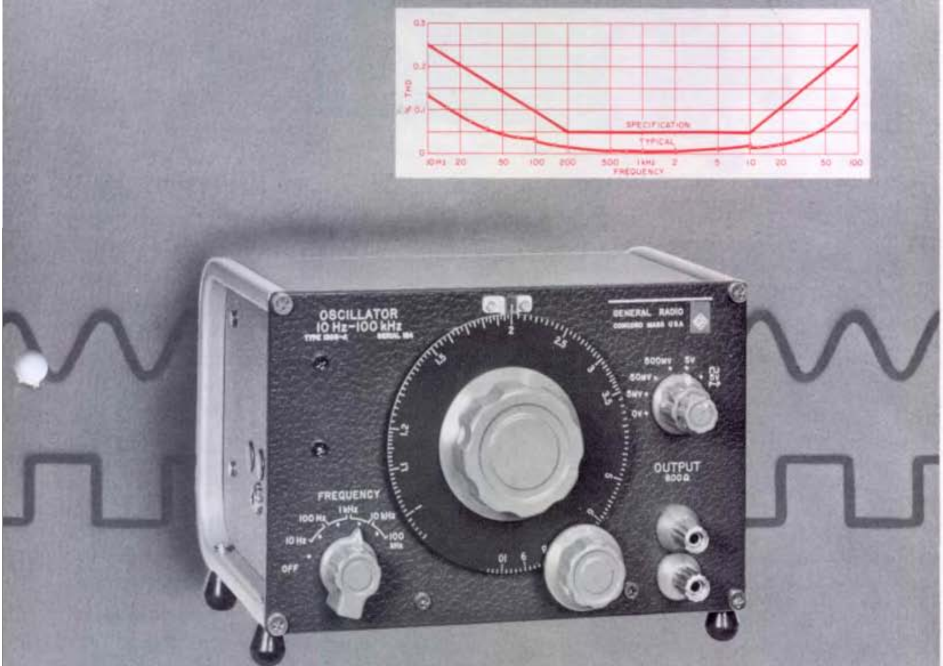
THE GENERAL RADIO

Experimenter



This Issue:

- All Solid-State, Low-Distortion Oscillator
- Sine-Squared Pulses

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Figure 1.

10 Hz TO 100 kHz

ALL-SOLID-STATE, LOW-DISTORTION OSCILLATOR

SINE- OR SQUARE-WAVE

The Type 1309-A is the second in our new line of general-purpose variable-capacitance-tuned RC oscillators, recently introduced with the Type 1310-A Oscillator.[1] It continues the modern, all-solid-state design used in the Type 1308-A and Type 1311-A Audio Oscillators.

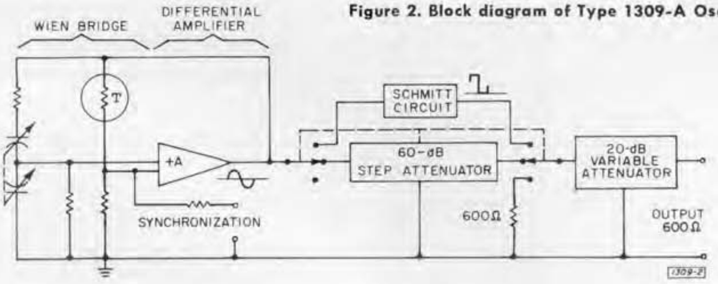
The continuing need for greater accuracy in electrical measurements, the improvements in sound-recording and reproduction equipment, and the increasingly stringent requirements on communication systems have all lowered the levels of distortion acceptable in new equipment. To design and to test this equipment, accurate distortion measurements must be made, and an essential part of any harmonic distortion measurement is a low-distortion source.

As distortion specifications have tightened, generators with lower and lower distortion levels have become available, but most of them have been quite expensive owing to a concomitant emphasis on extreme amplitude stability and a flat frequency characteristic. In lower-cost, general-purpose oscillators, on the other hand, the transition from vacuum tubes to transistors has led to higher, rather than lower, distortion levels, as a result of the techniques used to obtain these additional characteristics.

The new TYPE 1309-A Oscillator, an all-solid-state, capacitance-tuned oscillator, combines very low distortion with accuracy and stability ample for

[1] Robert E. Owen, "A Modern, Wide-Range RC Oscillator," *General Radio Experimenter*, August 1965.

Figure 2. Block diagram of Type 1309-A Oscillator.



general laboratory use. Output is quite constant over the entire frequency range of 10 Hz to 100 kHz, and an output attenuator provides the low signal levels necessary for testing active devices. As with other General Radio RC Oscillators, there is an input-output synchronization jack. An added feature is a square-wave output for transient-response measurements. This output has a symmetrical waveform and an unusually short rise time.

Figure 1 is a panel view of the oscillator, and Figure 2 shows the three major elements: a low-distortion Wien bridge oscillator, a Schmitt squaring circuit, and an output attenuator.

DISTORTION

The low distortion is achieved through the use of a high degree of negative feedback and a thermistor of special design for amplitude control.[2] The distortion at full output is approximately constant with load impedance for any linear load of 600 ohms or greater. When the open-circuit output is one volt or less, the distortion is independent of the size of the load. The distortion is typically less than 0.01% for frequencies near 1 kHz, often below what can be conveniently measured. Note that the shape of the distortion curve (Figure 3) is typical of most audio-frequency devices, so that the margin between the source distortion and a device under test remains approximately constant with frequency.

Low levels of hum and noise are always desirable, but to be useful for broadband distortion measurements an oscillator must have noise and hum that are at least as low as the distortion. The 1-kHz output of the Type 1309-A has noise typically less than 0.005% in a bandwidth of 5 Hz to 500 kHz, and

[2] Robert E. Owen, "Solid-State RC Oscillator Design for Audio Use", *Journal of the Audio Engineering Society*, Vol 14, January, 1966.

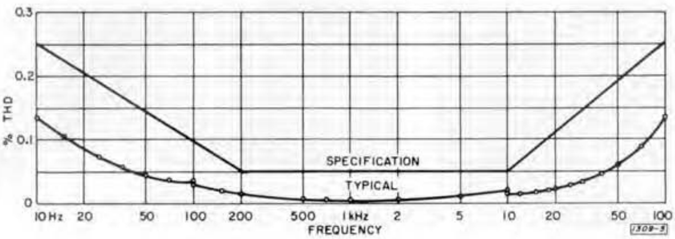


Figure 3. Oscillator distortion for 600-ohm load or open circuit.

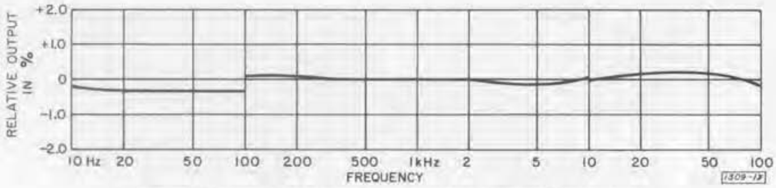


Figure 4. Typical oscillator output voltage versus frequency.

hum is less than 0.001% (−100 dB) of the full output.

ATTENUATOR

The sinusoidal open-circuit output voltage can be varied continuously between 5 volts and less than 0.5 millivolt by means of the output attenuator. An additional position, labeled zero volts, disconnects the oscillator output from the terminals yet maintains the 600-ohm output impedance. This provides a convenient transient-free means of reducing the output to zero without disturbing the continuous attenuator setting or shorting or disconnecting a carefully shielded system. Further, it aids in locating ground loops and other sources of extraneous signals when one is working with small signal levels. With the oscillator output removed, the extraneous signals are not masked, so that they are easier to measure and to eliminate. This technique offers considerable advantage over the often-used one of short-circuiting the output. Shorting drastically changes the impedance levels and can, in effect, change the whole circuit, possibly eliminating the very source that one is trying to isolate.

The variation of the output of any oscillator at different frequencies is perhaps its most noticeable departure from ideal. Because of this, and because a constant output is convenient for response measurements, most modern transistor oscillators have relatively flat output-frequency characteristics, although this property may be accompanied by moderately high distortion, which is uniform across the frequency range. The output of the Type 1309-A is constant within ±2% over its whole frequency range and is typically within ±0.5% (see Figure 4). It is stable within ±0.2% for one hour, typically, under normal laboratory conditions and after warm-up.

One position on the step attenuator connects the high-speed Schmitt circuit to the sinusoidal oscillator. Symmetrical, positive-going square waves with a rise time of less than 100 nanoseconds

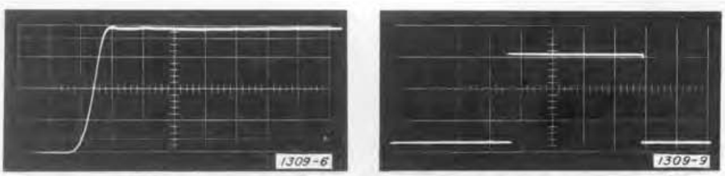


Figure 5. (Left) Leading edge of 10-kHz square wave into 50-ohm load. Horizontal scale: 50 ns/div. (Right) Direct-coupled 10-Hz square wave has flat top. Horizontal scale: 10 ms/div.

into 50 ohms are then available at the output terminals. This rise time is typically 40 nanoseconds into 50 ohms at full output, which corresponds to the response time of an amplifier with greater than 10-MHz bandwidth. (See Figure 5.) This output is greater than 5 volts, peak-to-peak, open-circuit, and is dc-coupled through the 20-dB attenuator, so that the waveform is flat-topped even at the lower frequency limit of 10 Hz.

SYNCHRONIZATION

This oscillator has a combination input/output synchronization capability similar to that described for the TYPE 1310-A 2-c to 2-Mc Oscillator[1], and its usefulness is enhanced by the high purity of the oscillator output. The sync output is greater than 1.5 volts, open-circuit, behind 12 kilohms and is in phase with the normal front-panel output. This output is particularly convenient for triggering counters and tone-burst generators, etc, when the attenuator output is set at a very low level. Because this output is always connected to the sinusoidal oscillator, both square-wave and sinusoidal outputs are available simultaneously. The square waves expand the uses of the synchronizing capability by providing an output waveform and amplitude that are independent of the input waveform. Figure 6 shows a further use of the combined synchronization and square-wave functions.

[1] *Ibid.*

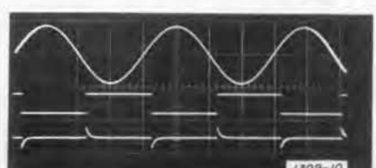


Figure 6. Using phase-shift capability of synchronized oscillator to get variable time delay pulses. (Top) sinusoidal input to oscillator synchronization jack. (Middle) Square-wave output with adjustable phase. (Bottom) Differentiated square wave (pulse) that has been adjusted to follow zero crossing of input sine wave by approximately 20°.

Robert E. Owen received his B.E.E. from Rensselaer Polytechnic Institute in 1961 and his M.S.E.E. from Case Institute of Technology in 1963. During his student career, he was employed summers by Dresser Electronics and Boonton Radio Corporation. He came to General Radio as a development engineer in 1963. His field is electrical networks, both active and passive.

APPLICATIONS

The variety of uses for an oscillator with this frequency range and types of waveforms is almost unlimited. Its purity of waveform and range of available output level, however, make it particularly valuable for laboratory design and measurement use. As an example of its versatility, it can be used in audio amplifier measurements as a source:

with a wave analyzer to measure hum, noise, and harmonic distortion;

with another oscillator and a wave analyzer to measure intermodulation distortion;

with a tone-burst generator and oscilloscope to measure overload recovery and peak power output;

with an oscilloscope to measure transient response;

with a wattmeter to measure power output; and

with a voltmeter to measure frequency response.

— R. E. OWEN

Figure 7. The Type 1309-A Oscillator and associated equipment used for testing of an audio amplifier.

SPECIFICATIONS

FREQUENCY

Range: 10 Hz to 100 kHz in four decade ranges.
Control: Continuously adjustable main dial covers range in 1 turn, vernier in 4¼ turns.

Accuracy: ±2%.

Synchronization: An external reference signal can be introduced through phone jack to phase-lock oscillator. One-volt input provides ± 3% locking range. Frequency dial can be used for phase adjustment.

OUTPUT

Sine Wave

Power: 10 mW into 600-Ω load.

Voltage: 5.0 V ±5% open circuit.

Impedance: 600 Ω. One terminal grounded.

Control: Minimum of 20-dB continuously adjustable and 60-dB step attenuator (20 ± 0.2 dB per step). Also, a zero-volts output position with 600-Ω output impedance maintained.

Distortion: Less than 0.05% from 200 Hz to 10 kHz, increasing to less than 0.25% at 10 Hz and 100 kHz open circuit or 600 Ω. See Figure 3.

Frequency Characteristic: ±2% over whole frequency range for loads of 600 Ω or greater. See typical curve in Figure 4.

Hum: Less than 50 μV regardless of attenuator setting. (0.001% of full output.)

Synchronization: High-impedance (12 kΩ), constant amplitude output of approximately 1.5 volts for use with external counter, for triggering an oscilloscope, or for synchronizing other oscillators.

Square Wave

Voltage: Greater than +5 V, peak-to-peak, open-circuit. Dc-coupled output.

Impedance: 600 Ω.

Rise Time: Under 100 ns into 50 Ω. Typically 40 ns at full output.

Control: Minimum of 20 dB continuously adjustable attenuator only.

Symmetry: ±2% over whole frequency range.

GENERAL

Terminals: Two Type 938 Binding Posts, one grounded.

Accessories Supplied: Type CAP-22 Power Cord, spare fuses.

Accessories Available: Type 1560-P95 Adaptor Cable (telephone plug to Type 274-M Double Plug) for connection to synchronizing jack, relay-rack adaptor set.

Power Required: 100 to 125 V, 200 to 250 V, 50 to 400 Hz, 6 W.

Mounting: Convertible-bench cabinet.

Dimensions: Width 8¼, height 6, depth 8⅛ inches (210 by 155 by 210 mm), over-all.

Net Weight: 6¾ lb (3.1 kg).

Catalog Number	*Description*	*Price in USA*
1309-9701	**Type 1309-A Oscillator, 10 Hz-100 kHz**	**$325.00**
1560-9695	**Type 1560-P95 Adaptor Cable**	**3.00**
0480-9638	**Type 480-P308 Rack-Adaptor Set**	**7.00**

GENERATION OF SINE-SQUARED PULSES WITH THE TONE-BURST GENERATOR

Sine-squared, or raised-cosine, pulses are useful in testing broadband transmission systems and, in particular, in video-bandwidth tests of television systems.[1] The sine-squared pulse, for instance, resembles very closely the electrical pulse from a television camera corresponding to a scanned white line. The spectrum envelope of a sine-squared pulse is shown in Figure 1 with that of a rectangular pulse for comparison. Above twice the fundamental, the sine-squared pulse has no components of appreciable magnitude. Below that frequency, however, its spectrum resembles very closely that of the rectangular pulse.[2]

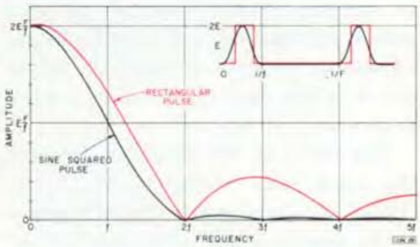


Figure 1. Spectrum envelopes of a rectangular pulse and a sine-squared pulse.

Sine-squared pulses can easily be produced by the TYPE 1396-A Tone-Burst Generator. By means of the gating controls, the interval between pulses can be set at 1, 3, 7, 15, 31, 63, or 127 periods, or from 1 millisecond to 10 seconds with a timed control.

To generate sine-squared pulses with the Tone-Burst Generator, proceed as follows:

1. Connect a $\frac{10}{f_{\mathrm{HZ}}}$-$\mu$F capacitor between upper terminals of the SIGNAL INPUT and TIMING INPUT pairs.

2. Apply a signal of the desired frequency, f, to the SIGNAL INPUT terminals.

3. Set both GATE DURATION switches to 2.

4. Set CYCLE COUNTS switch to MINUS ONE. This produces one-cycle bursts similar to those of Figure 2 as seen on an oscilloscope.

5. By means of the SLOPE switch and TRIGGER LEVEL control, change the phase of the pulse so that gating occurs at peak points, as in Figure 3.

[1] Nelson, Joseph E, "Television and Sine-Squared Testing," *Tektronix Service Scope*, April 1964.
[2] Colin Cherry, *Pulses and Transients in Communication Circuits*, Chapman and Hall, Ltd., London, 1949, pp 175–181.

(Left) Figure 2. One-cycle sine-wave burst. (Center) Figure 3. One-cycle burst gated at peak. (Right) Figure 4. Sine-squared pulse.

6. Add a dc voltage source in series with the input signal and adjust this voltage to remove the steep parts of the waveform and to produce the sine-squared pulse of Figure 4.

7. Set GATE DURATION-CLOSED switch to desired cycles interval between pulses. Alternatively, if a continuously adjustable interval is wanted, set to ×1 or ×100, and adjust TIMED control to give desired interval.

The value of the capacitor between the signal and timing inputs is not critical. Its purpose is to shift the phase of the timing signal relative to the input so that when switching occurs at the peak points the input circuits are working at level somewhat below peak. This ensures more reliable operation.

James K. Skilling is a 1953 graduate of the University of California at Berkeley, with a BS in Electrical Engineering. He received his MS from Johns Hopkins University in 1963. He has been a junior engineer at Douglas Aircraft and an instructor in electronics at the U. S. Naval Academy. Since 1959 he has been a development engineer at General Radio, specializing in pulse techniques and circuits.

The output amplitude must be limited to 7 volts, peak-to-peak, because the input is dc-coupled. The output has a dc component, which can be blocked by a coupling capacitor.

Figure 5 is an oscillogram of typical sine-squared pulses generated in the manner described above. The fundamental input frequency is approximately 2.5 kHz, and the interval between pulses is 7 periods.

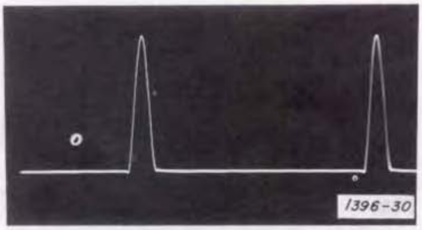


Figure 5. Typical sine-squared pulse train produced with the Tone-Burst Generator.

— J. K. SKILLING

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