RITEC
SQUARE WAVE PULSER
MODEL SP-801A

OPERATION MANUAL

TABLE OF CONTENTS

SECTION I
INTRODUCTION

The Model SP-801A Square Wave Pulser is a source of a high power, square wave pulse that can be used to drive an ultrasonic transducer. The pulses are rectangular with a nominal maximum output voltage level of –400 volts. The output source impedance of the driving circuit is approximately 4 ohms. The rise and fall times are less than 15 nanoseconds when working into a 50 ohm load. The response of the ultrasonic transducer is normally optimized when the width of the square wave corresponds to one half the period of the resonant frequency of the transducer. Four fixed widths corresponding to 0.5 MHz, 1 MHz, 2.25 MHz and 5 MHz can be selected on the front panel. In addition to these fixed widths, the width can be controlled from approximately 25 nanoseconds to greater than 10 microseconds, by selecting one of four variable width ranges. This allows the instrument to generate half-period square wave pulses from below 50 kHz to 20 MHz. A minimum pulse width of approximately 20 nanoseconds may be obtained when a fixed 10 ohm resistive load is placed on the output. A switch-selectable 10 ohm load is available in the RDX-2 diplexer.

The repetition rate is adjustable from 10 kHz to 0.17 Hz in 20 steps with a 10, 5, 2.5, 1.7 ratio sequence. The instrument can be triggered from an external source by either a positive or a negative TTL/CMOS compatible logic. Protection has been incorporated into the external trigger circuitry so that an existing spike generator can be used to trigger the SP-801A. Up to 1W of average power can be dissipated in the protection circuitry.

The SP-801A is limited in duty cycle, calculated as the per-cent-on time or the burst width multiplied by the repetition rate, by the impedance of the transducer or the load on the output connector. For example, when driving a typical 500 kHz ceramic transducer, the maximum duty cycle will be slightly greater than 2%. If the load is reduced to 20 ohms, the maximum duty cycle will be 0.15%. With a 20-Ohm load, the peak current will be approximately 16 amperes, as the current will be determined by the sum of the external load and the output source impedance or 24 ohms in total. The peak pulse power in the load will be 5 kilowatts ($I^2R=16^2\times20$). The average power dissipated in the load will be the peak pulse power multiplied by the duty cycle or 7.5 W (5KW × 0.15%). The average current draw from the SP-801 will be approximately 24 mA. The duty cycle into 50 ohms is 0.3%. A heavier load or a higher duty cycle will result in a larger average current draw from the power supply. This will activate the internal high voltage shut down mechanism. If this occurs, the yellow overload light will be illuminated and the high voltage supply will be turned off. If such an overload occurs, the “High Voltage” switch must be turned off. The “High Voltage” switch can be turned back on after the duty cycle is decreased by either reducing the repetition rate or reducing the width of the square wave. With a 4-ohm load, the instrument can operate at a duty cycle of 0.045%.

The maximum power transfer will occur when the load impedance equals the output source impedance of 4 ohms. In this case, approximately 10 KW of peak power will be provided in each pulse. When greater amplitude is required, a broadband high power step-up transformer can be used to increase the output voltage. A square wave of 650 V can be generated in a 50-ohm load by using a 1:2 step-up transformer. A 1200 V driving signal can be generated in a high impedance piezoelectric transducer by using a 1:3 step-up transformer. Please note the bandwidth of the transformer decreases as the step-up ratio increases. Step-up transformers can be supplied for either inverting or non-inverting operation as required by the load characteristics.

The average power levels available from the SP-801A are modest. Consider the following examples: Driving a 50 Ohm resistive load at a 0.2% duty cycle, the average power dissipated in the load will be 5.6 W. Driving a 4-ohm resistive load at the 0.045% duty cycle, the average power dissipated in the load will be 4.5W.

A monitor for the high voltage output is provided on the front panel. The voltage appearing at the monitor will be 1/100th (-40 dB) of the high power output when the monitor cable is terminated in 50 ohms at the oscilloscope or digitizing card.

SECTION II
A BRIEF DESCRIPTION OF OPERATION

The SP-801A has three sections of active electronics. The first section is mounted on the rear of the front panel; it contains the repetition rate generator, which uses TTL/CMOS compatible logic, and the low-level pulse width generator. The pulse width circuitry is based on the emitter coupled logic (ECL) devices with very fast switching speeds and low transition times. The second section contains the power amplifiers and mounts inside a shielded box. The third section contains the circuitry to enable the high voltage supply. It also contains the current monitoring circuitry to turn off the high voltage supply during an overload condition.

The width of the ECL width generator is converted to a +5V TTL/CMOS compatible level and amplified before it is sent to the first stage of the power output board. On the power output board, it is applied to the gates of six N-channel pull-down metal oxide semiconductor field effect transistors (MOSFETs) and to three P-channel MOSFETs. The pull-down devices switch the output to approximately –400 volts during their on time. The actual voltage produced in an external load will be determined by the impedances of the outside load and the internal series output impedance of the instrument. This output impedance is made up of the on resistance of the MOSFETs ($R_{DS\ ON}$), a 5.6 Ohm, non-inductive series resistor in the drain of each of the six N-channel MOSFETs, and the board and wiring inductances connecting the power MOSFETs to the front panel connector. When the drive signal is removed from the pull-down transistors, it is restored to the pull-up transistors that have 10 ohms in each drain. The result is that the output impedance during the on time is approximately 4 ohms and during the off time, it is approximately 6 ohms.

All of the high voltage power supply circuitry appears on the third section printed circuit board. The low voltage supplies are provided by a linear power supply along with conventional three terminal regulators. The high voltage supply is adjustable through a front panel switch labeled "Output Amplitude" which provides eleven pre-set positions to reduce the supply voltage from approximately 430V (which yields a –400V pulse into 50 ohms) to 43V in 2 dB steps. A neon high voltage indicator is mounted on this board as a reminder of the high voltage hazard when servicing the instrument. The limiting of the average current of the high power output occurs by sensing the average current in the 425V high voltage supply. If the total current, (output current plus internal consumption) exceeds 60 mA, a shutdown circuit is activated which turns off the pulse width generator.

SECTION III
SPECIFICATIONS

Pulser

Pulse Amplitude ....-400V to –40V in 2 dB steps
Output Impedance .... approximately 4 ohms resistive during the burst (on-time)
.... approximately 6 ohms resistive during the off time.
Output Duty Cycle .... 0.3% into a 50 Ohm load
.... 0.045% into a 4 Ohm load
Fixed Transducer Frequencies............... Pulse width optimized for 0.5 MHz, 1 MHz, 2.25 MHz and 5 MHz
Adjustable Frequency operation..
.... Pulse width is adjustable over 4 ranges from less than 25 ns to greater than 12 µs.
.... See calibration data for pulse width control for Ranges A, B, C and D.
Output Pulse Rise Time.. approximately 9 ns into 50 ohms
Output Pulse Fall Time .... approximately 9 ns into 50 ohms
Repetition rate ....0.17 Hz to 10 kHz in 20 steps in a 0.17, 2, 5, 10 sequence
Outputs on Front panel.. High Power Output
....Output Monitor (-40 dB when terminated into 50 ohms)
....Trigger output; a positive 4 V, 75 ns pulse into 50 ohms.
External Trigger Input ....positive or negative TTL pulse
.... Or high voltage spike of either polarity with average power of less than 1 W.
.... Input impedance of External Trigger Input is approximately 500 ohms.

Cabinet

Cabinet Style ....Bench-top
Dimensions .... 18.5" (47 cm) side, 4" (10.16 cm) high, 10.5" (26.67cm) deep
Shipping Weight .... Approximately 21 pounds (10 kg)

Power Supply

AC Line Fuse .... Bussman MDL-1 1A 250V fuse for operation at 100-120VAC
.... Bussman MDL-0.5 0.5A 250V fuse for operation at 220-240VAC
AC Power Requirements .... 100, 120, 220, or 240 Volts RMS, 50-60 Hz, ~30 VA
....Voltage selectable on power entry module

Specifications are subject to change without notice.

SECTION IV
PLACING THE UNIT IN OPERATION

Using the SP-801A square wave pulser in an ultrasonic system is, in general, quite straight forward. However, several pre-cautions should first be noted relating to the transducer to be used with the SP-801A:

1. Conventional ceramic transducers with internal tuning (impedance matching) elements, in general, will not tolerate the voltage and/or the power available from the SP-801A output. The item that typically fails is the inductor. The failure mechanism is apparently due to overheating and/or possible due to voltage breakdown to the metal housing. Many suppliers will provide their transducers for operation at high voltages/high powers without the built in tuning inductor. It is suggested therefore to set the “Output Level” to the minimum value (-20 dB) when setting up the system for the first time or with a new transducer.

2. Modest heat can be generated internally with conventionally housed ceramic transducers if the SP-801A is operated at its maximum available output power. Cooling the transducer may then be required.

The following steps may be used to initially place the instrument into operation:

1. Connect the unit to a proper source of AC power. The unit can be set for 100, 120, 220 and 240 VAC, 50 to 60 Hz. The input voltages can be changed by changing the setting on the power entry module located on the rear of the instrument. Conventional three-wire, with one line hot, one line neutral and one line ground is required. The instrument is normally set to the voltage that is typically available in the area to which it has been shipped, based upon the best knowledge we have available. If the local line voltage is not consistent with the setting shown on the power entry module, the proper line voltage may be selected by changing the setting on the power entry module.

2. Connect the “Trigger Output” from the SP-801A to the “Trigger Input” on the oscilloscope using a BNC cable. Set the trigger select switch on the SP-801A to “Internal.”

3. Set the “Repetition Rate” switch to “1 kHz.”

If a 1 MHz transducer is to be used, the instrument may be adjusted as follows:

4. Set the “Transducer Operating Frequency” control at 1 MHz. The actual pulse width will be approximately 500 ns. If finer tuning is required, set the switch to the B tuning range and adjust the ten-turn “variable” control. The A, B, C and D ranges along with the variable control permit the width to be precisely set for the maximum response in the echo field using a given transducer. If a different frequency transducer is to be used, an appropriate change in the pulse width to make it equal to approximately one-half the period of the new transducer will be required. Typically, it has been found experimentally that tuning to slightly wider pulse widths (corresponding to slightly lower frequencies than the nominal setting for the transducer) provides the maximum response. The response on the transducer to adjustments of the “Repetition Rate” and the “Transducer Operating Frequency” controls may be observed by monitoring the output of the “Output Monitor” into a 50 Ohm input on the oscilloscope, setting the “Output Amplitude” to “-20 dB,” and turning on the “High Voltage” switch.

Before actually driving a transducer, it is suggested that the high power output pulse be examined by following the next steps:

5. Connect a non-inductive 50-ohm load such as the RITEC RT-50 termination, to the “Pulse Output” connector. This load should have a power rating of at least 10 watts if the unit is to be operated at the maximum output level and duty cycle.
6. Connect a BNC cable from the “Output Monitor” to a 50-ohm input on the oscilloscope.
7. Set the “Output Level” control to “-20 dB” and then turn on the “High Voltage” switch. A 400mV replica (corresponding to the 1:100 division of the output pulse amplitude) will be displayed on the oscilloscope as in Step 4 above. The various controls may now be adjusted and their affects on the output pulse may be observed.
8. The current limit function may be checked by setting the repetition rate to “1 kHz” and the variable frequency control to a width of 3 microseconds. If the “Output Level” control is now set to “-2dB,” a nearly 4 V signal should be observed at the “Monitor” connector. Increasing the output to the maximum level should still allow the instrument to function, but the current overload circuitry will be on the edge of shutdown. If the

width is then slowly increased, the output will suddenly disappear and the "Shutdown" light will illuminate. Normal operation can be re-established by turning off the "High Voltage" switch briefly (until the amber "Shutdown" light is extinguished), reducing the pulse width back to approximately 180 ns and again enabling the high voltage supply by switching the "High Voltage" switch to the on position. It should be noted that the average power delivered to the 50-ohm load under these maximum duty cycle conditions is nearly 10 watts.

After successfully driving the 50 ohm resistor as a dummy load and reviewing the action of the various controls, it is appropriate to consider some of the requirements for driving a transducer in actual experiments as opposed to demonstration techniques. Cabling from the instrument is generally carried out in a conventional manner when doing through-transmission or "Pitch-Catch" operation where two transducers are used, one for transmitting and one for receiving. "Pulse-echo" operation with a single transducer requires some careful attention to external coupling techniques to take advantage of the very low output impedance of the SP-801A in the off condition.

Two possible arrangements appear below in Figures 4A and 4B.

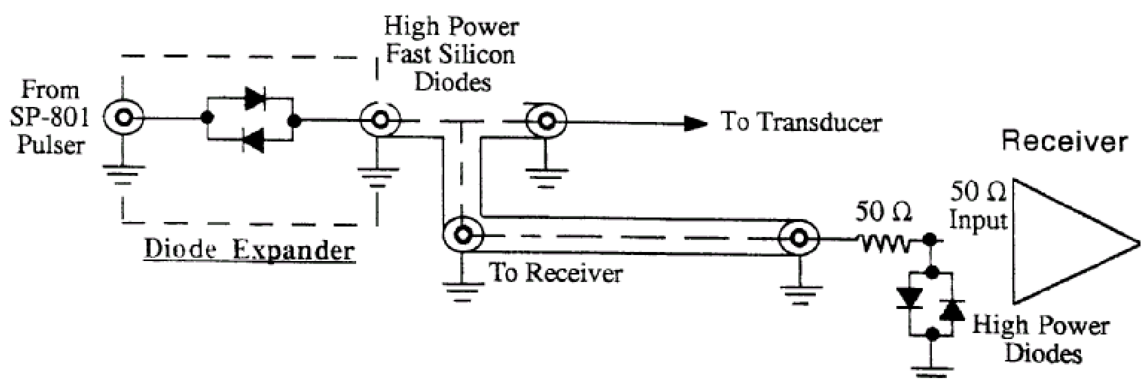

Figure 4A

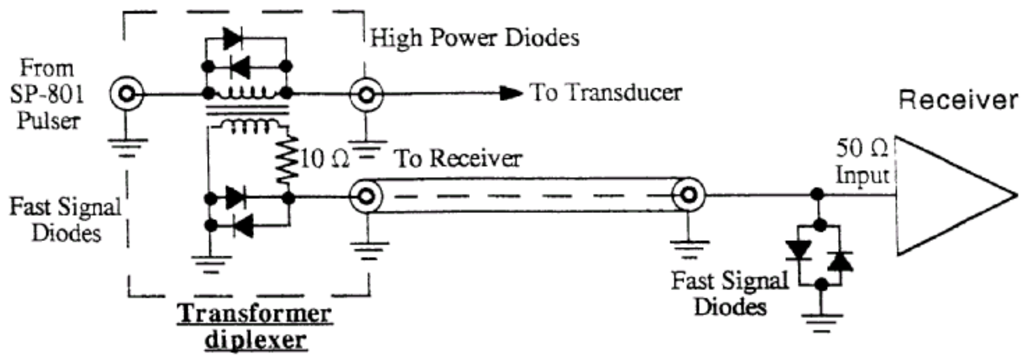

Figure 4B

In the first arrangement, Figure 4A, the high power pulse passes through the bottom series diode of the diode expander and is applied to the transducer and the protected input of the receiver. This technique works fairly well for receiving signals back from the transducer because the output impedance of the SP-801A is effectively raised to a very high level for signals below the conduction threshold of the diodes. The technique is not efficient, however, from either a driving power point of view or a received point of view. Much of the transmitted power is coupled to the receiver where it is absorbed by a resistor of approximately 50 ohms. If the SP-801A is operating at a high duty cycle, this limiting resistor could be dissipating approximately 10 watts. It is also necessary, of course, that the diodes to ground be able to handle the high peak currents. In addition, the return signal undergoes a 6 dB loss if the input impedance of the receiver is 50 ohms. This is a direct degradation in the signal-to-noise performance of the receiving system.

In the second arrangement, Figure 4B, the high power pulse again passes through the bottom diode of the “diode expander” in parallel with the transformer diplexer. The diode is in parallel with the primary winding of the broadband transformer. This is the arrangement in the RDX-2 diplexer. Almost all of the available power is transferred to the transducer because only a very small voltage, corresponding to the threshold voltage of one diode junction (approximately 0.7V), is induced into the secondary winding of the transformer. A small resistor is in series to the “Out to Receiver” connector so that small signal diodes may clip any residual spikes coupled across the transformer so that they will not be coupled to the delicate input of a low noise receiver or pre-amplifier. Returned signals from the transducer are developed across the top winding of the transformer because they are typically much smaller than the diode threshold voltage. In addition the very low output impedance of the SP-801A, in the region of 6 ohms during the “off” time, results in nearly all the returned signal being coupled to the receiver (via the secondary winding of the transformer) with only a very small loss. No degradation in the signal to noise ratio will take place. The 10 ohm load of the RDX-2 can be switched into the circuit when operating at higher frequencies to maintain the pulse fidelity. Because of reflections from the 10 ohm load in the 50 ohm cable, the RDX-2 should be placed as close to the SP-801A with as short as cable as possible, (preferably a male-to-male BNC adapter, if possible).

If signals larger than 1 V peak to peak are to be received from the test piece, the output level of the SP-801A should be reduced until the level of the returned signal to be examined is less than 1 V peak to peak.

Because of the very low output impedance of the SP-801A, a 1:2 or 1:3 step-up transformer may be used to drive many types of loads if their impedances are in the region of 50 ohms or greater. An example of a 1:2 step up transformer is shown along with the diplexer in Figure 4C.

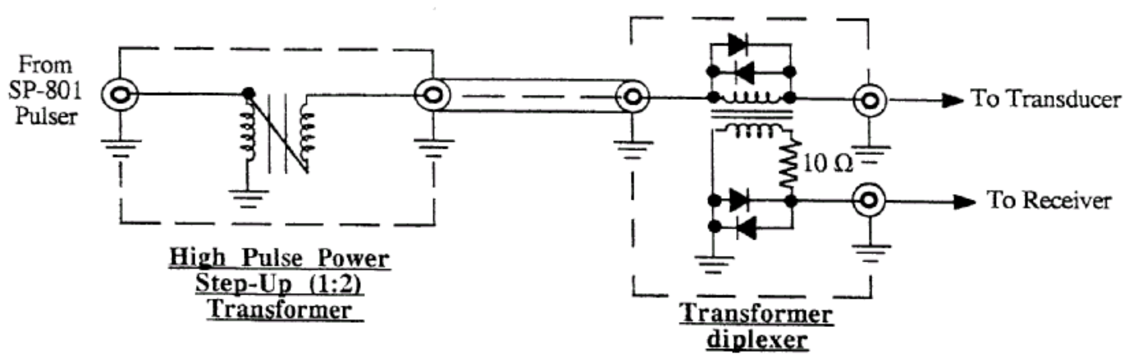

Figure 4C

If a load significantly different than 50 ohms is to be driven in a remote location, a 1:2 step up transformer should be installed at the “Pulse Output” of the SP-801A.   This will allow a long 50 ohm coaxial cable to be used. A second impedance matching device should be installed at the remote location to convert from the 50 ohm cable to the load impedance. A transformer diplexer may also be used, preferably at the load end of the cable with a receiver pre-amplifier at the same location. If a 50 ohm load is placed on the output of a 1:2 step up transformer driven by the output of the SP-801A, approximately 725V will be present on the load; if a 1:3 transformer is used, approximately 825 V peak will be on the load. If a high impedance load is placed on the output of a 1:2 step up transformer driven by the output of the SP-801A, approximately 830 V will be present on the load; if a 1:3 transformer is used, approximately 1300 V peak will be on the load.

All the foregoing material has been presented to aid in understanding how to take advantage of the high pulse power available from the SP-801 and to assist in preventing damage to receivers, pre-amplifiers and/or delicate transducers. If questions arise concerning various matching techniques and signal transfer techniques, further information can be found on the RITEC web site under the applications section or can be obtained by contacting factory personnel.

The next step in the set-up procedure is to actually drive a transducer. If the “through transmission” or “Pitch-Catch” arrangement is to be used, the transducer can be coupled directly to the “Pulse Output” of the SP-801A. If the “pulse-echo” arrangement is to be used, either a diode expander or a transformer diplexer should be used as explained above. After obtaining return signals from the material being examined, the “Transducer Operating Frequency” controls may be used to optimize the return signals.

APPENDIX C
CHANGING POWER ENTRY MODULE VOLTAGE SETTING

The correct power line voltage should be supplied to the AC power entry module that is mounted on the rear of the unit. Different line voltages can be accepted by properly setting a small circuit board mounted in the module. Access to this board is provided by removing the plastic cover plate on the module by gently prying out one edge with a small screwdriver. (Access to the power line fuse is achieved in this same manner.) A small projection on the card protrudes through one of the four holes on the cover plate to indicate at which line voltage the unit has been set. If the unit has been previously operated at a different line voltage, the board should be removed and carefully re-set so that the projection appears through the correct hole to match the available line voltage.

For 90Volts to 109Volts use the 100 Volts setting on the Power entry module.
For 110Volts to 125Volts use the 120 Volts setting on the Power entry module.
For 215Volts to 224Volts use the 230 Volts setting on the Power entry module
For 225Volts to 245Volts use the 240 Volts setting on the Power entry module

Remove the power selector card, and move the white plastic indicator so that the arrow for the desired voltage will be pointing into the power entry module. For example, the setting for 120V is shown below:

The left hand side of the board (with the 120 and the arrow pointing to the left) would be inserted into the power entry module. To set the voltage for 230V, the indicator would be moved so that the indicator stub is pointing up and the rounded end is pointing forward the 230V with the arrow.

APPENDIX W

WARRANTY

All RITEC instruments are warranted against defects in material and workmanship for a period of one year after date of shipment. RITEC agrees to repair or replace any assembly or component found to be defective under normal use during this period. RITEC's obligation under this warranty is limited solely to repairing any such instrument, which in RITEC's sole opinion, proves to be defective within the scope of the warranty when returned to the factory. Transportation to the factory is to be prepaid by the purchaser. Shipment should not be made without prior authorization by RITEC.

This warranty does not apply to any products repaired or altered by persons not authorized by RITEC, or not in accordance with instructions furnished by RITEC. If the instrument is defective as a result of misuse, improper repair, or abnormal conditions or operations, repairs will be billed at cost.

RITEC assumes no responsibility for its product being used in a hazardous or dangerous manner either alone or in conjunction with other equipment. High voltage used in some instruments may be dangerous if misused. Special disclaimers apply to these instruments. RITEC assumes no liability for secondary charges or consequential damages and, in any event, RITEC's liability for breach of warranty under any contract or otherwise shall not exceed the purchase price of the specific instrument shipped and against which a claim is made.
Any recommendations made by RITEC for use of its products are based upon tests believed to be reliable, but RITEC makes no warranty of the results to be obtained. This warranty is in lieu of all other warranties, expressed or implied, and no representative or person is authorized to represent or assume for RITEC any liability in connection with the sale of our products other than set forth herein.