

BEHLKE

HIGH-TECH IN HIGH VOLTAGE

FSWP HIGH-VOLTAGE PUSH-PULL PULSER

Models FSWP 51-02, FSWP 71-02 and FSWP 91-01



INSTRUCTION MANUAL

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1. Introduction

The FSWP model pulsers are universal electronic high-voltage switching devices for capacitive and resistive loads. In conjunction with an external high-voltage supply and a suitable control signal source, high-voltage square-wave pulses can be produced. The FSWP pulsers are variable on-time devices where the output pulse width is controlled by the pulse width of the control input. Because of the push-pull principle, the connected load capacitance can be charged as fast as discharged. In standard configuration, the output is positive-only however the FSWP can be ordered with an optional negative output or in a floating output configuration. Note that once manufactured with a certain polarity at the factory, the polarity of the output cannot be changed. The rise time of the pulses depends essentially on the load capacitance/parasitic capacitance of the load element connected.

2. Construction and Mode of Operation

The FSWP pulser contains high-voltage push-pull switching elements and associated driver electronics. In addition, there are internal pulse-shaping elements that are meant to produce a clean square-wave output into a small capacitive load.

The high-voltage switching module is made up of two electronic switches operating in a push-pull principle (half-bridge). The switches are formed by series-connected power MOSFETs (metal oxide semiconductor field-effect transistors) which are triggered synchronously by a galvanically isolating driver control. Grounding of one end of the push-pull arrangement is done internally (unless the unit is ordered in a floating configuration). To match the impedance and to protect the switches, series resistors are built in. Internal ceramic capacitors ensure adequate buffering of the external high voltage supply. In standard configuration, the transistors are liquid cooled however the FSWP can be ordered without liquid cooling albeit at a much reduced power rating. The control circuit guarantees the precise timing of the switches and also monitors their temperature and rate of repetition. For this purpose, a thermo trigger with a 75°C threshold is incorporated into the switch module. Overheating and too high of a frequency will result in the switch being turned off.

3. Operation

3.1. External Auxiliary Power Supply Inputs

It will be necessary to provide external auxiliary power supplies in order for the unit to operate. The following is a list of the external auxiliary power supplies needed:

External auxiliary +5VDC power supply*
External auxiliary +15VDC power supply (option HFS)
External auxiliary +120VDC power supply (option HFS)

3.2. Control Input

The control input (trigger input) has an input impedance of 100 Ohms and a threshold voltage of about 2 Volts. An input of up to 6 Volts is allowed continuously and an input of up to 10 Volts for a short time however an input of 5 Volts should be considered optimum in the interest of low output jitter. The control signal is internally processed in a way that prevents inadequate control pulses from negatively affecting the pulser output pulses. ***Neither the output pulse rise time nor the output amplitude can be influenced by the control input.***

3.3. Power and Control Pin Assignments

The control and power inputs are on the front of the pulsers and are connected using two LEMO shielded connectors. FSWP units ordered without option HFS will only have one LEMO connector. The pin assignments are:

LEMO 1: 4-Pole

Pin 1: Control Input (trigger); TTL-level signal 3 to 10V positive with respect to ground.

Pin 2: INHIBIT input; +5V/open input = pulser operation, 0V/grounding this pin = pulser operation inhibited

Pin 3: Fault Output; TTL-level status output. High = No Faults, Low = Fault

Pin 4: +5 VDC auxiliary power supply input* $\pm 5\%$ (power supply current should be limited to 0.6 A).

Shield: Ground

*Note: With Option HFS, if the two HFS auxiliary power supplies are connected then the 5 VDC supply is unnecessary.

LEMO 2: 3-Pole (Option HFS only)

Pin 1: + 15 VDC $\pm 3\%$, auxiliary power supply input, current requirement: 0.4 mA/kHz

Pin 2: +120 VDC $\pm 3\%$, auxiliary power supply input, current requirement: 0.2 mA/kHz

Pin 3: Ground

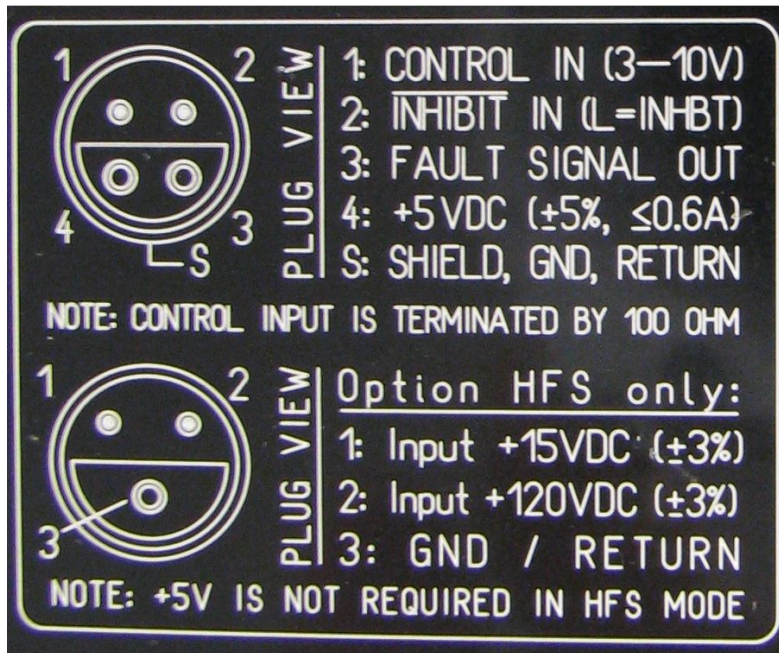


Figure 1: Control Connection Information Printed on FSWP Label

The note “Plug View” indicates that the diagram printed on the label refers to the orientation as one looks into the face of the mating plug connector and not the bulkhead connector on the pulser.

In the interest of good noise immunity, the ground of the control side should be connected with a low-inductance wire to the ground of the high-voltage side using the M3-threaded ground boss on the front of the pulser. This should be done with a very short wire. Failure to do this may cause the control circuit to float dangerously high when the output is pulsed, particularly in high di/dt conditions. Never rely on the control input connector only as a suitable low-impedance ground. It is advisable to use this connection as a star-type earth point for all high-voltage connections

3.4. Pulse Monitor Output

The purpose of the pulse monitor output is to check the high voltage ramp at the output. By means of a special coaxial cable, which is supplied with the unit, the monitor output is connected to the high-impedance input of an oscilloscope. The monitor output is provided by an internal capacitive coupling circuit. The amplitude of the monitor output will depend on the capacitance of the monitoring device, therefore the monitor output can never be used to determine the actual pulse output amplitude. Likewise, due to droop, the monitor output cannot be used for DC output signals or signals with long pulse durations. The monitor output may have a rise time slower than that of the actual output pulse, particularly if connected to a low-capacitance load. If there is any doubt about the output amplitude or wave shape it is recommended that a special high voltage probe be used such as the Tektronix P6015A.

3.5. LED Indicators

There are three LED indicators visible from the top of the pulser. A green LED indicates that the unit is properly powered and no fault exists. If one of three fault conditions exist; (a) Temperature is greater than 75°C, (b) Vaux (pin 4) is less than 4.75V, and (c) switching frequency is too high, then the green LED will extinguish and the red LED will light up. A fault will also correspond with the fault output signal (pin 3) going low. If properly triggered, the yellow LED will illuminate. An internal timing circuit allows the yellow LED to “blink” for a pre-determined amount of time to ensure that very short pulse width trigger inputs are indicated. Because of this, the yellow LED may not blink at the actual pulse frequency, particularly at very high repetition rates.

3.6. High Voltage Input Connection

The FSWP pulser does not contain an internal high-voltage source. An external high-voltage power supply is needed, the polarity of which matches that of the pulser. The high voltage input to the FSWP pulser is via a SHV coaxial connector located on the front panel. The mating plug is included with the pulser. Regarding the choice of coax cable, there are a lot of inferior-quality coax available that are not suitable for high voltage operation. Use only cables that have a “solid PE” insulation. RG-59/BU has a slightly higher insulation thickness which will add to the voltage ratings over RG-58 however another option would be to choose a manufacturer of specialty high voltage cable such as Teledyne Reynolds part number 167-9785 which is dimensionally similar to RG-58 and RG-59 but has a voltage standoff rating of 40kV.



Figure 2: Front control, high-voltage, and coolant connections.

3.7. High Voltage Output Connections

The high-voltage output connections are via M3 threaded bosses located on the rear of the pulser.



Figure 3: High-Voltage Output Connections

The actual ground output is on the bottom of the pulser. A grounding bar, provided with the unit, brings this connection out to the rear of the pulser. Note that this grounding bar is removable and that the unit will not mount on a flat surface with it in place however if the grounding bar is removed, the HV ground output cannot remain unconnected.



Figure 4: Grounding Bar Location and Connection

The maximum operating voltage allowed must on no account be exceeded. When using laboratory power supplies capable of higher output voltages, it is advisable to limit the input power supply voltage such as

by the mechanical lock on the voltage adjust knob and/or by the use of series/parallel connection of varistors or zener diodes.

Both capacitive and resistive loads may be connected. In the case of resistive loading, care must be taken that the continuous current allowed is not exceeded. Inductive loads may be connected only when, as a result of suitable clamping measures, there is no danger of a change in the direction of the current flow. Internal parasitic diodes associated with MOSFET devices will allow reverse current flow however these intrinsic diodes have poor recovery time characteristics so current reversals may cause damage to the pulser. For the same reason it is imperative to minimize the stray inductances of the load circuit, which in combination with the load capacitance, can produce strong oscillations at the pulse edges. This so-called "ringing" should be avoided as far as possible. To minimize unwanted ringing due to stray inductances, the cable connections from these high-voltage output points to the load should be kept as short as possible. If ringing due to stray inductances cannot be controlled using good wiring techniques, then additional series resistance is advised for damping purposes.

The maximum permitted load capacitive depends on the operating voltage and switching frequency. The FSWP is rated for a maximum continuous power dissipation of 200W with option ILC and 1500W with option DLC. It must be noted that the 3 MHz rating of the pulser pertains to the rating of the driver electronics using option DLC. *This does not mean that the pulser can be operated up to 3 MHz under all output voltage and load conditions.* A considerable threat for switch failure is due to overheating of the internal components due to switching and ohmic losses. There are two categories of losses to consider; charge/discharge switching losses and ohmic losses. The two combined must be taken into account to prevent overheating.

3.7.1. Switching Losses

For every switching cycle the energy in both the switch capacitance and the load capacitance must be charged and discharged. This energy transfer must be considered as power losses in the switch. The formula for this calculation is:

$$P_{sw} = C_{total} * V^2 * freq.$$

The total capacitance is the sum of the load capacitance, the stray capacitance, and the capacitance of the switch. It is worth noting that since the switching power dissipation is a function of the square of the voltage, optional cooling must be considered as the voltage increases.

3.7.2. Ohmic Losses

For resistive loads, the internal switch heating is a function of the internal peak power and the system duty cycle. Peak power losses can be calculated according to the formula:

$$P_{peak} = i^2 * R_{stat}$$

Duty cycle can be calculated according to the formula:

$$Duty\ Cycle = pulse\ width / pulse\ period$$

The basic formula for considering average ohmic losses is:

$$P_{R-avg} = P_{peak} * duty\ cycle$$

3.7.3. Total Switch Losses

For total switch losses, both switching and ohmic losses are summed together:

$$P_{total} = P_{sw} + P_{R-avg}$$

3.7.4. Coolant Connections

For FSWP pulsers with options DLC (direct liquid cooling) and ILC (indirect liquid cooling), there are two coolant fittings located on the front of the unit. The tubing connected to these fittings must have an inner diameter of 8 mm (0.32"). There are two sizes of cap nuts which are provided. The nuts with the smaller hole are for tubing with 1 mm (0.04") wall thickness and the nuts with bigger hole are for tubing with 1.5 mm (0.06") wall thickness. Any flexible or semi rigid plastic tubing can be used.

Note that the input and output fittings are labeled accordingly and these two should never be swapped or overheating may result. The input coolant pressure should be limited to 1bar/14psi max and the output temperature should not exceed 55°C/131°F. If this maximum output coolant temperature is exceeded then the switch is being operated under conditions with excessive internal power dissipation.

It is important to note that pulsers with option DLC cannot be cooled with any form of water. A dielectric fluid such as Galden HT-135 must be used or damage to the unit may result. Water may be used with option ILC. Detailed instructions on the use of the optional external PU-2 pump can be found on our website at: http://www.behlke.com/pdf/pu-2_instructions.pdf. Note also that a DLC-equipped pulser cannot be operated "dry". The dielectric fluid acts as an insulator for the internal electronics!

4. Guarantee

We guarantee impeccable quality of our devices in line with the current state of technology. The guarantee lasts for five years beginning with the date of delivery. Guarantee claims must be lodged within the above time span either with us or with an authorized representative office and be accompanied by the invoice or delivery note. Within the guarantee period, we undertake to rectify free of charge any defects which can be proved to result from material or construction faults. Damage resulting from improper use is not covered by the guarantee. In particular, we accept no responsibility for devices damaged by overvoltage, thermal overload, or short circuits. The guarantee period is neither extended nor renewed as a result of repairs carried out during this time. A claim for transformation or decrement is not included unless we are unable to rectify the fault. Wider claims for damage are not created by virtue of these conditions of guarantee.

WARNINGS

- Do not exceed the maximum operating voltage and the maximum peak current.
- Stay within the thermal limits of the switch.
- Avoid short circuits and sparkovers.
- Use high-voltage rated external components only.
- Avoid self-induced overvoltage spikes.
- Do not connect unclamped inductive loads.
- Do not apply high voltage to the output leads with the input control connector(s) and ground connection unterminated.
- Adequate clearance should be given to any electrical component at high-voltage potential to ground. As a rule of thumb, a clearance distance of 10 kV/inch (4 kV/cm) should be used.
- Water of any kind should never be used as a coolant for switches with the direct liquid cooling (DLC) option. A dielectric fluid such as Galden HT-135 should be used.
- For electrical connection of the control inputs, the information printed on the switch label should be considered the most accurate and will supersede any other information such as that contained in the datasheet or this document.
- Read all information and warnings printed on the switch label.

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