THE GENERAL RADIO

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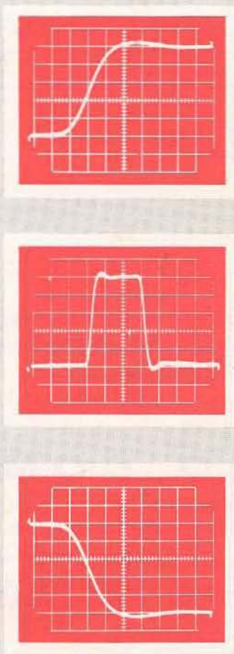


This Issue

VHF Pulse Generator

Precision Coaxial Adaptors

VOLUME 40 · NUMBER 7 / JULY 1966

Figure 1. Panel view of the Type 1394-Z High-Rate Pulse Generator, consisting of *(top)* the Type 1394-A High-Rate Pulse Generator and *(bottom)* Type 1394-P1 Pulse-Offset Control.

VHF PULSE GENERATOR

NEW CIRCUITS YIELD HIGH PERFORMANCE AT MODERATE COST

> The continuing rapid expansion of digital techniques into the vhf region has created a demand for generators of high-prf, fast-rise-time pulses. General Radio's new vhf pulse generator makes maximum use of standard, economical components in straightforward yet novel circuits, resulting in state-of-the-art performance at a moderate price.

The new Type 1394-A High-Rate Pulse Generator meets the growing requirements for test sources for high-speed computers and data-transmission and processing systems. Its important features include:

1. High repetition rate; 1- to 100-MHz range internally generated; dc to 100 MHz with external drive.
2. Fast rise time: 2 nanoseconds.
3. Duty ratios up to 96%.
4. Internal prf generator with excellent frequency stability.
5. Controls for precise synchronization with external clock signals.
6. Calibrated controls for pulse repetition frequency, amplitude, delay, and duration.

Performance of this order is essential in the design and test of high-speed digital systems. In addition to its use in computer development, this pulse generator has many applications in such fields as data transmission, modern radar systems, nuclear instrumentation, and component testing.

Through the development of new circuits, the above features are made available in a pulse generator of comparatively modest price. Both the prf oscillator and the bistable output circuit embody new ideas; the delay functions are performed by lengths of coaxial cable.

A companion instrument, the Type 1394-P1 Pulse-Offset Control (page 7), is available for those applications where dc output coupling is required. The combination is the Type 1394-Z.

Figure 2 is a simplified block diagram of the generator. A pulse train from the prf oscillator is applied to

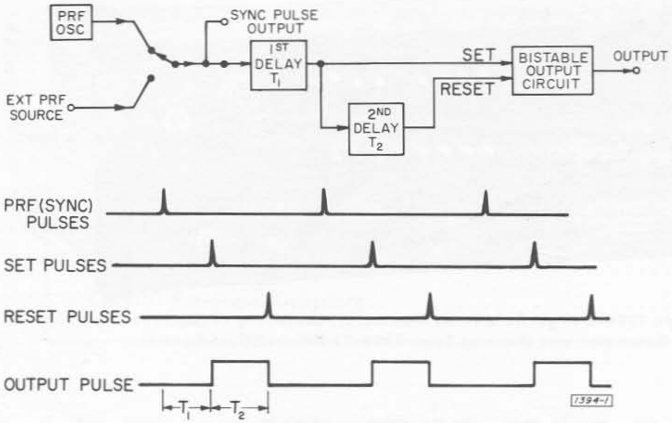


Figure 2. Elementary block diagram with waveforms.

the first delay circuit, which delays the pulses by time T_1. The delayed pulses are applied to the bistable output circuit as set pulses and also to the second delay circuit, which delays the train further by an amount T_2 to form reset pulses. The first delay is thus the delay between the sync pulse and the leading edge of the output pulse, and the second delay is the duration of the output pulse. On page 5 is a discussion of the individual circuits, illustrating their unique aspects and pointing out their advantages to the user.

APPLICATIONS

One important application of the Type 1394-A High-Rate Pulse Generator is in testing of complementary flip-flops or scalers. Tests of maximum input pulse frequency as a function of pulse duration, amplitude, supply voltage, etc are easily made with this generator. Double- or triple-pulse testing at low repetition rates, on the other hand, although it gives an indication of the maximum frequency at which a digital circuit may operate properly, is not completely adequate. Only sustained operation at the maximum frequency can show the effects of self-biasing due to ac coupling and nonlinearities and also the effects of power dissipation due to rapid switching, both of which may be significant factors in circuit performance.

Another application of the instrument is as a clock-pulse generator for a digital system. Both the precision of setting and the stability of the prf oscillator are quite important in this application.

Many digital devices have the properties of a threshold detector; when a pulse exceeds a certain voltage level, the circuit acts. Threshold circuits can be conveniently tested with the Type 1394-A/P1, since the combination of a stepped pulse attenuator and a smooth, precise offset control allows continuous adjustment of pulse level through a range of +6 to −6 volts.

The input circuits include a calibrated trigger-level control and a slope-polarity switch. Sensitivity is better than 0.4 volt, peak-to-peak. Consequently, when the instrument is triggered by an external signal, optimum operation can be obtained over wide ranges of input waveform and voltage level. This capability is important when the instrument is used as a regenerator in a system.

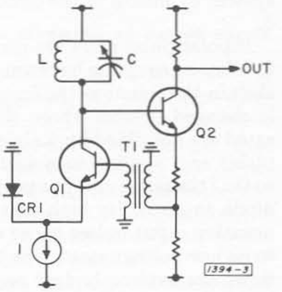
The circuit configurations were chosen to provide the high performance necessary to meet today's vhf pulse needs and to do so without pushing conventional techniques to the limits, which is never satisfactory from either the cost or the reliability standpoint. These circuits provide two additional advantages that improve on present practice.

The first is freedom from the duty-ratio limits usually imposed by delay-circuit recovery or output-circuit power-dissipation limits. This instrument is very convenient to operate, and it is satisfying to know that the output circuit will operate in any environment and with any combination of control settings without being on the edge of a dissipation limit.

The second advantage is that the instrument has accurately calibrated controls and is stable in operation. Because the settings of the panel controls tell the operator what the generator is doing, he can devote his attention to the system under test with a minimum of attention to the pulse source, and without the necessity of tying up an expensive scope to monitor the pulses.

CIRCUIT DESCRIPTION

Figure 3. PRF Circuit, simplified circuit diagram.



PRF Oscillator*

The circuit of the prf oscillator is shown in elementary form in Figure 3.

A constant-current source, *I*, is switched between diode *CR1* and transistor *Q1* by a large sinusoidal signal on the base of *Q1*. The resulting square wave of collector current drives the LC tuned circuit at its resonant frequency, producing a high-amplitude sinusoidal voltage at the base of *Q2*. The collector of *Q2* supplies the sinusoidal output voltage. The feedback loop is closed by the application of a fraction of *Q2's* emitter voltage to the base of *Q1*, via inverting transformer *T1*, which is a wideband one-to-one transformer of the type described by Ruthroff[1].

The advantages of this circuit configuration are that the simplest resonant circuit is used for frequency determination and that the amplitude is proportional to the current from the constant-generator current, which is the collector of a transistor used in the automatic amplitude control. Figure 4 shows the variation of oscillator frequency with warmup time and with line voltage.

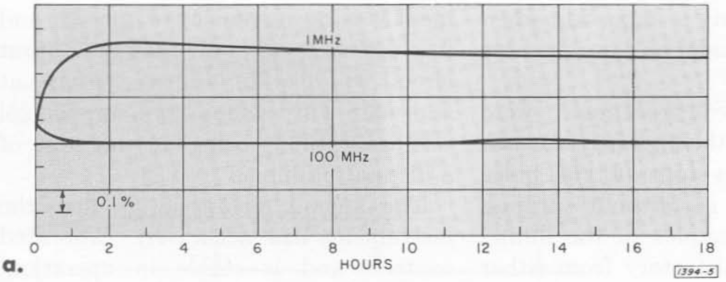
The Delay Function

Pulses propagating through polyethylene-dielectric coaxial cable are delayed by one nanosecond for approximately every 20 cm (7.8 in) of cable length. Since the delays required by this generator are less than 100 nanoseconds, they can be provided by reasonable lengths of cable. The delay circuits consist of lengths of coaxial cable cut for 1, 2, 4, 2, 10, 20, 40, and 20 nanoseconds. These can be switched in or out of the signal path to change the delay in one-nanosecond increments from zero to 99 nanoseconds.

Cable-delay circuits have the advantages of economy, high duty ratio, high prf, and accuracy as compared to the usual lumped-constant delay circuit. The conventional lumped circuit charges a reactance to produce a time delay. The time taken to discharge the reactance before the next delay period can start places a limit on attainable duty ratios. At high prf's the rates of change of energy to and from the reactance become large and make it desirable to use very small inductances or capacitances, introducing inaccuracies due to uncontrolled stray reactances. Attempts to improve prf or

* Patient Applied For.

[1] C. L. Ruthroff, "Some Broad-Band Transformers," *Proceedings of the IRE*, August 1959, p 1337 ff.



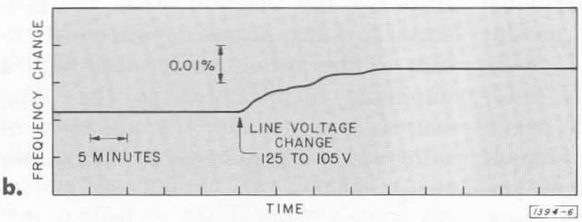


Figure 4. Stability records. (a) Frequency variation on 1- and 100-MHz ranges from cold start. (b) Frequency variation on 100-MHz range due to line-voltage change.

duty ratio by a decrease in the voltage or current swing on the reactance also result in decreased accuracy, because the error in detection of the charged voltage or current level does not decrease in proportion to the signal swing.

Cable-delay circuits operate on a much different principle from that of the conventional delay circuit, and duty-ratio restrictions are not applicable in the same sense as they are to the latter. The delay of a pulse train in cables may even exceed its period. Accuracy of cable-produced delay depends upon the stability of the cable length and upon the cable dielectric constant. Cable-produced delays are accurately known and are much more stable than those obtainable by conventional circuits operating at very high prf's.

Pulse Regeneration

When cables are used for delay, the pulse shape deteriorates as the pulse is propagated along the line and must be restored. Pulse shapes are regenerated at several points in the system by means of the circuit shown in Figure 5.

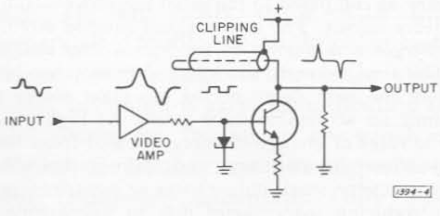


Figure 5. Pulse-Regeneration Circuit.

Bipolar pulse pairs are used in this generator to allow ac coupling between stages without a dc shift in the signal as the frequency of the signal is changed. Pulses whose shapes have deteriorated are amplified by a class-A broadband amplifier and applied to a bistable tunnel diode, so that the positive input pulses cause the tunnel diode to go to its high-voltage state, and the negative input pulses cause the diode to return to its low-voltage state. The tunnel diode transitions are extremely fast and, as a result, the higher-frequency components of the signal, which were lost in the delay line, are restored. The fast pulse from the tunnel diode is applied to a clipping line, which differentiates the signal to reproduce the desired bipolar pulse.

The Bistable Output Circuit

Figure 6 is a simplified schematic diagram of the bistable output circuit. The set and reset pulses are applied to the tunnel diode through 100-ohm coaxial cable, and, since the tunnel diode appears as a very low impedance (approximately 5 ohms except for the extremely short time that it is switching between states), the pulse voltages appear almost equally on both bases. The differential amplifier *Q3-Q4* amplifies only the signal difference between its bases and not a voltage applied to both bases. Thus, although the tunnel diode voltage is amplified, the set and reset pulses are not and do not appear in the output. This type of connection

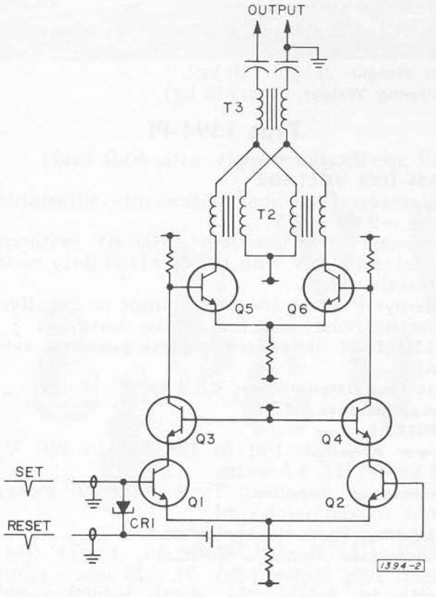


Figure 6. Simplified schematic of output circuit.

greatly reduces the sensitivity of output wave shape to variations in the set or reset pulses.

Q5 and *Q6* are grounded-base stages that allow *Q3* and *Q4* to operate into very low collector impedances, for maximum bandwidth. The grounded-base stages drive a second differential amplifier, *Q7* and *Q8*, which is coupled to the output by transformers *T2* and *T3*.

Transformer *T2* is a 2:1 balanced transformer constructed along the lines suggested by Ruthroff.[1] It has an extremely wide bandwidth, from less than 100 kHz to a few hundred MHz. Figure

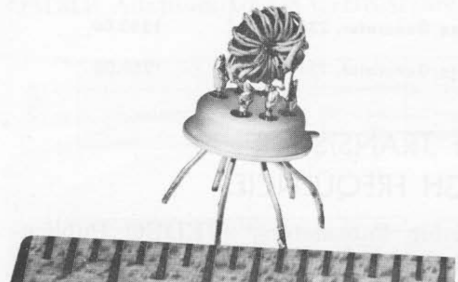


Figure 7. Photograph of output transformer, T2. Size is indicated by scale on the ruler.

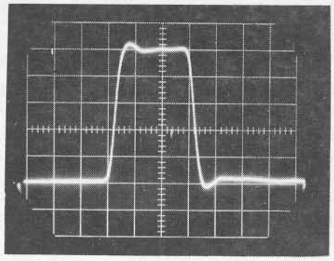


Figure 8. Output-pulse waveform. A 15-ns pulse at 20-MHz repetition rate. Horizontal scale, 5 ns per major division.

7 is a photograph of *T2* with its protective cover removed. *T3* is a balanced-to-unbalanced transformer.[2] Figure 8 shows the output-pulse waveform. The output circuit includes a precision 50-ohm attenuator, which drops the output from a maximum of four volts to zero in half-volt steps.

Pulse-Offset Control

The Type 1394-P1 Pulse-Offset Control is a companion instrument to the Type 1394-A High-Rate Pulse Generator (see Figure 1). Interconnections are made at the rear of the instruments since both are designed so that all front-panel connectors are easily transferred to the rear panel. The Pulse-Offset Control consists of a peak-voltage detector, reference voltage generator, and a high-gain control-amplifier. It inserts a dc component in the pulse output of the pulse generator so that the base line of the pulse is regulated to be equal to the reference voltage. This combination of instruments meets the needs of those applications that require dc coupling. The pulse-offset voltage is continuously adjustable from −2 to +2 volts.

— J. K. Skilling

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[1] *Ibid.*

[2] Lewis and Wells, *Millimicrosecond Pulse Techniques*, 2nd Edition, Pergamon Press, 1959, p 104 ff.

Note: A brief biography of James K. Skilling, author of the foregoing article, appeared in the March 1966 issue of the *Experimenter*. — Editor

SPECIFICATIONS

Type 1394-A

PULSE REPETITION FREQUENCY

Internally Generated: 1.0 MHz to 100 MHz; six ranges in 1-2, 2-5, 5-10 sequence. Continuous coverage, ±5% of setting. Jitter, <0.1 ns, peak.

Externally Controlled: dc to 100 MHz, 0.4 to 4.0 V, p-to-p, amplitude range plus 10 to 1 attenuator,

(*Continued*)

SPECIFICATIONS (Cont'd)

1 W max. 50 Ω, choice of ± slope, and trigger level from −2 to +2 V.

SYNCHRONIZING-PULSE CHARACTERISTICS
Description: Bipolar pulses, leading edge of positive pulse is reference.
Duration: 4 ns, typical.
Amplitude: Approx 250 mV, p-to-p, into 50 Ω.
Delay (between sync pulse and leading edge of output pulse): 0 to 99 ns in 1-ns steps, ±2.5% ± 1-ns accuracy. No restriction on ratio delay period. Jitter, <0.1 ns, peak.
Residual Delay: 35 ns, typically.

OUTPUT-PULSE CHARACTERISTICS (all specifications apply to 50-Ω load)
Duration: 4 to 99 ns in 1-ns steps, ±2.5% ± 1-ns accuracy. Jitter, <0.1 ns, peak.
Rise and Fall Times: 2.0 ns ±20%.
Voltage: Ac coupled. 0 to 4 V in calibrated ½-volt steps. Plus or minus polarity.
Duty Ratio: Limited only by rise-plus-fall time.
Overshoot: 12% typically.
Droop: <±10% at maximum duration.

GENERAL
Power Required: 100 to 125/200 to 250 V; 50 to 400 Hz; 24 W.
Accessories Supplied: Type CAP-22 Power Cord; spare fuses.
Mounting: Rack-Bench Cabinet.
Dimensions: Bench, width 19, height 3^15^/16, depth 16¾ inches (485, 100, 425 mm); rack, width 19, height 3½, depth behind panel 14½ inches (485, 89, 370 mm), over-all.
Net Weight: 21½ lb (10 kg).
Shipping Weight: 34 lb (15 kg).

Type 1394-PI

(All specifications apply with 50-Ω load)

BASE-LINE VOLTAGE
Amplitude: Base line continuously adjustable from −2 to + 2 V.
Accuracy: Error less than ±100 mV (without pulse) ±100 mV with pulses whose duty ratio is less than 90%.
Polarity: Positive (negative pulse) or negative (positive pulse) base line can be controlled.

DISTORTION (introduced in pulse-generator output)
Rise-Time Deterioration: <0.2 ns.
Droop Increase: <2%.

GENERAL
Power Required: 100 to 125/200 to 250 V; 50 to 400 Hz; 4.5 watts.
Accessories Supplied: Type CAP-22 Power Cord, coaxial patch cord.
Mounting: Rack-Bench Cabinet.
Dimensions: Bench, width 19, height 2⅛, depth 16¾ inches (485, 54, 425 mm); rack, width 19, height 2⅛, depth behind panel 14½ inches (485, 54, 370 mm), over-all.
Net Weight: 12¼ lb (6 kg).
Shipping Weight: 17 lb (8 kg).

Catalog Number	*Description*	*Price in USA*
1394-9801	**Type 1394-A High-Rate Pulse Generator,** Bench Model	**$995.00**
1394-9811	**Type 1394-A High-Rate Pulse Generator,** Rack Model	**995.00**
1394-9611	**Type 1394-P1 Pulse-Offset Control,** Bench Model	**255.00**
1394-9621	**Type 1394-P1 Pulse-Offset Control,** Rack Model	**255.00**
1394-9911	**Type 1394-Z High-Rate Pulse Generator,** 115 volts Bench Model	**1250.00**
1394-9912	**Type 1394-Z High-Rate Pulse Generator,** 115 volts Rack Model	**1250.00**
1394-9913	**Type 1394-Z High-Rate Pulse Generator,** 230 volts Bench Model	**1250.00**
1394-9914	**Type 1394-Z High-Rate Pulse Generator,** 230 volts Rack Model	**1250.00**

MEASUREMENT OF TRANSISTOR PARAMETERS AT HIGH FREQUENCIES

Users of the Type 1607-A Transfer-Function and Immittance Bridge for transistor measurements will be interested in a recent JEDEC standard entitled "A Method for the Measurement of Small-Signal High-Frequency Transistor Parameters," JEDEC Publication No. 55, March 1966, $1.10. Copies can be obtained from EIA, Engineering Department, 2001 Eye Street, N.W., Washington, D.C. 20006.