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A New 1 CPS-1 MC Square Wave Generator with a 20-Millimicrosecond Rise Time

SQUARE wave generators which have a fast rise time and a high repetition rate are valuable in many fields. When used with a fast oscilloscope for video amplifier testing, they permit rapid examination of an amplifier's frequency characteristic up to many megacycles. In computer, pulse code, telemetering and other applications, they offer considerable convenience as a variable trigger source or for switching purposes. In television work they make excellent bar generators. In high-frequency applications they are useful for modulating purposes. They are also useful in testing devices such as attenuators, filters, and delay lines. Finally, of course, a square wave generator is an excellent device for testing audio systems.

SEE ALSO:
"Waveform Effects on Voltmeters," p. 2

The new *-hp-* 211A 1 cps - 1 megacycle square wave generator has been designed with special emphasis on its suitability for applications such as those listed above. The rise time of one of the two outputs from the generator is only 20 millimicroseconds, sufficiently fast to test the response of video devices out to approximately 20 megacycles or to provide a high-speed triggering voltage of variable rate.

Fig. 1. *New -hp- Model 211A Square Wave Generator operates from 1 cps to 1 megacycle, has only 20 millimicroseconds rise time from fast output. A second output provides up to 55 volts peak-to-peak.*

The fast 75-ohm output provides 7 volts peak-to-peak across its 75-ohm internal impedance or 3.5 volts peak-to-peak into a 75-ohm load. The output level is selected with a 60 db step attenuator in combination with an amplitude control, an arrangement which is especially convenient when lower level outputs are required.

The quality of the generated waveform is nearly ideal, even at the highest repetition rates, as can be seen in Fig. 2. At a repetition rate of 1 megacycle, the rise time is less than one twenty-fifth of the wave duration, while the wave top is free from overshoot or undershoot. At low frequencies the top is free from droop.

The second output from the generator provides 55 volts peak-to-peak from a source impedance of 600 ohms. The rise time of this

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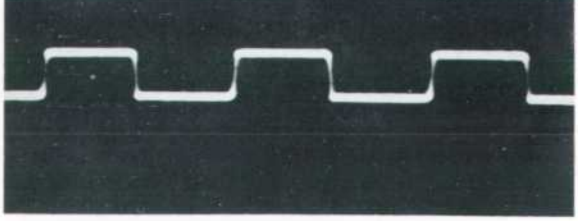

Fig. 2. *Oscillogram of fast output from -hp- 211A when operating at repetition rate of 1 megacycle into a 75-ohm resistive load.*

Some Effects of Waveform on VTVM Readings

(Continued from previous issue)

THIRD HARMONIC WITH AVERAGE-READING METERS

A wave consisting of a fundamental and the third harmonic causes considerably greater variations in the reading of an average-reading type voltmeter than does a wave with second harmonic content. This is shown in Fig. 5. Whereas the reading of the meter on a wave containing second harmonic is always lower than the rms value, the reading with a wave containing third harmonic can be either high or low for harmonic contents up to amounts as high as 75%.

In the case of a wave having third harmonic, the maximum area under the complex envelope and thus the maximum meter reading occur when the harmonic contributes the area of an extra half-cycle (Fig. 6[a]) of the harmonic to the total waveform. This situation determines the values of the upper boundary of the shaded area in Fig. 5. The minimum average area occurs when the harmonic subtracts the area of one-half cycle of its waveform from the fundamental. This determines the lower boundary for the shaded area for harmonic content up to 33$\frac{1}{3}$%.

For more than 33$\frac{1}{3}$% third harmonic slope reversals occur as before and the extra added area causes the lower limit to begin to rise.

The calculated data in Fig. 5 were verified experimentally in a manner similar to the verification for Fig. 3. The results are plotted in Fig. 5.

Not only does the third harmonic cause greater variations in the meter reading than the second harmonic, but, it will cause greater variations than any other harmonic. The extremes of error with "small amounts" of odd harmonics are given by the percentage of the harmonic divided by the order of the harmonic. "Small amounts" of harmonic in this case can be defined as percentages less than 100/n where n is the order of the odd harmonic.

It should be noted that, for typical amounts of this worst harmonic, the third, the accuracy of an average-reading meter is still good. Third harmonics up to 10%, for example, can cause errors of up to only 3.3%.

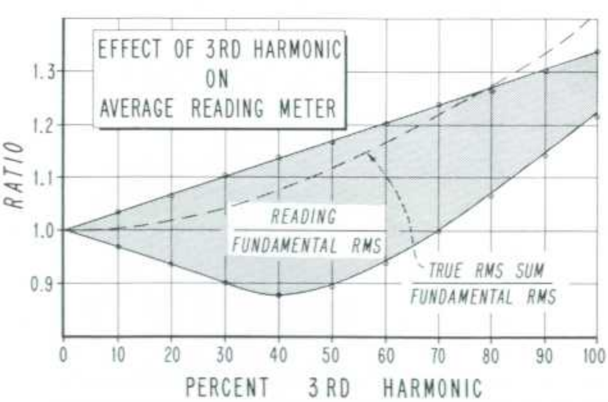

Fig. 5. *Calculated limits of absolute average values of wave consisting of fundamental with various amounts of third harmonic. Small circles show experimental verification of calculated data.*

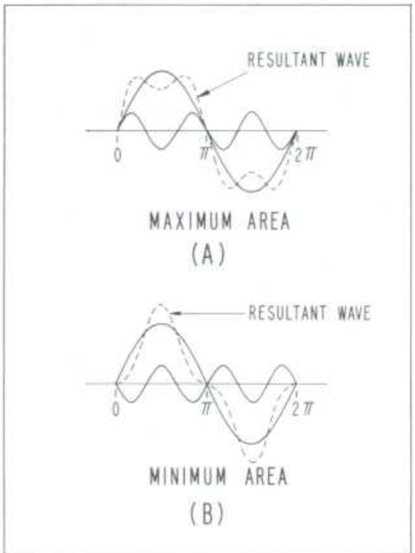

Fig. 6. *In-phase (a) and out-of-phase (b) third harmonic. In phase relation gives more accurate readings.*

COMBINED HARMONICS WITH AVERAGE METERS

When more than one harmonic is present in the applied wave, the mathematics of each case becomes more complicated and the number of cases is increased tremendously. As a result no analytic study of the situation has been made.

Some experimental data have been compiled, however, for the case of combined second and third harmonics with various amounts of fundamental. This case is of interest in distortion measurements made by the fundamental rejection method.

The data are shown in the second, third, and fourth curves of Fig. 7 for waves containing second and third harmonics in various ratios of fundamental from infinite fundamental (i.e., zero harmonics) to zero fundamental (i.e., infinite harmonics). The shaded areas represent the extremes of readings (as per cent of true total rms) obtained as the phase of the fundamental varied with respect to the harmonics. For these curves the second and third "harmonics" were adjusted to be off frequency with a slow beat of ap-

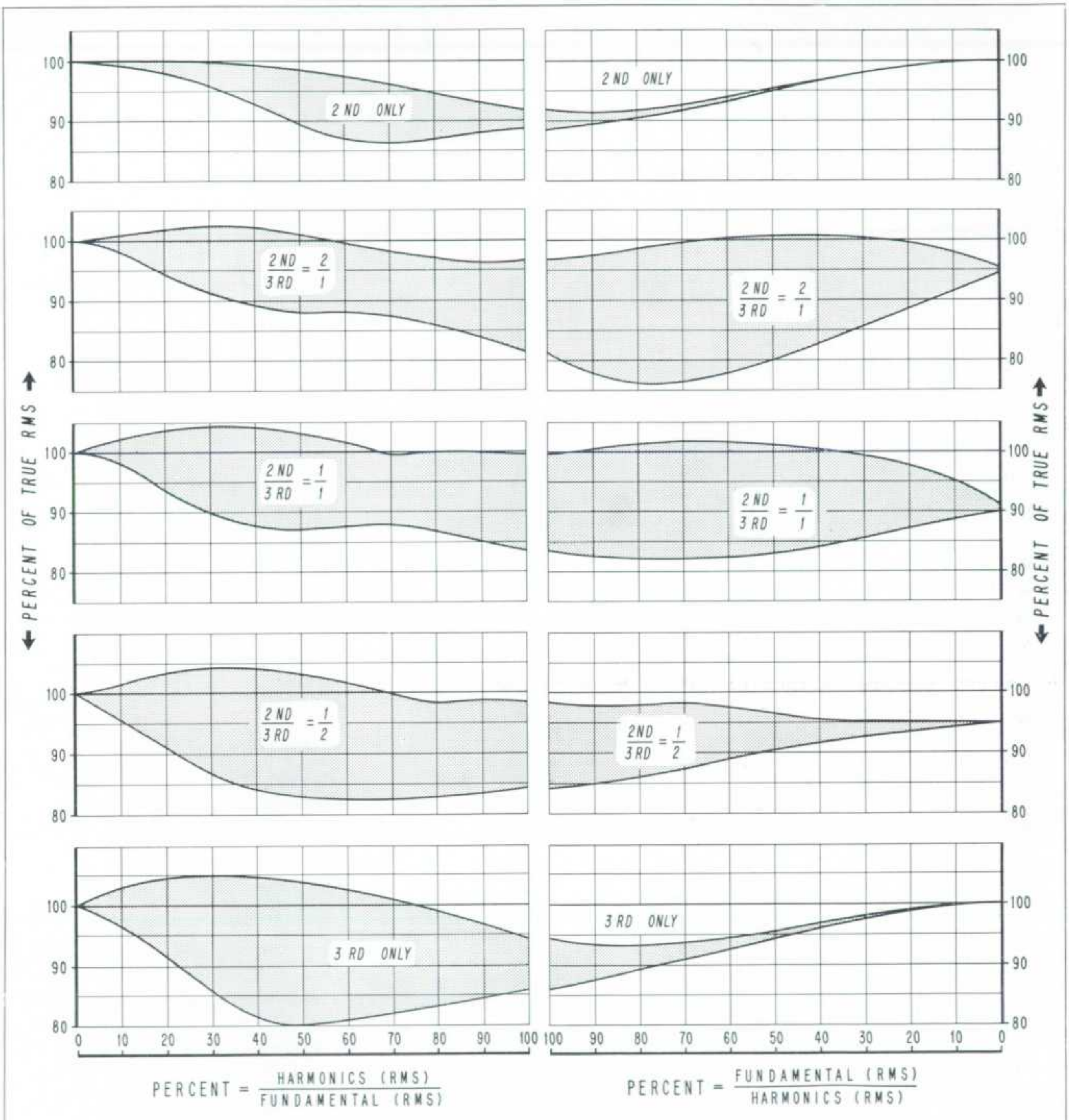

Fig. 7. *Data showing effects of harmonics in various amounts and combinations on average-reading type voltmeter. Curves for* 2nd only *and* 3rd only *on both halves of figure are calculated and experimentally confirmed as explained in text. Note change of scale in right half of figure.*

proximately 1 cps. Then the fundamental frequency was adjusted to beat at 0.1 cps with respect to this combination. The extremes of deflection were then noted during the course of many complete cycles of the lowest beat frequency. The data obtained are plotted as the limits of the shaded areas. The shaded areas thus give the extreme errors for all relative phases of the fundamental and second and third harmonics.

These curves show the tendency of an average-reading meter to read low on complex waves. When the input consists of many inharmonically related sinusoids, the error approaches that for gaussian noise, which is about 11% low as will be shown later.

(Concluded in next issue)

—B. M. Oliver

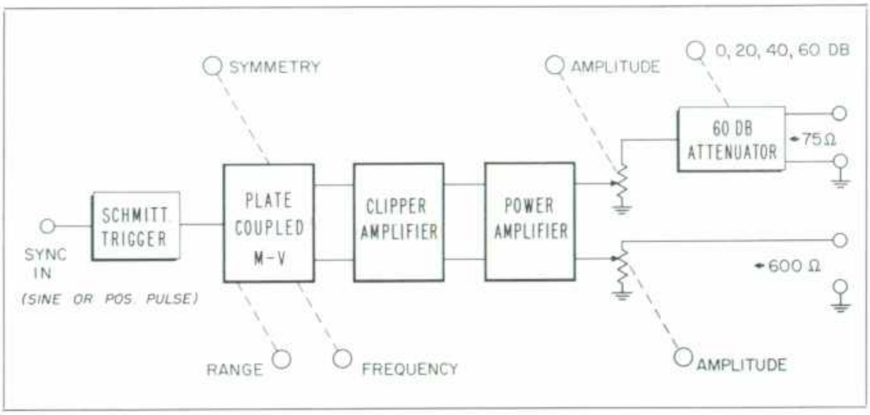

Fig. 3. *Basic circuit arrangement of -hp- 211A Square Wave Generator.*

output is less than 0.1 microsecond. The output level is controlled by an amplitude control separate from that of the first output. Both outputs are usable simultaneously.

The 1 cps - 1 mc range of the generator is covered in six 10:1 bands. The $4\frac{5}{8}''$ diameter frequency dial is linearly calibrated from 1 to 10 cps. Six positions on the frequency range switch multiply these calibrations in decade steps.

CIRCUIT ARRANGEMENT

Fig. 3 shows the circuit arrangement of the generator. For synchronization purposes a Schmitt trigger circuit is located at the front end and is arranged to trigger at less than a 5-volt level from sine waves or positive pulses. The Schmitt circuit provides a fast trigger of uniform rise time and amplitude which aids in obtaining accurate time-switching of the repetition frequency multivibrator. If no synchronizing voltage is used, the repetition frequency multivibrator free runs, its frequency controlled by the frequency control dial.

The multivibrator uses two type 6CL6 power pentodes with precision components in the time constant networks. Any remaining variation in the time constant values or tube characteristics is overcome by a symmetry control which varies the relative plate voltages on the multivibrator tubes. A potentiometer in the time networks serves as the frequency control. A six-position range switch changes the values in the time networks in decade steps.

Two outputs are taken from the repetition-rate multivibrator and applied to a push-pull clipper amplifier consisting of two 6CL6's. In turn the clipper drives four 6CL6's which operate in push-pull parallel as the output power stage. Local feedback is used in the output stage to stabilize against variations in output level as the frequency range is switched or the frequency dial tuned. This feedback, coupled with the fact that the instrument has a regulated power supply, is sufficient to keep the output amplitude essentially constant for a given setting of the output controls over the complete 1 cps to 1 mc rated frequency range. This feature is of considerable convenience in making tests where the driving frequency is changed.

One side of the output amplifier is applied to the 75-ohm output control and 60 db attenuator. The other side is applied to the 600-ohm output control as shown in Fig. 3. Both outputs are direct-coupled and provide their waves as negative-going voltages from ground potential.

The 75-ohm output is provided at a type BNC jack which can be used with a suitable mating connector and 75-ohm (RG-59/U) flexible cable. The 600-ohm output is provided at a pair of binding posts on standard $\frac{3}{4}''$ c-c spacing.

ETCHED CIRCUITS

Physically, the generator is constructed with much of its wiring in the form of etched circuits, a type of construction which gives special advantages in a generator of this type. Besides simplifying the layout and reducing physical size, it reduces stray capacities and stabilizes those that do exist. This results in simplified maintenance procedures because, for example, the peaking coils in the circuit do not require adjustment and it has been found unnecessary to make them an adjustable type.

Mechanically, the generator is provided with a collapsible bail which permits the instrument to be tilted for easy viewing of the front panel. The cabinet construction is such that the equipment chassis is held in the cabinet by guided glides, a feature that facilitates removal of the chassis for inspection or maintenance purposes.

Finally, fan cooling is used to maintain the ambient temperature within the cabinet at a low value.

—Don Broderick

SPECIFICATIONS
-hp-
MODEL 211A
SQUARE WAVE GENERATOR

FREQUENCY RANGE: 1 cps to 1 mc, continuous coverage.

LOW IMPEDANCE OUTPUT: 7.0 v peak-to-peak across 75 ohm internal impedance. Rise time less than 0.02 μsec. BNC connector.

HIGH IMPEDANCE OUTPUT: 55 v peak-to-peak across 600 ohm internal impedance. Rise time less than 0.1 μsec. Dual banana jacks—$\frac{3}{4}''$ centers.

AMPLITUDE CONTROL: Low Impedance Output—Potentiometer and 60 db attenuator, variable in 20 db steps. High Impedance Output—Potentiometer.

FREQUENCY CONTROL: Dial calibrated "1 to 10" and decade multiplier switch. Six bands.

SYMMETRY CONTROL: Allows exact square-wave balance.

SYNC INPUT: Positive-going pulse or sine wave signal, minimum amplitude 5 volts peak. BNC connector.

POWER: 115/230 v $\pm$10%, 50/60 cps, 195 watts.

SIZE: Cabinet Mount: $9\frac{3}{4}''$ wide, $15\frac{1}{4}''$ high, $13\frac{3}{8}''$ deep.

WEIGHT: Cabinet Mount: Net 25 lbs.; shipping weight 55 lbs.

PRICE: -hp- Model 211A Square Wave Generator, cabinet mount, $265.00 f.o.b. Palo Alto, California.

Data subject to change without notice.