THE General Radio EXPERIMENTER

VOLUME XXVIII No. 11 APRIL, 1954

ELECTRONIC APPARATUS FOR SCIENCE AND INDUSTRY

A BALANCED MODULATOR FOR PULSE APPLICATIONS

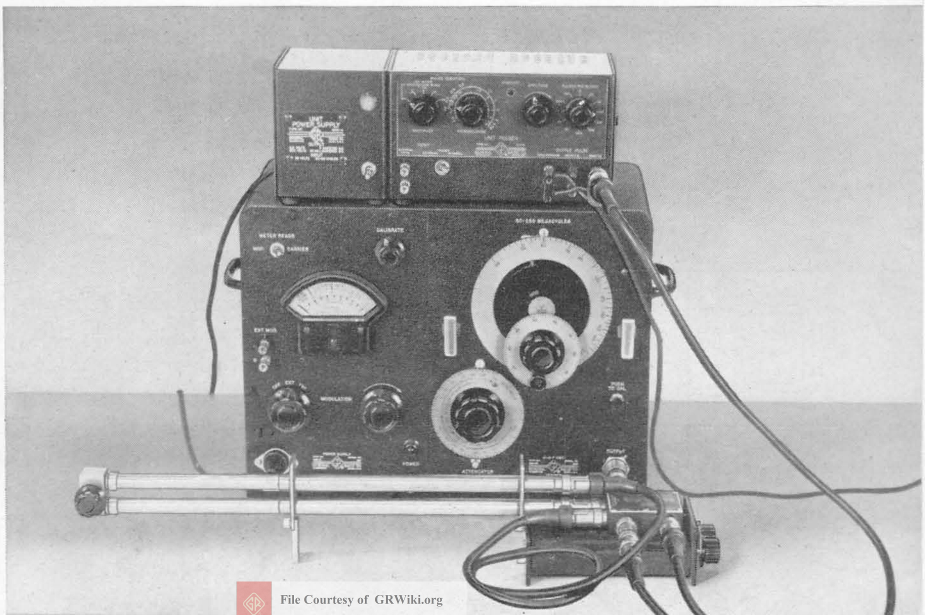
Also

IN THIS ISSUE

● **IN THE MARCH, 1950, EXPERIMENTER,** a simple loss-type modulator (TYPE 1000-P6) using a silicon-crystal diode was described. This device made possible wide-frequency-range amplitude modulation of existing oscillators and signal generators. At a nominal expenditure, test sources for pulse and video systems were therefore made available to the engineer, previously hampered by lack of even expensive alternatives.

Not only did this device permit modulation frequencies far in excess of those previously available in test instruments, but also the generation of the amplitude modulation substantially without incidental frequency

Figure 1. The Type 1000-P7 Balanced Modulator (in foreground) set up with the Type 1217-A Unit Pulser to pulse-modulate the Type 1021-A Standard Signal Generator.



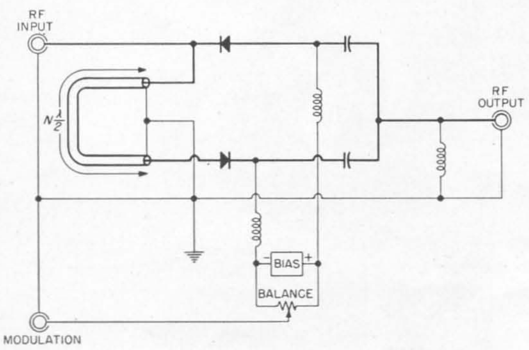
modulation. The modulator was therefore useful not only for television, radar, and other applications requiring wideband modulation but also for a-m tests on f-m systems and for tests of omnirange equipment, where freedom from fm is essential.

The success of this device for simple uses has led to the development of a more sophisticated device, the TYPE 1000-P7 Balanced Modulator, which has a still wider range of applications than the single-diode model.

The limitations of the TYPE 1000-P6 Crystal-Diode Modulator arose principally from the capacitive leakage that occurred when the crystal impedance was high. This reduced the percentage modulation at high carrier frequencies below that which could be obtained at low frequencies and thereby limited its usefulness.

This capacitive leakage can be materially reduced and, in fact, a nearly perfect null obtained at a particular value of modulating voltage, by adjusting the resistive balance as well as the capacitive balance in a balanced-modulator circuit using two crystals. With this method of operation, used in the TYPE 1000-P7 Balanced Modulator, pulse modulation with 60 db ratios of off-on can be achieved, as well as substantially perfect 100 per cent modulation for video testing.

Figure 2. Elementary schematic circuit diagram of the Type 1000-P7 Balanced Modulator.



CIRCUIT

The elementary schematic illustrates the principle of operation of the TYPE 1000-P7 Balanced Modulator. Two crystals are used, with a phasing line so arranged that the carrier voltage applied to one diode is 180 degrees out of phase with the carrier voltage applied to the other. The relative bias currents applied to the diodes can be adjusted to equalize their impedances and consequently produce a null in the carrier output.

The adjustable phasing line is a "trombone" section of coaxial line, which must be set to an odd multiple of one-half wavelength at the carrier frequency. The BALANCE control is a differential control in the bias supply. A BIAS control, not shown in the schematic, is provided which permits setting the operating point on the diode characteristics for best linearity and which also operates a switch in the extreme counterclockwise position to disconnect the bias battery.

The diodes are oppositely poled so that an applied pulse or modulating signal increases the impedance of one while decreasing the impedance of the other. A pulse of either polarity will drive the circuit from the initial balanced condition to produce a pulse of radio-frequency output. The carrier level between pulses depends on the degree of balance of the circuit. It is relatively easy to obtain a residual carrier level 60 decibels below the pulsed level.

For the usual amplitude-modulation applications, the BALANCE control can be offset to insert the desired amount of carrier. Since the modulator can be operated as close to balance as desired, very good linearity can be obtained. With proper adjustment of BIAS and BALANCE controls, good linearity at 100 per cent modulation can be obtained with 10 millivolts of radio-frequency output on modulation peaks. The oscillogram of Figure 3 shows the modulation characteristic obtained at a carrier frequency of 900 megacycles at this output level.

CONSTRUCTION

The cutaway view of the basic modulator unit shows the internal arrangement of components. The radio-frequency-input connector is at the top right of the picture, the adjustable line connectors are at the top, and the radio-frequency-output connector is at the top left. The modulation-input connector is at the bottom left. The two crystal diodes join the output connector via two built-in capacitors. The modulation-bias-feed chokes are in the middle compartment. The resistors in the lower compartment constitute a mixing pad for superposing the d-c battery bias and modulating signal.

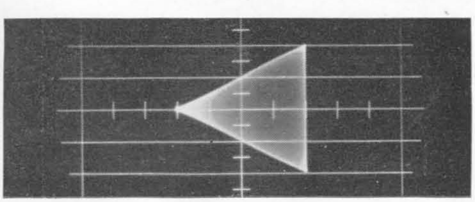
PERFORMANCE

Figure 1 shows the TYPE 1000-P7 Balanced Modulator set up to pulse-modulate the TYPE 1021-A U-H-F Signal Generator with the TYPE 1217-A Unit Pulser supplying the modulation. The Adjustable Line is shown with one of the flexible line extensions which are used at carrier frequencies below 400 megacycles.

This method of pulsing oscillators and signal generators has a number of advantages over the conventional method of starting and stopping the oscillator.

The wave-shape of the modulating pulse is preserved in the pulsed output,

Figure 3. Amplitude modulation characteristic at 900 megacycles. Peak r-f output is 10 millivolts; r-f input, 50 millivolts.



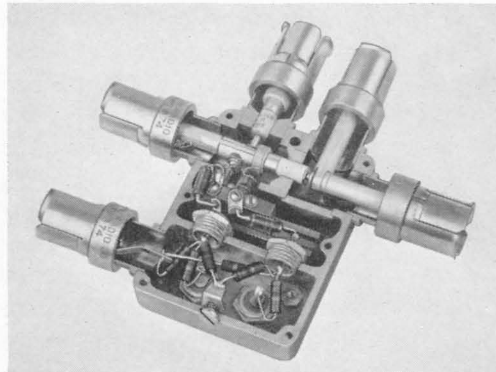


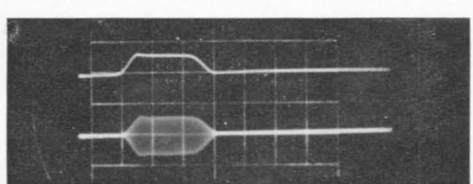
Figure 4. Cutaway view of the modulator, showing internal construction and arrangement of elements.

and yet a high on-off ratio is obtained. In addition, the r-f output is coherent with itself from pulse to pulse, i.e., the phase of the r-f carrier at the beginning of each pulse is the same as it would be at that instant if the carrier were unmodulated.

The coherent r-f signal with pulse modulation is difficult to obtain in the pulsed oscillator, but with the external modulator it is provided automatically.

With an internally modulated generator, the wave-shape of the leading edge of the pulse is modified by the starting conditions of the oscillator, which must depend upon circuit noise, feedback, and impedance relationships. The oscillogram of Figure 5 shows the applied pulse from the TYPE 1217-A Unit Pulser and the resulting radio-frequency pulse. The rise time of the applied pulse is about 50 millimicroseconds and the fall time is 150 millimicroseconds. The resulting radio-frequency envelope shows no degradation of pulse shape.

Figure 5. Oscillogram showing modulating pulse and r-f output pulse. Pulse duration is 0.25 μsec with 0.05 μsec rise time. Carrier frequency is 60 megacycles. Scale is 0.1 μsec per horizontal division.



The high on-off ratio (60 db) is an advantage in testing radar and other pulsed systems because it permits the test condition to approximate very closely the normal operating condition of the system.

USES

The modulation frequency response is flat to 20 megacycles, making the modulator suitable not only for short pulses but for any wide-band modulation. Television video is easily accommodated and, since the modulation characteristic is flat to dc, even a d-c component can be included with the modulating signal. Since linear 100-percent modulation can be obtained throughout the U-H-F TV band, the TYPE 1000-P7 is superior to the TYPE 1000-P6 for TV applications. As with the earlier type, the resulting signal has double side bands and, if it is desired to simulate exactly a standard TV picture signal, a vestigial side-band filter must be provided at the radio-frequency output.

Other uses include tests on micro-wave relay systems using multiplex pulse-code modulation, on omni-range and DME equipment, on telemetering circuits, and on high-resolution radar.

— W. F. BYERS

SPECIFICATIONS

Carrier-Frequency Range: 60 to 2300 megacycles.

Modulation-Frequency Range: Flat from 0 to 20 megacycles. For pulsing, the rise-time contribution is less than 20 millimicroseconds.

Impedance: The impedance looking into either input or output terminals is a function of the bias and modulating voltages. The source and load impedances should be 50 ohms. The impedance at the modulation input is 50 ohms ±5%. It is recommended that a TYPE 874-GF (20 db) or a TYPE 874-GG (10 db) fixed attenuator be used at the input and another at the output whenever the attenuation can be tolerated. The attenuator at the input is useful for isolation to minimize reaction on the oscillator frequency and hence frequency modulation. The attenuator at the output provides a known source impedance for gain and noise measurements and insures that the proper load is presented.

Modulation: Double-sideband suppressed-carrier modulation, pulse modulation with 60-db carrier suppression between pulses, and 100% amplitude modulation can be obtained throughout the carrier frequency range. One volt, peak, at the modulation terminals is sufficient to produce full r-f output from a zero output initial condition.

R-F Output: A maximum output of 10 millivolts into a 50-ohm load can be obtained during pulses or at modulation peaks, with a source of 50 millivolts behind 50 ohms. At this level and at lower input levels, the modulation characteristics are independent of input voltage. However, somewhat higher input voltages and, consequently, higher output voltages are permissible if bias and balance readjustments are made for each change in level. The r-f source must not exceed 0.5 volt behind 50 ohms or the crystal diodes may be damaged.

Bias Supply: Bias is supplied by a self-contained battery consisting of readily available, inexpensive flashlight cells.

Terminals: The radio-frequency input and output terminals and the modulation input terminals are TYPE 874 Coaxial Connectors. The radio-frequency input terminal is of proper elevation to plug directly into the output connector of the TYPE 1021-A Signal Generator.

Crystal Diodes: Two TYPE 1N21-B.

Accessories Supplied: One TYPE 1000-P7-28 40-cm Cable; one TYPE 1000-P7-28-2 80-cm Cable; one TYPE 874-C Cable Connector; four 1.5-volt bias cells.

Other Accessories Required: Terminal adaptors, unless generator and load are equipped with TYPE 874 Coaxial Connectors; suitable coaxial cable for connecting modulation source.

Accessories Available: TYPE 874-GF Fixed Attenuator, 20 db; TYPE 874-GG Fixed Attenuator, 10 db; TYPE 1000-P5 V-H-F Transformer; TYPE 874-R20 Patch Cord; TYPE 874 Adaptor to types N, BNC, C, and UHF connectors and to TYPE 938 Binding Posts.

Dimensions: (Including fully extended adjustable line) 30 inches (width) x 3 inches (height) x 5 inches (depth) over-all.

Net Weight: 6 pounds.

Type		*Code Word*	*Price*
1000-P7	**Balanced Modulator**	AWAKE	**$225.00**

U. S. Patents Nos. 2,125,816 and 2,548,457.