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Model-10 Precision Delay Trigger Generator

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by

A. T. Brousseau

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MODEL-10 PRECISION DELAY TRIGGER GENERATOR

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A. T. Brousseau

ABSTRACT

This report describes the Model-10 Precision Delay Trigger Generator, which, together with its precursor models, has been used extensively throughout the Los Alamos Sherwood Project for the last ten years. The intent is to provide the user with an operating instruction manual.

I. INTRODUCTION

In the early days of plasma physics instrumentation, triggering requirements were less stringent than at present. Early instrumentation requirements were adequately met by the Los Alamos Scientific Laboratory Model-106 series of delay generators, but the increasing complexity of plasma devices led to development of the Model-10 system described here. This second-generation system had to meet certain minimum performance criteria and provide greater application flexibility, increased number of trigger channels, ease of operation, and improved reliability of circuit functions. The hostile electrical noise environment of pulsed plasma devices requires unique circuit design, particularly where solid-state devices are involved. It is essential that precautions be taken to guard the delay system against external electrical influences, and at the same time prevent the generation of spurious electrical noise in the delay generator itself which could be detrimental to sensitive diagnostic instruments.

II. GENERAL INSTRUMENT DESCRIPTION

The Model-10 trigger delay generator provides six independent delay channels, including a prompt trigger section, all of which provide a negative 30-V, low-impedance current pulse at each output. Time delay in each channel is variable from 1 μ sec

to 10 msec. The generator drives energetic 5- and 10-kV multichannel pulsers. The proximity of the generator to these high-voltage sources and the associated interchassis cabling determined the design of the generator's output circuitry. Mass production and system reliability at low cost is provided by a minimum use of solid-state devices, NIMS-type modular packages, and printed circuit wiring on single-sided boards.

The instrument consists of seven plug-in type modules, all removable at the front panel as shown in Fig. 1. Two basic types of modules (A and B) are required for a complete system. One type A module is required per chassis and functions as the prompt trigger and reset generator section. Type B modules are the individual time-delay generating sections, and six are required per chassis. The rear chassis apron of the instrument (Figs. 2 and 3) is hinge-mounted and supports all output trigger connectors and regulated power supplies. The hinged apron allows easy access for maintenance. To minimize external radiation of noise pulses that might interfere with other diagnostic cabling, all output trigger sources emanating from the Model-10 system are maintained at a low voltage level. Negative low-impedance current triggers of -30-V amplitude are provided at all output BNC connectors (Fig. 2). Figure 4 is a block diagram of the interconnections

Fig. 1. Front view of Model-10 Precision Delay Trigger Generator.

between the type A and B modules.

III. FUNCTIONAL DESCRIPTION

A. Type A Module (Prompt Trigger and Reset Generator Section).

The type A module is constructed on an anodized aluminum panel, $2 \times 8\frac{3}{4}$ in., supporting a printed circuit board which terminates in a 22-pin, card-edge configuration (Fig. 1). The front panel operating and functional controls are: (1) master power switch and indicator, (2) external input trigger connector (BNC), (3) manual trigger switch, (4) automatic-manual output reset switch, and (5) manual confirmation reset switch.

The type A prompt trigger module may be

Fig. 2. Rear view of Model-10 Precision Delay Trigger Generator.

Fig. 3. Rear view of Model-10 Precision Delay Trigger Generator with rear apron lowered.

actuated manually or by applying a positive 10-V pulse. The shape and duration of the input external trigger pulse are not critical for proper triggering of the unit. The circuit diagram (Fig. 5) shows that an input attenuator (R-1 and the 1-K) resistor has been designed into the unit; this attenuator may be fixed to meet specific needs.

A positive trigger pulse to Q-1 (Fig. 5) turns on this high-speed silicon-controlled switch to provide six isolated prompt triggers routed to the time-delay type B module (to channels of Fig. 4). Simultaneously, a trigger pulse from Q-1 initiates a second high-speed switch Q-2, whose main function is to provide a capacitive-discharge, high-current, low-voltage trigger into a low-impedance load (~30-V output pulse) through the rear output connector T_0 . (This primary trigger is termed the prompt triggering source.) Transistor Q-3, a medium-current, low-speed, silicon-controlled switch, is also initiated by the prompt switch Q-1. When turned on, Q-3 actuates relay RY-1, which in turn excites an Amperite time-delay relay. If programmed in the automatic mode at the front panel, this delay serves the dual function of resetting Q-3 and all output confirmation lamps in each type B module. The retention time of the confirmation lamps may be selected to suit the user's requirements. The front-panel automatic-manual reset mode switch allows the user to bypass this resetting, thus holding the confirmation lamps on indefinitely. Switches Q-1 and Q-2, manufactured by Solid State

Fig. 5. Type A module circuit diagram.

Products, Inc., were selected for maximum turn-on speed. We found that these shelf-stocked items will generally trigger within 100 nsec.

B. Type B Module (Time-Delay Generating Sections)

The type B module is $\frac{3}{8}$ -in. wider than the type A module, and the printed circuit board (Fig. 1) terminates in a 15-pin, card-edge configuration. The front panel operating and functional controls are: (1) external input trigger connector (BNC), (2) three-position trigger-mode selector switch, (3) five-position coarse delay range selector switch, (4) nine-turn fine-delay control, and (5) output trigger confirm lamp indicator.

The type B module provides a wide range of delayed adjustable triggers from 1 μ sec to 10 msec in four decades. A nine-turn Helipot provides continuous delay adjustments within each selected coarse delay decade. Each unit is capable of generating delayed triggers independently of any of other modules in the system. For example, any type B Module installed into an alien chassis, with the appropriate supply voltages provided externally, would be an operational single-trigger delay unit. Functionally, this module may be sectorized into four circuit areas as follows (Fig. 6): (1) the time domain, or gate generating section, Q-1, Q-2, and Q-3; (2) differentiating and inverter amplifier Q-4; (3) output amplifier Q-5; and (4) output pulse confirmation driver amplifier Q-6.

The time-gate generating section consisting of Q-1 through Q-3 is a dc voltage-controlled pulse-width circuit, capable of generating over a 10:1 range a highly stable, low jitter gate. A number of attractive features result from this gate design. One advantage is the ability to directly calibrate the fine-delay front panel adjustment to read out the set delays to high accuracy and repeatability. Another advantage is the fast rise- and - fall characteristic of the gate on all selected ranges, with better than 70% duty cycle rate, allowing a simple circuit preceding the gate. Although the generator is designed to operate over the range of 1 μ sec to 10 msec, both the upper and lower bounds may be extended. The measured system jitter, from input to output of a complete channel, is less than 5 nsec. Repeatability of delay setting has also been measured to better than 1%.

Referring again to Fig. 6, resistor R-1 is

used as a constant-current source for the base of Q-1. The emitter of Q-3 controls the charging current, or the voltage feedback applied to the base of Q-1 during the charging cycle. Transistors Q-1 and Q-2 are normally both turned on prior to input trigger application through pin C. Upon application of a positive trigger of approximately 10-V amplitude, Q-2 turns off. Transistor Q-3 will then clamp Q-2's collector, thereby controlling the amount of feedback voltage required to turn off transistor Q-1. A speed-up capacitor, C-2, aids in switching off Q-2 rapidly. Transistors Q-1 and Q-2 will remain turned off until the constant-current charging resistance R-1 recharges one of the feedback capacitors, C-5 through C-8 (whichever has been selected in the time range), and the base of Q-1 rises to conduction. Q-1 and Q-2 again revert to their normal conducting state. The timing capacitor also aids in returning transistor Q-1 to its conducting state.

The advantages of this circuit in the generation of precision gates, over the more conventional multivibrator types, are as follows: The low impedance method of discharging the time network reduces the need to provide extra pulse-shaping circuitry. False triggering from noise pickup is greatly reduced over a multivibrator circuit. Power variations have negligible effect on timing, and gate time variations are approximately 20 times less than conventional techniques. Temperature effects on the solid-state devices also have negligible effect on timing accuracy of the gate. The upper and lower bounds of each delay range are calibrated to track within 2% or better, with stock-selected timing capacitors.

To obtain a direct dial readout on the fine-delay control, one mechanical turn is removed from the conventional 10-turn Helipot. We occasionally order the modified Helipot directly from the manufacturer at a slight additional cost.

Differentiation of the gate fall time is accomplished by C-3 and R-8. The RC time constant is adequate to cover the full time-delay range of the system. The differentiated pulse is then inverted by transistor Q-4, which in turn triggers a fast silicon-controlled switch, Q-5. The switch Q-5 generates two fast trigger pulses: one, a low-impedance capacitive discharge, negative-current

Fig. 6. Type B module circuit diagram.

trigger to the output connector (pin 9 to the rear BNC connector) of the channel; the other a positive pulse, driving an isolating transformer T-1. Transformer T-1 in turn provides two triggers. One initiates a silicon-controlled switch Q-6, whose function is to arm the pulse confirmation lamp connected to pins M and N. The second trigger is made available to the socket of the delay module (pin 11) for use as a source trigger through pin 3 of the next type B module in the chassis. This provision (with the trigger mode switch in its add position) allows cascading of the type B modules and obviates the need to patch delay channels externally by cumbersome coaxial cables. Manually cascading six channels can provide a total delayed time of 60 msec.

C. Power Supplies

Five regulated voltages are provided for the complete generator as shown in Fig. 7. A combination of integrated circuits and discrete devices are used wherever feasible. The time-gate generator collector bus is supplied by the +15-V, 400-mA, 1%-regulator (utilizing the LM-200 integrated circuit and transistors Q-5 and Q-6). The constant-current charging source for this section is provided by the +100-V, 50-mA, 1%-regulator comprised of Q-1, Q-2, Q-3, and Q-4. The remaining output trigger switches and confirmation switching circuits are supplied by simple Zener regulated sources Z-3, Z-4, and Z-5. To overcome the effects of noisy power lines, 3-A Sprague line filters (not shown in Fig. 7) have been installed in each leg and securely grounded at the immediate entrance to the chassis. To protect

the series pass regulator transistors and other solid-state devices in the power supply section against destructive line and switching transients, Thyrector diodes are used across all power transformer secondary windings.

As indicated in Figs. 4 through 7, liberal use of diode decoupling and Zener protection has been used throughout the system, to help reduce false triggering and circuit destruction which could result from the application of noise spikes from outside sources. Some of the area protection may appear superfluous; however, it is often difficult to assess the subtle ways in which noise enters instruments, particularly when operating in the hostile environment of pulsed plasma devices.

IV. CONCLUSION

Twelve Model-10 systems have been placed into service during the past 20 months. During this period, less than 1% failures have been reported as the direct result of circuit difficulties.

To increase the flexibility of the prototype Model-10 generators, an additional seven-channel trigger inverting chassis has been provided with each delay system. This small auxiliary chassis gives the user a positive output trigger, complementing each Model-10 channel.

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