign: - Baseline Amplitude: fully CCW (0.00) Range: 10V Trig In: open Trig Mode: center position	Measure the voltage across the output with the DMM.	Adjust R619 (BSLN + offset) for minimum voltage.

Pulse Amplitude Adjust (R602)

Controls	Inputs/Observations	Adjust/Check
Trig Mode: Free Mode Pulse Amplitude: 10.00 Timing: Delay =none; Burst =single; Duration =1.00*1; Period =0.01*10-4 Pulse Sign: - Trig In: open Range: 10V	Measure the voltage across the output with the DMM.	The Overlap indicator should be on. Adjust R602 (Max Level) for -10.00V out.

Pulse Sign Gain (check)

Controls	Inputs/Observations	Adjust/Check
Trig Mode: Free Mode Pulse Amplitude: 10.00 Timing: Delay =none; Burst =single; Duration =1.00*1s; Period =0.01*10-4s Trig In: open Range: 10V	Measure the voltage at the output with the DMM for the Pulse Sign at + and - positions	The absolute values of the voltages should differ by less than 100mV.

Baseline Amplitudes (check)

Controls	Inputs/Observations	Adjust/Check
Range: 100mA *Trig Mode*: center position *Baseline Amplitude*: fully CW (10.00) *Trig In*: open	Measure the voltage at the output with the *DMM with Baseline Sign in +, Zero, and - positions.*	Gain the matching of current levels at = and - positions; and offset current in Zero position..

Output Range Amplitude and Drive (check)

Controls	Inputs/Observations	Adjust/Check
Pulse Amplitude: 10.00 Pulse Sign: + Trig Mode: Free Run Timing: Delay =none; Burst =single; Duration =1.00*1; Period =100*10-4 Trig In: open	Load the output with a 10KV 1W 0.1% resistor. Measure the voltage at the output with DMM.	Verify that full scale output is within specification: Scale: Range: 100V 100V 10V 10V 100mA 1V 1mA 10V 10mA 100V

Pulse Sign and Short Circuit Protection (check)

Controls	Inputs/Observations	Adjust/Check
Timing: Delay =none; Burst =single: Duration =2.00*;10-4 Period =0.01*10-3 Baseline: Zero Pulse Amplitude: 2.5 Range: 10V Trig Mode: Free Run Trig In: open	Measure the voltage at the output with the oscilloscope. Check for Pulse Sign set to each of: +, -, biphasic. Watch for Error indicator when shorting the output.	Verify that pulses of approx. 2.5V amplitude (62.5V for biphasic mode) of the correct sign are produced every 10ms. Short output in biphasic mode. Output should return when opened.

Output Transient Response (check)

Controls	Inputs/Observations	Adjust/Check
Pulse Sign: + Timing: Delay =none; Burst: =single; Duration =2.00*10-4; Period =0.01*10-3 Pulse Amplitude: 2.50 Baseline: Zero Trig Mode: Free Mode Trig In: open	Connect the oscilloscope to the output with a 310 attenuator probe. Test both 10V and 100V ranges.	Verify that overshoot and risetime meet specifications.

Specifications

There are three classes of specifications. Class A specifications tested in all units, and are guaranteed. Class B specifications are inherent in the design; they are indirectly tested, and are guaranteed. Class C specifications are typical operating values which are occasionally tested-, these are typical values, given for your information but not guaranteed. The class for each specification is noted in the center column of the following sections.

Inputs		
Switching level	A	1.6 V (± 0.2 V)
Hysteresis	C	approx. 50 mV
Input equivalent circuit	C	100K Ω to +5 in parallel with no more than 35pF
Minimum duration (TTL-level signal)	C	> 50 ns.
Open circuit condition	B	defaults to high/on level
Timing and rate accuracy		
Rate selector steps	B	100µs to 100s in 7 steps
Timing multiplier steps	B	1% of rate selector step size. Maximum value is 9.99 x the rate selector step size
Resolution	B	approx. 0.1% of the maximum value
Timing error (second and later pulses after resetting controls)	B	< 0.02% of rate selector value + 0.15 µs
Timing error (first pulse after readjusting timing controls)	C	an additional 0.25 µs error may occur
Timing repeatability	C	< 0.01% setting + 20 ns (monophasic)

TRIG IN to OUTPUT delay (DELAY set to 0), output set to 2 V	C	approx. 0.5 µs for a load of no more than 10 KΩ in parallel with 50 pF
Timing jitter from TRIG IN to OUTPUT (for TTL trigger input with risetime <10 ns)	C	< 125 ns (all rates except 100s) < 1.25 µs (100s rate)
Timing jitter from TRIG OUT (either BURST or PULSE) and OUTPUT	C	Less than 20 ns (all rates)
Trigger output to pulse output delay	C	approx. 350 ns
Output characteristics		
Pulse level error (voltage mode: open circuit; current mode: short circuit	A	< 0.3% of setting + 0.5% of r range (plus an additional 0.5 µA in 100 µA range)
Biphasic level difference | V + + V- | /2	C	< 0.3% of range (voltage modes: into open circuit; current modes :into short circuit)
Baseline level error (voltage mode: open circuit; current mode: short circuit)	A	< 0.3% of setting of setting + 0.1% of range (plus an additional 0.5 µA in 100µA range)
Risetime (2.5 V out)	A	≈ 200 ns into less than 30 pF
Risetime (25 V out)	A	≈ 1.5 µs into less than 30 pF
Transient response	A	< 8% overshoot into less than 30 pF for pulse voltages different than baseline voltage by at least 10% of range
Output impedance (voltage mode)	C	≈ 50 ohms
Output impedance (current mode)	C	>>10 GΩ (typically 200 GΩ)
Isolation resistance	A	>>100 MΩ
Isolation capacitance	C	≈ 60 pF at 100 Hz

Noise (differential mode)	C	≈ 1 mV rms (10 V scale; 10 Hz - 4 MHz)
Noise (common mode: earth to isolated ground) with no signal output	C	≈ 8 mV rms (10 Hz - 4 MHz); ≈ 100 mV p-p (200 Hz - 10 MHz), measured with a 10 MΩ, 15 pF oscilloscope probe
Overload error indicator (low frequency, short circuited voltage mode)	C	Turns on for set amplitude at or greater than approx. ±1 V (10 V range); or ±2 V (100 V range)
Overload error indicator low frequency, open circuited current mode)	C	Turns on for set amplitude at or above approx. 2% of range
Overload error response time	C	Flat to approx. 30 µs duration Decreasing sensitivity for shorter pulses

Miscellaneous

Power	approx. 11 watts
Fuse	1 amp 3 AG
Operating temperature range	10 - 30° C
Storage temperature range	0 - 50° C
Operating humidity	5 - 80% RH
Dimensions	17 x 4.75 x 11.25 (inches) 43.2 x 12.1 x 28.6 cm
Weight	20 lbs (9 kg)

Warranty and Service

What does this warranty cover?

A-M Systems, Inc. warrants to the Purchaser that the Instrument, excluding cables, Headstage Probes and any other accessories shipped with the Instrument, (hereafter the "hardware") is free from defects in workmanship or material under normal use and service for the period of one (1) year. This warranty commences on the date of delivery of the hardware to the Purchaser.

What are the obligations of A-M Systems, Inc. under this warranty?

During the warranty period, A-M Systems, Inc. agrees to repair or replace, at its sole option, without charge to the Purchaser, any defective component part of the hardware. To obtain warranty service, the Purchaser must return the hardware to A-M Systems, Inc. or an authorized A-M Systems, Inc. distributor in an adequate shipping container. Any postage, shipping and insurance charges incurred in shipping the hardware to A-M Systems, Inc. must be prepaid by the Purchaser and all risk for the hardware shall remain with purchaser until such time as A-M Systems, Inc. takes receipt of the hardware. Upon receipt, A-M Systems, Inc. will promptly repair or replace the defective unit, and then return the hardware to the Purchaser, postage, shipping, and insurance prepaid. A-M Systems, Inc. may use reconditioned or like new parts or units at its sole option, when repairing any hardware. Repaired products shall carry the same amount of outstanding warranty as from original purchase, or ninety (90) days which ever is greater. Any claim under the warranty must include a dated proof of purchase of the hardware covered by this warranty. In any event, A-M Systems, Inc. liability for defective hardware is limited to repairing or replacing the hardware.

What is not covered by this warranty?

This warranty is contingent upon proper use and maintenance of the hardware by the Purchaser and does not cover batteries. Neglect, misuse whether intentional or otherwise, tampering with or altering the hardware, damage caused by accident, damage caused by unusual physical, electrical, chemical, or electromechanical stress, damage caused by failure of electrical power, or damage caused during transportation are not covered by this warranty. **Products may not be returned to A-M Systems, Inc. for service, whether under warranty or otherwise, which are contaminated by infectious agents, radioactive compounds or other materials constituting a health hazard to employees of A-M Systems, Inc.**

What are the limits of liability for A-M Systems, Inc. under this warranty?

A-M Systems, Inc. shall not be liable for loss of data, profits or savings, or any special, incidental, consequential, indirect or other similar damages arising from breach of contract, negligence, or other legal action even if the company or its agent has been advised of the possibility of such damages, or for any claim brought against you by another party. **THIS EQUIPMENT IS NOT INTENDED FOR CLINICAL MEASUREMENTS USING HUMAN SUBJECTS. A-M SYSTEMS, INC. DOES NOT ASSUME RESPONSIBILITY FOR INJURY OR DAMAGE DUE TO MISUSE OF THIS EQUIPMENT**. Jurisdictions vary with regard to the enforceability of provisions excluding or limiting liability for incidental or consequential damages. Check the provision of your local jurisdiction to find out whether the above exclusion applies to you.

This warranty allocates risks of product failure between the Purchaser and A-M Systems, Inc. A-M Systems, Inc. hardware pricing reflects this allocation of risk and the limitations of liability contained in this warranty. The warranty set forth above is in lieu of all other express warranties, whether oral or written. The agents, employees, distributors, and dealers of A-M Systems, Inc. are not authorized to make modifications to this warranty, or additional warranties binding on the company. Accordingly, additional statements such as dealer advertising or presentations, whether oral or written, do not constitute warranties by A-M Systems, Inc. and should not be relied upon. This warranty gives you specific legal rights. You may also have other rights which vary from one jurisdiction to another.