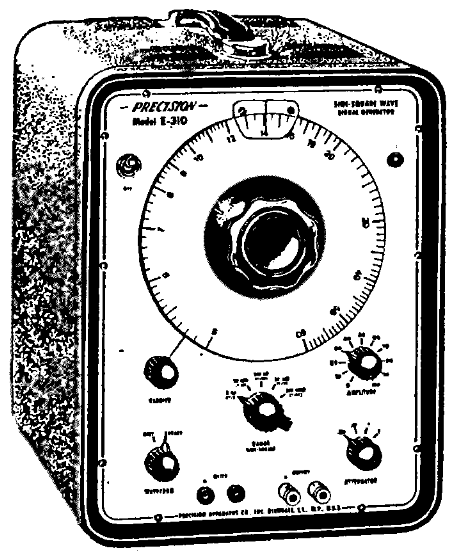
OPERATING INSTRUCTIONS FOR

PRECISION



MODEL E-310

SINE and SQUARE WAVE GENERATOR

(Range 5 cps to 600 kc)

PRECISION TEST EQUIPMENT
Standard of Accuracy

PRECISION APPARATUS COMPANY, INC.

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INTRODUCTION

The Model E-310 is a wide range Audio-Video Generator, providing both Sine and Square Wave Output over the frequency range of 5 cycles to 600 kilocycles.

Its dual-function features have been designed to provide the most efficient, all-inclusive generator facilities for the Laboratory and for the Audio-Video Service Engineer.

A portion of this manual has been prepared for those who may require re-familiarization with Sine and Square Wave fundamentals and testing techniques. Once a good foundation in audio-video test methods is established, the use of Model E-310 will afford considerable streamlining of Amplifier test procedures with resultant savings in time and effort . . . . . and with more uniformly high standards of amplifier performance.

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GENERAL SPECIFICATIONS

Frequency Range
(both Sine and Square Wave Output)

5 cycles to 600 kilocycles in five bands

(fx1). . . . . 5 to 60 cycles

(fx10). . . .50 to 600 cycles

(fx100). . .500 cycles to 6 kilocycles

(fx1K). . . . 5 kilocycles to 60 kilocycles

(fx10K). . . 50 kilocycles to 600 kilocycles

Output Characteristics

Minimum recommended load:- 600 ohms

0-10 volts RMS at 600 ohms load flat within 1 Db

Within 1 Db band to band

Max. power output into 600 ohms, approx. 160 MW

Max. Distortion:- Less than 1%

Max. Hum and Noise:- Less than .1%

Square Wave Rise Time:- .15 microsecond

Square Wave overshoot:- negligible

Calibration Accuracy

1 cycle or 2% - 5 cps to 60 cps

2% 60 cps - 600 Kc

This accuracy specification includes component and tube aging, and dial calibration factor.

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TUBE COMPLEMENT AND FUNCTIONS

1 - 6CB6 Variable Frequency Oscillator

1 - 6CL6 Cathode Follower-Buffer for the 6CB6 VFO

1 - 6BQ7A Square Wave Clipper

1 - 6BL7 Series-connected Push-Pull Output

1 - 6X4 Rectifier

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DESCRIPTION AND FUNCTIONS OF PANEL CONTROLS AND SWITCHES

All panel controls and components are used in identical fashion for either Sine or Square Wave Output. Conversion from Sine Output to Square Wave Output and vice versa is simply accomplished by use of the "Waveform" Switch at the lower left corner of the instrument panel:-

1. "Range" Switch - 5 frequency ranges for both Sine and Square Wave Output are selected through use of this switch.

2. "Output Level" Control & "Output" Controls:- Sine or Square Wave Output from the final amplifier of the E-310 is fed to the "Output Level" potentiometer. The signal from the arm of this potentiometer is then fed to a decade attenuator, controlled by the "Output" knob. Maximum output is therefore obtained with the "Output Level" Control turned clockwise to 100 and with the "Output" Switch set to "x1".

   NOTE: To preserve the optimum characteristics of Square Wave Output, the "Output" knob on the decade attenuator should be kept in the "x1" position. The Square Wave Output is then controlled by use of the "Output Level" Control. This note becomes more important at the upper frequency limit of Square Wave Output. At low frequencies, the "Output" decade attenuator has relatively little effect upon the Rise Time and general characteristics of the Square Wave Output.

3. "Waveform" Switch - This switch converts the Output of the E-310 from Sine to Square Wave or vice versa.

4. "Output" Posts - These posts provide Output termination for Model E-310.

5. "Meter" Panel Jacks - These jacks permit access to the arm of the "Output Level" Control. A low range, wide band AC Voltmeter connected to these jacks will provide monitoring facilities to the input of the decade attenuator. All voltage readings at these jacks should be multiplied by the "x.001", "x.01", "x.1", "x1" factor of "Output" Switch to determine the voltage appearing at the "Output" posts.

6. "Vernier" Knob - This vernier knob provides 12 to 1 reduction ratio in the drive for the main tuning gang assembly.

7. Main Tuning Dial - The frequency of all Sine-Square Wave is indicated directly on this main tuning dial; all readings on this dial must be multiplied by "fx1", "fx10", "fx100", "fx1K", and "fx10K", multiplying factors on the "Range" Switch.

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MISCELLANEOUS FEATURES

Etched-Anodized Tuning Dial and Panel both of heavy gauge aluminum, resistant to moisture and abrasion. NO-glare, engine-turned dial finish and satin aluminum panel field, afford utmost visibility and ease of reading.

Fully licensed under patents of RCA, Western Electric and AT & T.

Full One Year Warranty:- Series E-310, as do all PRECISION products, carries a factory warranty against any defective parts or workmanship for a period of one year from date of purchase. See warranty certificate for complete statement of terms and conditions.

PRECISION Performance, Stability and Accuracy:-

Carefully engineered circuitry, plus preselected-pretested components, plus controlled production-engineering - - - - - assures the highest performance standards to be expected from an instrument such as the Series E-310.

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SET-UP AND TYPICAL APPLICATION

1. Insert the Line Plug into a source of 110/120 volts 50/60 cps power.

   CAUTION:

   Do not connect this instrument to a power source other than that described above UNLESS your particular instrument has been otherwise designed and is so identified.

2. Snap the LINE Toggle Switch ON.

3. Allow a warm-up period (for maximum stability) of about 15 minutes.

We will assume for the purpose of describing a typical application that a simple frequency response test is to be performed on an Audio Amplifier.

4. Set the Controls and Switches of the E-310 as follows:-

   "Waveform" Switch to "SINE"

   "Range" Switch to "50-600"

   "Output Level" Control to approximately 50

   "Output" to "x1"

5. Connect the "G" (Ground) Binding Post of the E-310 to ground of the amplifier; connect the other output post of the E-310 to the input of the amplifier.

6. As an indicator of output from the amplifier, any high impedance AC measuring instrument with flat response over the anticipated frequency range may be used. A VTVM equipped with AC measuring facilities, such as PRECISION Model 68 or 88 may be used; however, the OSCILLOSCOPE is one of the most useful High Impedance Vacuum-Tube-Voltmeters available to the technician-engineer. We will therefore assume that an Oscilloscope such as PRECISION Model ES-550 equipped with a Low Capacity Probe (SP-5A) is connected directly across the output (the speaker voice coil or to the plate of the last amplifier).

7. Set the E-310 Tuning Dial to 60 cps for example and adjust the gain of the 'Scope and the output of the E-310 to obtain a good sized sine pattern on the 'Scope screen, always keeping in mind the caution that the output of the E-310 be kept at a minimum, consistent with operating conditions, in order to minimize the possibility of overloading the amplifier and introducing false indications of distortion.

   Use the "Output Level" Control to set the maximum Output desired from the E-310 and then use the "Output" Switch to reduce the Output from the E-310 by factors of 10.

8. Note the total height of the sine pattern on the 'Scope screen by counting the number of vertical squares it occupies on the 'Scope's calibrated cross-hatch mask. (Peak-to-peak measurement).

9. Now, without touching any other controls or switches, merely rotate the tuning dial of the E-310 to 200 and note the difference, if any, in the height of the sine pattern on the 'Scope.

10. Repeat the procedure for as many frequency points as required to display the curvature of the amplifier response, using the peak-to-peak sine wave amplitude readings as read on the 'Scope's cross-hatch mask.

    NOTE: The flat output of the E-310 permits the use of the generator as noted above without repeated VTVM measurements of direct generator output at the various frequencies.

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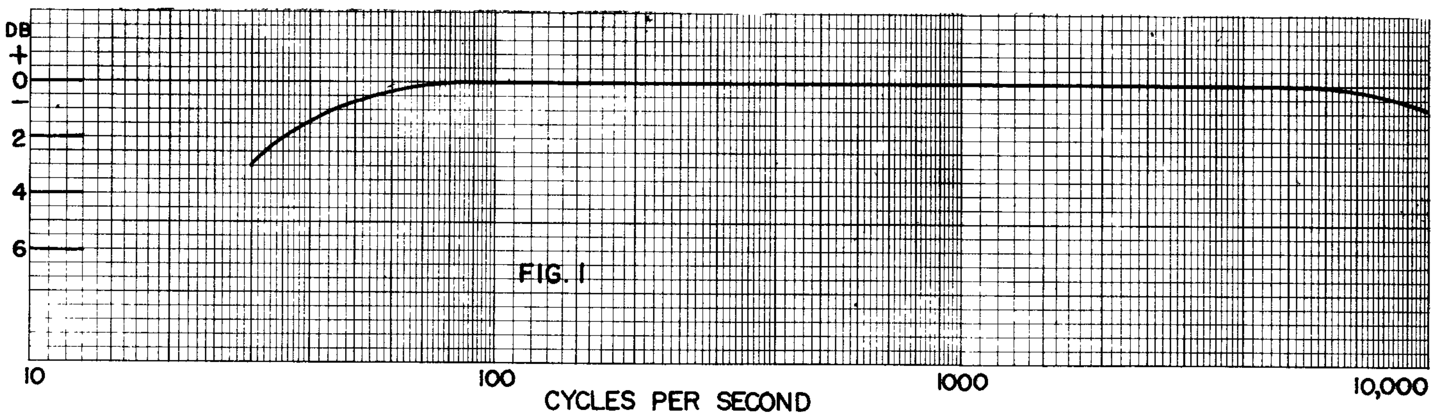
SINE APPLICATION NOTES

The use and application of a Sinusoidal Audio Generator are quite general and varied due to the Basic nature of the output.

One of the more commonly encountered applications is the determination of amplifier frequency response characteristics as previously outlined. The response of a typical audio amplifier as plotted on 3 cycle log paper is illustrated in Fig. 1. Sufficient output readings on the Oscilloscope are taken throughout the range of 30 cps to 10,000 cps to permit a smooth curve to be developed.



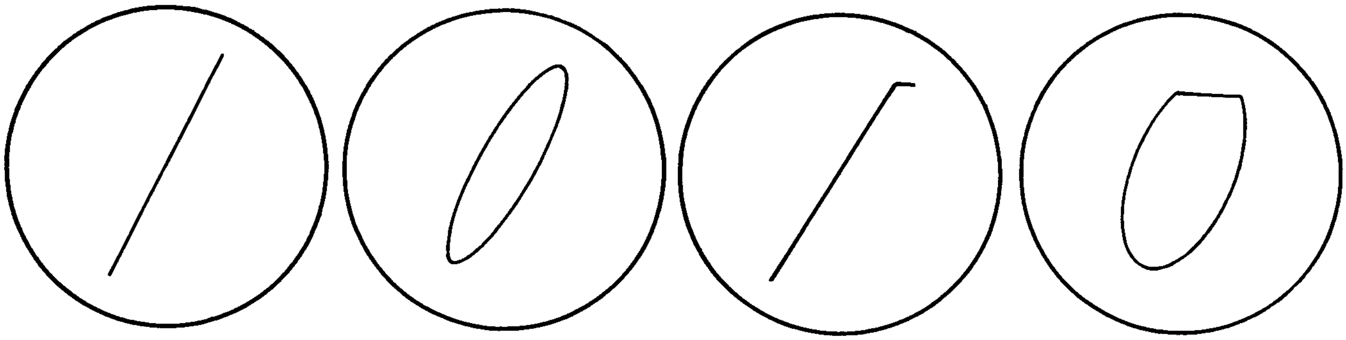
It should be noted at this point that although the point-by-point sine response curve as portrayed in Fig. 1 provides an accurate panoramic view of amplifier response, such a characteristic does not tell the complete story which will include the element of phase distortion. The technique of Square Wave testing, covered later in this manual, provides the required sensitive indication of phase relationships.

The Sine Generator becomes a useful trouble-shooting tool when it is used to locate defective frequency selective circuits in medium and wide-band amplifiers. A low frequency check (applying generator to input and 'scope to output) may indicate the output to be significantly greater than the same identical check at for example 500 cps.

In this case the Generator is being used to indicate the NATURE of the trouble. From then on the experience and background of the technician will assist in locating the exact trouble spot itself.

The sine output of the E-310 can be used in some cases to determine the degree of phase shift in an amplifier at a particular frequency as follows:-

1. Set the sine output of the generator to the desired frequency.
2. Set the LEVEL CONTROL to maximum position and apply the output directly to the Vertical PLATES of an Oscilloscope.
3. Construct a simple resistive voltage divider by connecting a 2000 ohms potentiometer across the Output of the generator. Feed the voltage developed across the arm of the potentiometer and ground to the input of the amplifier under test. (Set the potentiometer for minimum voltage consistent with a sizeable 'scope pattern.) The output of the amplifier is fed directly to the HORIZONTAL Plates of the Oscilloscope. The resulting 'scope waveform will display an elliptical form should phase distortion in the amplifier exist at the test frequency. The degree of phase shift is of course indicated by the shape of the elliptical pattern. (Top or bottom flattening of the elliptical shape indicates overloading produced by excessive input to the amplifier: set potentiometer at a lower level.) See Fig. 2, next page.



In-phase (or 180° out of phase) - no overload distortion

Phase shift - no overload distortion

In phase and overload distortion

Phase shift and overload distortion

FIG. 2

NOTE: The Vertical and Horizontal amplifiers of the 'scope are avoided in this example in order to eliminate whatever small degree of phase shift is inherent in their design. If, however, a PRECISION ES-500A, ES-520 or ES-550 is used, the operator may go thru the 'scope amplifiers inasmuch as all "PRECISION" 'scopes are compensated and corrected for Phase shift.

The Sine Audio Generator becomes especially useful when it is applied to the correction of the usual mis-match between the Loudspeaker in audio systems and the Loudspeaker Enclosure itself.

In most instances the commonly encountered "boomy" Bass response of commercial speaker-enclosure combinations can be transformed into smooth natural response which is characteristic of the well designed and adjusted audio system.

A brief method of checking a Bass Reflex speaker system is detailed as follows:-

1. Connect the variable sine output of the E-310 in series with a 100 ohm resistor to the speaker voice coil.

2. Connect an A. C. Voltmeter or 'scope across the speaker voice coil.

3. Determine the two low frequency resonant peaks in the system by noting peak voltmeter readings. The frequency of these peaks will vary with the size of the speaker and cabinet but should occur in the region between 40 and 150 cycles. In a properly tuned system the two peaks should be rather broad and of approximately the same amplitude. If one of the peaks is greater than the other, try damping the port with additional layers of grille cloth.

Other applications of the sine generator will suggest themselves to the technician and engineer in the course of test and design of electronic equipment. A few examples are use of the Generator to externally modulate R.F. generators over a wide range of frequencies; to externally power Impedance Bridges at frequencies other than those standardly provided; Direct check of Loudspeaker operation, using matching transformers where required; check of record equalization positions on Preamplifiers; source of potential for capacitance checks using capacitative divider and an AC VTVM; and other diversified applications.

SQUARE WAVE APPLICATION NOTES

The square wave output of the E-310 can be utilized to graphically display and reveal various types of distortions in electronic circuits.

However before attempting to correlate circuit analysis with Square wave shapes, it might be well to establish the "make-up" and significance of the Square Wave itself.

A theoretically perfect Square Wave can be considered to be comprised of an infinite series of sine waves. This statement is an expression of "Fourier's Theorem" which says that "ANY SINGLE-VALUED CONTINUOUS PERIODIC QUANTITY CAN BE EXPRESSED AS AN INFINITE SERIES OF SINE WAVES". More specifically, in the case of the Square Wave, the wave is made up of a large number of ODD HARMONICS, 1st, 3rd, 5th . . . . etc., etc.

Fig. 27 on Page 19 illustrates the basic make-up of a Square Wave. All ODD-NUMBERED harmonics are shown in in-phase relationship, ie: each sine wave in the series begins its cycle at the beginning of the Square Wave cycle. To develop the Square Wave in Fig. 27, it is merely necessary to draw a number of vertical lines thru the Square Wave and to add, Algebraically (observing polarity), the magnitudes of the sine waves along this vertical line. For the sake of simplicity, we will, of course, only consider the harmonic content up to the 9th harmonic in order that the sketches be made sufficiently illustrative.

At "A_1" for example, we have algebraically added the Fundamental, 3rd, 5th, 7th and 9th Harmonic with the resultant summation at point B_1. If we repeat this same algebraic summation of wave magnitudes along a large number of vertical "check" lines, we will obtain a RESULTANT wave shape which will of course turn out to be the Square Wave which we had started out to analyze.

This graphical analysis over 1/2 cycle immediately reveals a striking SYMMETRY to the left and right of the "vertical axis" for all harmonics. All harmonic wave trains are seen to begin the 1/2 cycle at zero amplitude and to end the 1/2 cycle at zero amplitude with the proper symmetry to left and right of the Vertical axis to equally "build up" both corners of one half cycle of the resultant Square Wave. If Even-Numbered harmonic waveshapes (2nd, 4th, 6th, etc.) were introduced into the content of a Square Wave, obvious distortions of the Square Wave would be produced because of its non-symmetrical contributions of a 1/2 cycle of the Square Wave.

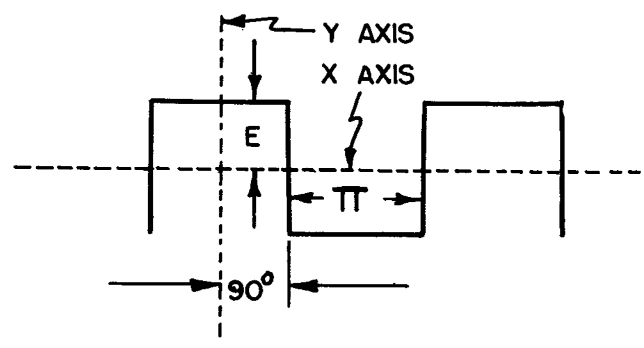
If all sine components of the Square Wave are beginning the 1/2 cycle at zero amplitude, they are of course In-Phase. In a well proportioned and shaped Square Wave we then have a whole series of Sine waves varying in frequency from low to very high, all in phase and all in a related amplitude. (The amplitude of any particular harmonic is in inverse relationship to the order of the harmonic. In other words the 3rd harmonic content has an amplitude one third that of the fundamental component, etc.).

Fourier's Theorem indicates the amplitude relation by the fraction preceding each mathematical expression for the harmonic element as noted in the illustration below.

FUNDAMENTAL, 3RD HARM., 5TH HARM., 7TH HARM.

$$Y = \frac{4}{\pi}E\left(\sin x + \frac{1}{3}\sin 3x + \frac{1}{5}\sin 5x + \frac{1}{7}\sin 7x + \cdots\right)$$

$$\ldots\ (\cos x - \frac{1}{3}\cos 3x + \frac{1}{5}\cos 5x \ldots)$$



When we apply a well-shaped Square Wave to the input of, for example, a wide band amplifier, we are, in effect, applying a large number of sine waves which must pass through the amplifier in the same phase relationship and with the same relative amplitude in order to "come out" of the amplifier the same well-shaped Square Wave as was applied to the input of the amplifier.

But to continue with the analysis of the Square Wave itself.

Fig. 27 cannot of course begin to illustrate the practically infinite number of harmonics which constitute a Sharp Square Wave. But if one takes Line "A_1" of Fig. 27 and imagines the presence of in-phase harmonics as high as the 100th or 500th and if we understand that we are to ADD all components up, to locate the resultant point on the Square Wave which is produced, we begin to see that a good Square Wave may start at 1/2 cycle at zero amplitude, BUT it builds up to MAXIMUM amplitude in a very small fraction of the 1/2 cycle (practically instantaneously).

This "build-up" from 10% above zero amplitude to 90% of Maximum amplitude is appropriately termed "RISE TIME" of the Square Wave and is an important factor in the composition of the Square Wave.

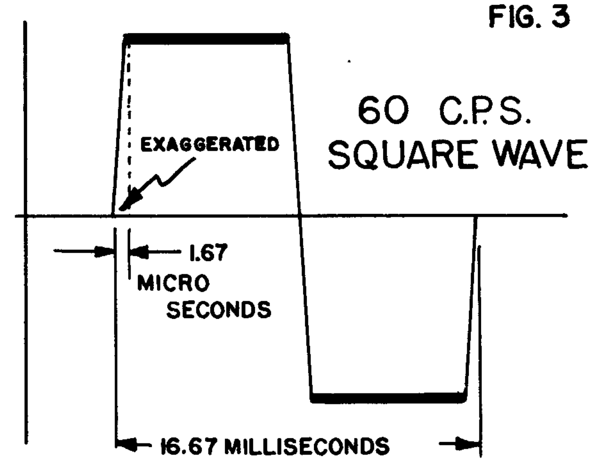
If we consider the time axis of Fig. 3 which illustrates a 60 cps Square Wave, we see that the BASIC alternation of waveshape is 60 cps but if we look closely, we see that the fast rise of amplitude from zero to maximum occurs in far less time than one sixtieth of a second and actually constitutes a relatively high frequency alternation. This leading edge of a Square Wave which includes the duration of the Rise Time, is a sensitive indication of the high frequency characteristic of the circuit to be tested.

In Fig. 27 we see that the shape of the flat top portion of the 1/2 cycle is influenced most strongly by the low order harmonics, ie: 3rd, 5th, etc. Should the AMPLITUDE of the fundamental, for example, be reduced below the value required for good square wave shape, an obvious curvature appears along the Square Wave top as illustrated in Fig. 4. On the other hand, in a theoretical case a reduction in Amplitude alone of the HIGH FREQUENCY components would have no noticeable effect on the flat top because of the "balancing-out" effect created by the multiplicity of alternations along the flat top as indicated in Fig. 5.

We have already noted that short RISE TIME which occurs at the beginning of the 1/2 cycle is created by the in-phase sum of all the medium and high frequency Sine components. The same holds true for the rapid drop at the end of the 1/2 cycle from maximum amplitude to zero amplitude at the 180° or 1/2 cycle point. Therefore, a theoretical reduction in amplitude alone of the high frequency components should produce a rounding of the square corners at all four points of one Square Wave cycle. (See Fig. 20, Page 18).

Thus far we have indicated that a useful Square Wave has fast Rise Time and well-squared proportions. Inasmuch as the Square Wave is to be observed on a 'scope, it might be wise to interpret the appearance of a Square Wave at various fundamental frequencies.

FIG. 3



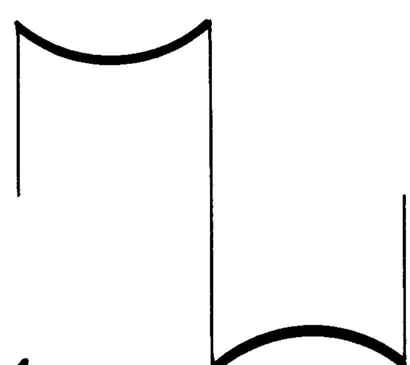


FIG. 4

If we first observe a 50,000 cps Square Wave directly on a wide-band 'scope, we will probably notice a fairly sharp rise-time. (See Fig. 6). A 50,000 cps Square Wave has a 20 Microseconds duration for ONE CYCLE. The Rise-Time in this case might be .05 Microsecond or one four-hundredth of one cycle. On this basis, if we should decide to establish a ratio between Square Wave cycle and Rise-Time of 400 to one, we would find that a similarly shaped 80 cps Square Wave with the same relatively sharp Rise-Time would have a rise time of 31 Microseconds, a much longer rise time than .05 Microseconds, but perfectly usable at an 80 cps fundamental Square Wave Frequency.

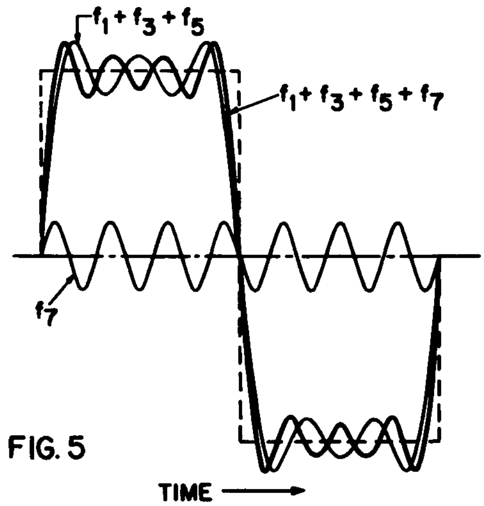


FIG. 5

Courtesy John F. Rider Publishing Co.

It becomes evident that the value of Rise-Time cannot be quickly determined by the appearance alone of the waveshape on the 'scope. A 60 cps Square Wave with a 15 Microsecond Rise-Time will appear to have shorter Rise-Time than a 50,000 cps Square Wave with a .05 Microsecond Rise-Time - See Figs. 6 and 7.

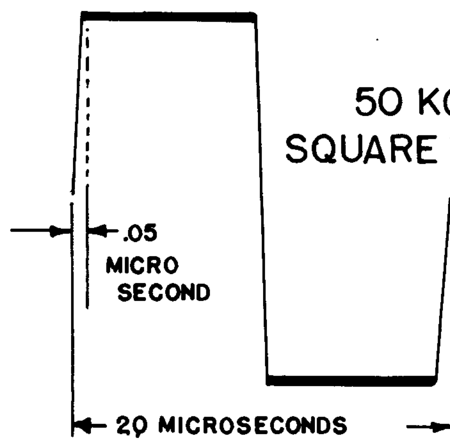


FIG. 6

The basic operation of the Oscilloscope itself contributes to misleading appearance of Rise-Time. To observe a single cycle of Square Wave at 30 KC the 'scope beam is travelling at a relatively fast rate and the Rise-Time portion of the trace is being traced by the 'scope beam many more times per second as compared to a 60 cps Square Wave, for example: The Rise-Time portion of the 60 cps Square Wave may then appear extremely sharp, being practically invisible, wherein the Rise-Time of the 30 KC may show relatively bright and thereby appear to be much slower than it really is.

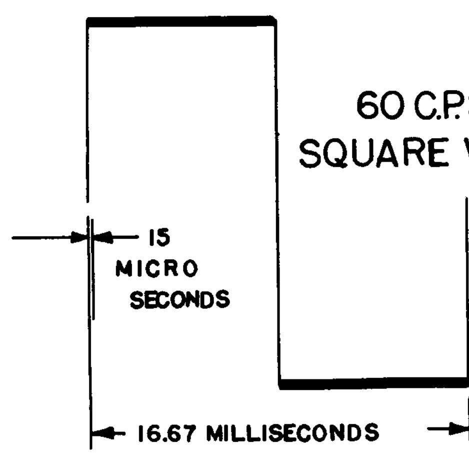


FIG. 7

At this point, it would be helpful to establish the relationship between Rise-Time and the amplifier bandwidth required to transmit the leading edge of the Square Wave: Any cyclic time duration per cycle can be converted to frequency in cps as follows:

A. $\text{Frequency in CPS} = \dfrac{1 \times 10^6}{\text{Time in Microseconds for one cycle}}$

OR

B. $\text{Time in Microseconds for one cycle} = \dfrac{1 \times 10^6}{\text{Frequency in CPS}}$

If we substitute .05 Microseconds in the denominator of "A", Frequency becomes 20 Megacycles.

However, it is generally recognized that if we are dealing with the special case of Rise-Time of a Square Wave, the expression becomes:

$$F_{cps} = \frac{1 \times 10^6}{2T} = \frac{1 \times 10^6}{2 \times .05\mu s.} = 10 \text{ Mc.}$$

or a minimum Bandwidth of 10 Mc is required to satisfactorily transmit the leading edge of a Square Wave with .05 Microsecond Rise-Time.

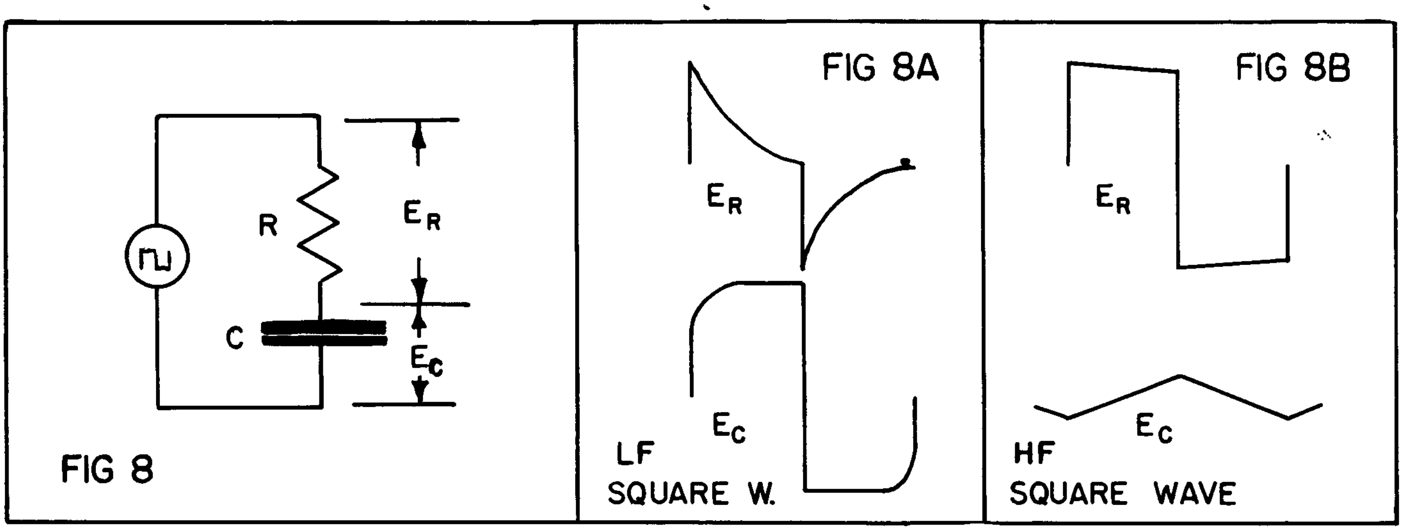
It is significant to note that the Rise Time portion of the Square Wave determines the bandwidth required to faithfully reproduce the Square Wave. Should one Square Wave be twice the Fundamental frequency of another, but both have the same Rise Time, then the SAME bandwidth (determined by the Rise Time) will be required by both for accurate reproduction.

The preceding discussion leads us to the conclusions that a good Square Wave can be faithfully transmitted through an amplifier or network only if the network does not selectively suppress the amplitude of a harmonic or harmonics; does not shift the relative PHASE of a harmonic or harmonics; and DOES have sufficiently wide AND linear bandwidth (in the case of an amplifier) to permit accurate reproduction of the Rise Time portion of the cycle.

Inasmuch as minor deviations from the above requirements result in distortion of the Square Wave, we are logically led into a discussion of the interpretation of Square Wave distortions and their significance.

As an example, let us take a simple RC circuit energized by a Square Wave potential.

If time duration of a cycle of the Square Wave is quite long as compared to the TIME CONSTANT (R in Megohms x C in Microfarads) of the RC network shown in Fig. 8, then we can say we are applying a relatively LOW FREQUENCY Square Wave to the network.



In such a case, the waveform across C would appear as E_c in Fig. 8A and the waveform across R would appear as E_r in Fig. 8A.

If we consider the RC network as a simple filter, then we can analyze the rounded corners of E_c in Fig. 8A as an indication of High Frequency component attenuation. In other words, the reactance of the capacitor at the higher component frequencies becomes lower, dividing DOWN the higher components. Conversely most of these higher components now appear across R, producing the excellent leading edge for E_r, Fig. 8A.

Now, if we change the frequency of the Square Wave such that the time duration of a cycle is relatively SMALL as compared to the RC time constant, then we can say that we are applying a HIGHER frequency Square Wave to the network.

In such a case, the waveform across C might appear as E_c in Fig. 8B.

Continuing the filter analysis, E_c of Fig. 8B results from the fact that the relative reactance of C is low for all frequencies of the Square Wave inasmuch as we are applying a relatively High Frequency Square Wave to begin with. Therefore the voltage across C shows "poor" high and low frequency "response".

E_r of Fig. 8B indicates the divider action of the filter which produces relatively low reactance for the highs and lows and results in the appearance of these components across R.

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GENERAL SQUARE WAVE TESTING OF AMPLIFIERS

Distortion can be classified into three distinct categories:-

The first is FREQUENCY distortion and refers to the change from normal amplitude of a component of a complex waveform. In other words, the introduction in an amplifier circuit of resonant networks or selective filters created by combination of reactive components will create peaks or dips in an otherwise flat frequency response curve.

The second is NON-LINEAR distortion and refers to a change in waveshape produced by application of the waveshape to non linear components or elements such as vacuum tubes, an iron core transformer, and, in an extreme case, a deliberate non-linear circuit such as a clipper network.

The third is DELAY or PHASE distortion, which is distortion produced by a shift in phase between one or more components of a complex waveform.

In the examples used up to this point, we discussed "amplitude" reduction of a particular component in a Square Wave as though it occurred independently of Phase distortion or was produced by a non-linear element. In actual practice however, a reduction in AMPLITUDE of a Square Wave component (sinusoidal harmonic) is usually caused by a Frequency Selective network which includes capacity, inductance, or both. The presence of the C or L introduces a difference in phase angle between components creating PHASE distortion or Delay distortion.

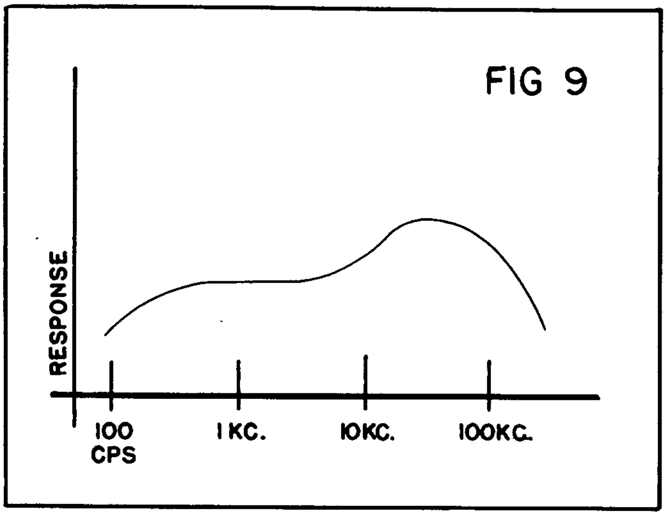
Therefore, in Square Wave testing of practical circuitry, we will usually find that the distorted Square Wave includes a COMBINATION of Amplitude AND Phase distortion clues.

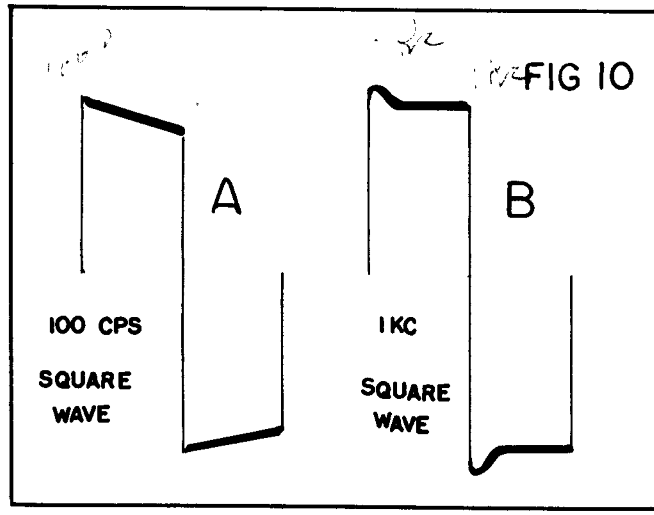
If we now proceed to the application of Square Waves to a typical wide band amplifier, we find that a Square Wave check accurately reveals many distortion characteristics of the circuit:-

The response of an amplifier is indicated in Fig. 9 revealing poor low frequency response along with overcompensated high frequency boost.

A 100 cps Square Wave applied to the input of this amplifier will appear as in Fig. 10A. This figure indicates satisfactory medium frequency response (approx. 1 KC to 2 KC) but shows poor low frequency response.

Next, a 1000 cps Square Wave applied to the input of this same amplifier will appear as in Fig. 10B. This figure displays good frequency response in the region of 1000 to 4000 cps but clearly reveals the overcompensation at the higher 10 KC region by the sharp rise at the top of the leading edge of the Square Wave.





As a rule of thumb, it can be safely said that a Square Wave can be used to reveal response and phase relationships up to the 15th or 20th odd harmonic or up to approximately 40 times the fundamental of the Square Wave. Using this rule of thumb, it is seen that wide band circuitry will require at least a two-frequency check to properly analyze the complete spectrum. In the case illustrated by Fig. 9, a 100 cps Square Wave will encompass components up to about 4000 cps. To analyze above 4000 cps and beyond 10,000 cps, a 1000 cps Square Wave should be satisfactory.

Now, the region between 100 cps and 4000 cps in Fig. 9 shows a rise from poor Low Frequency response to a flattening out from between 1000 and 4000 cps. Therefore we can expect that the higher frequency components in the 100 cps Square Wave will be relatively normal in amplitude and phase but that the lower frequency components in this same Square Wave will be strongly modified by the poor Low Frequency response of this amplifier. See Fig. 10A.

If the combination of elements in this amplifier were such as to only depress the Low Frequency components in the Square Wave, a curve similar to Fig. 4 would be obtained. However, reduction in amplitude of a component, as already noted, is usually caused by a reactive element causing, in turn, a phase shift of the component, producing the strong tilt of Fig. 10A. Fig. 30 on Page 19 reveals the graphical development of a similarly tilted Square Wave. The tilt is seen to be caused by the strong influence of the phase-shifted 3rd harmonic. It also becomes evident that very slight shifts in phase are quickly shown up by tilt in the Square Wave.

Fig. 27 to Fig. 30 at the end of the book reveals a few of the various distortions in Square Wave shape which can be produced by modifying harmonic components either phase-wise or in amplitude.

Fig. 29 indicates the tilt in Square Wave shape produced by a 10° phase shift of a low frequency element in a leading direction. The tilting shape of the resultant wave results from the simple algebraic addition of all components along a vertical line as has been previously noted in this discussion.

Fig. 28 also indicates a 10° phase shift in a low frequency component in a lagging direction. The tilts are opposite in the two cases because of the difference in polarity of the phase angle in the two cases as can be checked through algebraic addition of components.

Fig. 22 indicates low frequency components which have been reduced in amplitude and shifted in phase. It will be noted that these examples of low frequency distortion are characterized by changes in shape of the FLAT TOP portion of the Square Wave.

Fig. 10B previously discussed, revealed High Frequency "overshoot" produced by a rising amplifier response at the higher frequencies. It should again be noted that this overshoot makes itself evident at the top of the "leading" edge of the Square Wave. This characteristic relationship is explained by remembering that in a normal well-shaped Square Wave, the sharp rise at "0" is created by the summation of a practically infinite number of harmonic components rising in amplitude from "0". If an abnormal rise in amplifier response occurs at High frequencies, the High Frequency components in the Square Wave will be amplified disproportionately greater than other components creating a higher algebraic sum along the leading edge.

Fig. 11 indicates high frequency boost in an amplifier accompanied by a lightly damped "shock" transient. The sinusoidal type of diminishing oscillation along the top of the Square Wave indicates a transient oscillation in a relatively high "Q" network in the amplifier circuit. In this case, the sudden transition in the Square Wave potential from a sharply rising relatively high frequency voltage to a level value of low frequency voltage supplies the energy for oscillation in the resonant network. If this network in the amplifier is reasonably heavily damped, then a single cycle transient oscillation may be produced as indicated in Fig. 12.

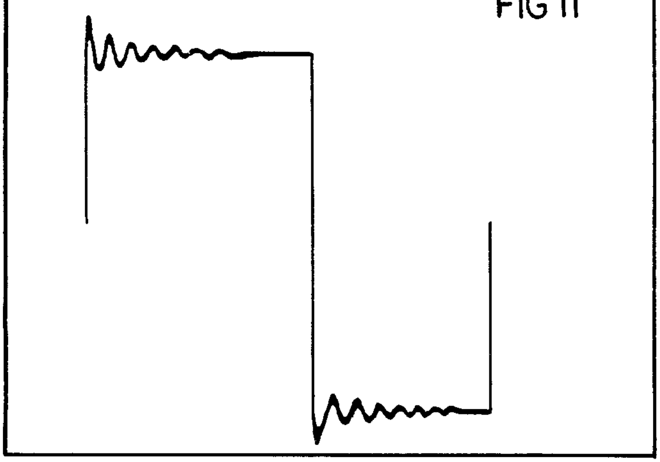


FIG 11

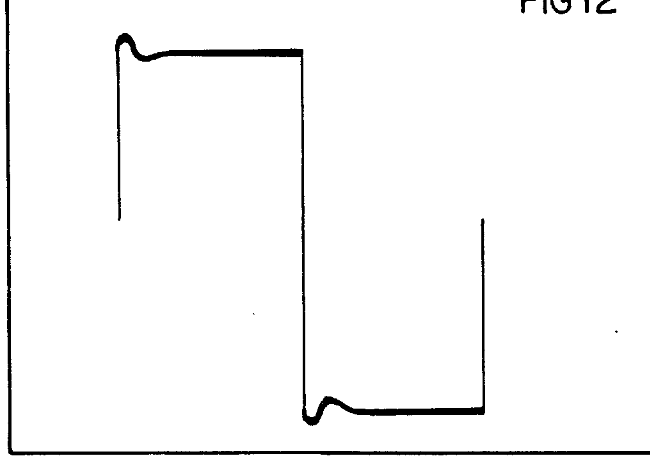


FIG 12

VIDEO AMPLIFIER TESTING

A common application of the Square Wave Output of the E-310 is its use in the testing of TV Video amplifiers. In actual operation, when amplifying picture information, the Video Amplifier must be capable of reproducing and amplifying rapid transitions from white to black and vice versa. These transitions are the equivalent of steep wave fronts and can be effectively simulated by substitution of a Square Wave Voltage.

We have already noted that the Square Wave is quite sensitive to Time delay or Phase shift between components of a complex Wave. In the Video Amplifier, maintenance of a linear Phase Characteristic is quite important inasmuch as Phase distortion in the amplifier can cause certain picture elements to arrive out-of-step time-wise creating detail interference or smear.

The instrument setup for checking a Video Amplifier is as follows:-

1. Set up the E-310 for 250 Kc Square Wave Output. Connect the "G" post to chassis and the High post to the grid of the 1st Video Amplifier through a .01 mfd capacitor.

2. Detune the front end or disable the local oscillator to prevent station information from interfering with the test waveform.

3. Connect the Output of the Video Amplifier (input of the CR tube) directly to the Vertical plates of the 'Scope (UNLESS a wide-band 'Scope such as PRECISION ES-550 is being used. If an ES-550 is used, then the Output of the Video Amplifier may be connected to the 'Scope's amplifier.)

4. Sync the 'Scope to obtain a stationary pattern on 250 Kc Square Wave.

5. A Square Wave pattern similar to Fig.13 indicates:-

   A. "Ringing" or shock oscillation of one or more of the peaking coil circuits used to compensate the Video Amplifier at the higher frequencies.

   B. Phase shift at the higher frequencies indicated by rounding off of the leading corner of the Square Wave.

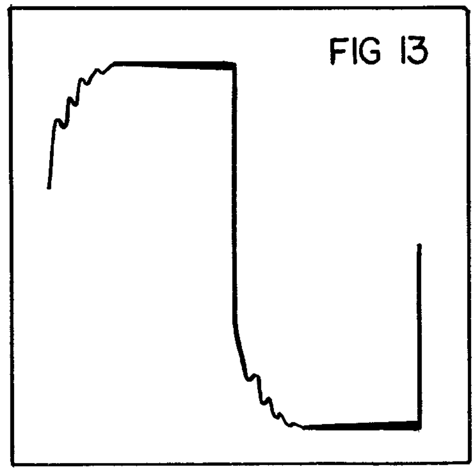


FIG 13

It must be borne in mind that a Square Wave test at 250 Kc is examining the characteristic of the amplifier from 250 Kc on UP and therefore indicates conditions at the Higher frequency limit of the amplifier. A 250 Kc Square Wave test however indicates nothing concerning the Low Frequency end.

Therefore it becomes apparent that a two-frequency Square Wave test of Video Amplifiers becomes a minimum necessity:-

One at 250 Kc which effectively reveals conditions from its fundamental frequency on up to the high limit of the Video Amplifier,

AND

One at approximately 60 cps which discloses the Low Frequency characteristic.

A third frequency in the region between 60 cps and 250 Kc may be used if desired; however, the two-frequency check is usually sufficient.

6. Next, to perform this Low Frequency Square Wave check, set the E-310 for Sine Wave Output at approximately 70 cycles.

7. Set the "Output Level" and "Output" knobs to provide Output as will produce a sizeable pattern on the 'Scope.

8. Set the tuning dial to approximately 70 cps and set the two "Output" Controls to as low a value as will produce a sizeable pattern on the 'Scope.

   NOTE: 70 cps is recommended instead of 60 cps in order to make 60 cycle hum modulation visible as a wavy reaction and not as a tilt distortion which might occur if the generator were accurately set to 60 cycles.

9. The relatively flat top of the resultant 70 cycle Square Wave of Fig. 14 indicates good Low Frequency response and insignificant Low Frequency phase shift. No rounding of the leading edge indicates no distortion of the HIGHEST FREQUENCY COMPONENTS IN THE 70 CPS SQUARE WAVE. The high components in this low frequency Square Wave do not approach the megacycles portion of the Video Amplifier response curve as far as ability to influence the shape of the Square Wave is concerned.

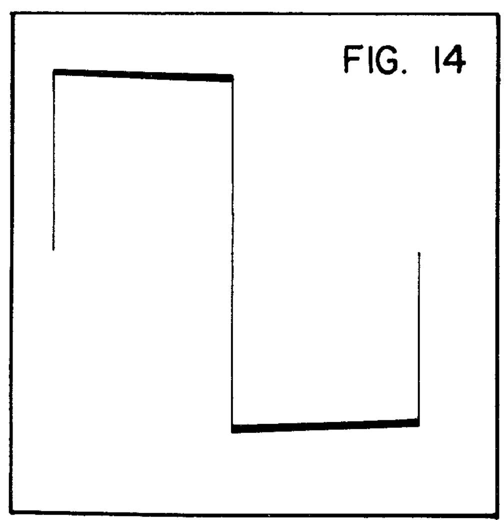


FIG. 14

However, if the frequency range of the E-310 is gradually increased up to 20 Kc, a progressive rounding of the leading corner will be noted. The small-radius corner at 20 Kc (See Fig. 15 is just as significant to the observer as the large-radius corner at 250 Kc (See Fig.13) if it is kept in mind that compression or reduction of the radius is a logical result of reducing the fundamental frequency of the Square Wave such that progressively higher frequency components are indicating the high frequency distortion. As the fundamental frequency of the Square Wave is reduced back down to 70 cps, the high frequency components which might conceivably affect the leading edge of the Square Wave are so high in order and therefore so insignificant in amplitude as to have negligible effect on the resultant Square Wave.

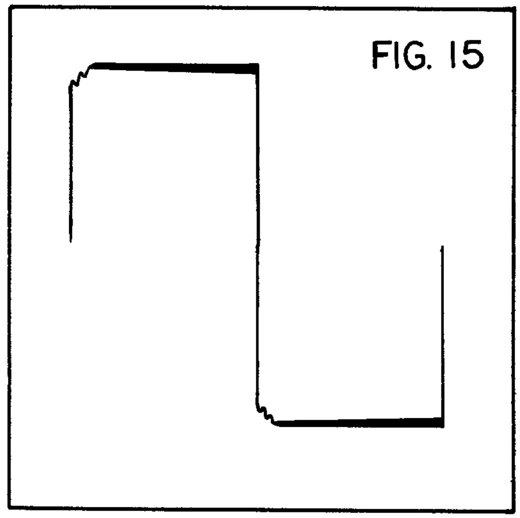


FIG. 15

We can therefore expect high frequency distortion to appear as a progressively larger rounding of the leading edge of a Square Wave as the frequency of the Square Wave is increased from a low value up towards a value approximately one-twentieth of the upper portion of the amplifier response spectrum. (Ten odd harmonics).

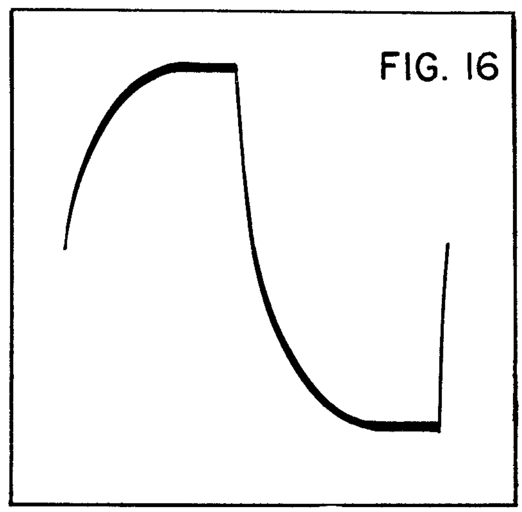


FIG. 16

But to go back to the 250 Kc Square Wave illustrated in Fig. 13. The degree of lead-edge rounding appears to be quite large; however, a reference for comparison must be established before the observer can decide when rounding is excessive. Fig. 16 therefore indicates the degree of rounding of a 250 Kc Square Wave which correlates with a condition of fuzzy picture detail indicating significant High Frequency loss.

It is important that the observer correlate the degree of rounding with the fundamental of the Square Wave being used, ie: had a 50 Kc Square Wave been used in the previous example, the rounding would have been less exaggerated; however, the analysis should be the same, meaning that the observer should be able to picture the degree of rounding of a 50 Kc Square Wave wherein a condition of fuzzy picture detail exists.

The sharp Rise Time of the Square Wave generated by the E-310 may induce ringing in a Video Amplifier (as observed on the 'Scope) where peaking coils are used to boost the high frequency response. The degree of ringing can be controlled by changing the value of the damping resistors across the peaking coils. It is mainly a matter of experience with particular TV sets as to what degree of ringing will cause deterioration of picture quality. The technician should attempt to arrive at a compromise between ringing and rounding of the leading edge of a Square Wave.

To sum up the basic principles of Video Amplifier Square Wave Testing, it should be said that experience in correlating Square Wave shape at particular fundamental frequencies with actual picture quality will fortify the technician with a series of reference Square Wave shapes against which new Trouble Jobs can be compared. No generalized textbook discussions can substitute for this kind of experience in Square Wave Testing.

* * * * * * *

Use of the E-310 as a PATTERN LINEARITY CHECKER:

We have noted previously that the abrupt rise of a Square Wave from zero amplitude to a maximum in a fraction of a cycle is analagous to the transition of a TV raster line from dark to light. It becomes obvious that the application of a Square Wave of the proper frequency to the video amplifier will produce alternating black and white lines with sharp definition.

The horizontal synchronizing pulses of a TV set is 15.750 KC. A Square Wave of 252 KC will therefore produce 16 Vertical pairs of black and white lines.

By the same token, a satisfactory number of Horizontal black and white alternations or lines can be produced by feeding a Square Wave at any desired multiple of 60 cps into the video amplifier. The E-310 therefore supplies the two rasters required for simplified linearity adjustments.

NOTE: Similar result will be obtained using sine wave output: the definition between black and white lines will be sharper with Square Wave as compared to the sine, however.

* * * * * * *

SERVICE AND MAINTENANCE NOTES

IN ALL CASES WHERE FAULTY OPERATION OF THE INSTRUMENT IS SUSPECTED, THE SERVICE DEPARTMENT OF PRECISION APPARATUS COMPANY, INC., SHOULD FIRST BE CONSULTED. SHOULD THE SERVICE DEPARTMENT RECOMMEND RETURN OF THE INSTRUMENT TO THE FACTORY, THE COMPLETE INSTRUMENT WITH ALL ITS CABLES SHOULD BE CAREFULLY PACKED IN A STRONG CORRUGATED SHIPPING CARTON AND ADDRESSED TO:-

PRECISION APPARATUS COMPANY, INC.
70-31 - 84th Street
Glendale 27, L. I., N. Y.
U. S. A.

Att: SERVICE DEPARTMENT

IMPORTANT NOTE: The original carton and fillers of the Series E-310 are admirably suited for this purpose.

IMPORTANT

If ever the Series E-310 is to be returned to the factory for repair, A COMPLETE description of faulty operation as noted by the operator MUST accompany the instrument. The more details submitted to the Service Department of PRECISION, the more quickly and efficiently the instrument can be repaired and returned. It is very important that this description of faulty operation be described in unusually exact detail due to the fact that in many cases, faulty operation can be traced to difficulties in other items of test equipment and/or to improper analysis of results obtained.

YOUR SERIES E-310 SINE-SQUARE WAVE GENERATOR IS A RELATIVELY CRITICAL AND DELICATE INSTRUMENT. DO NOT ATTEMPT ANY MAJOR REPAIRS OR ALIGNMENT BEFORE CONSULTING THE SERVICE DEPARTMENT OF PRECISION APPARATUS COMPANY, INC.

* * * * * * *

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3. Obtaining and Interpreting Test Scope Traces
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5. Arguimbau, L. B., Vacuum-Tube Circuits
   John Wiley and Sons, Inc., Publishers

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U. S. A.

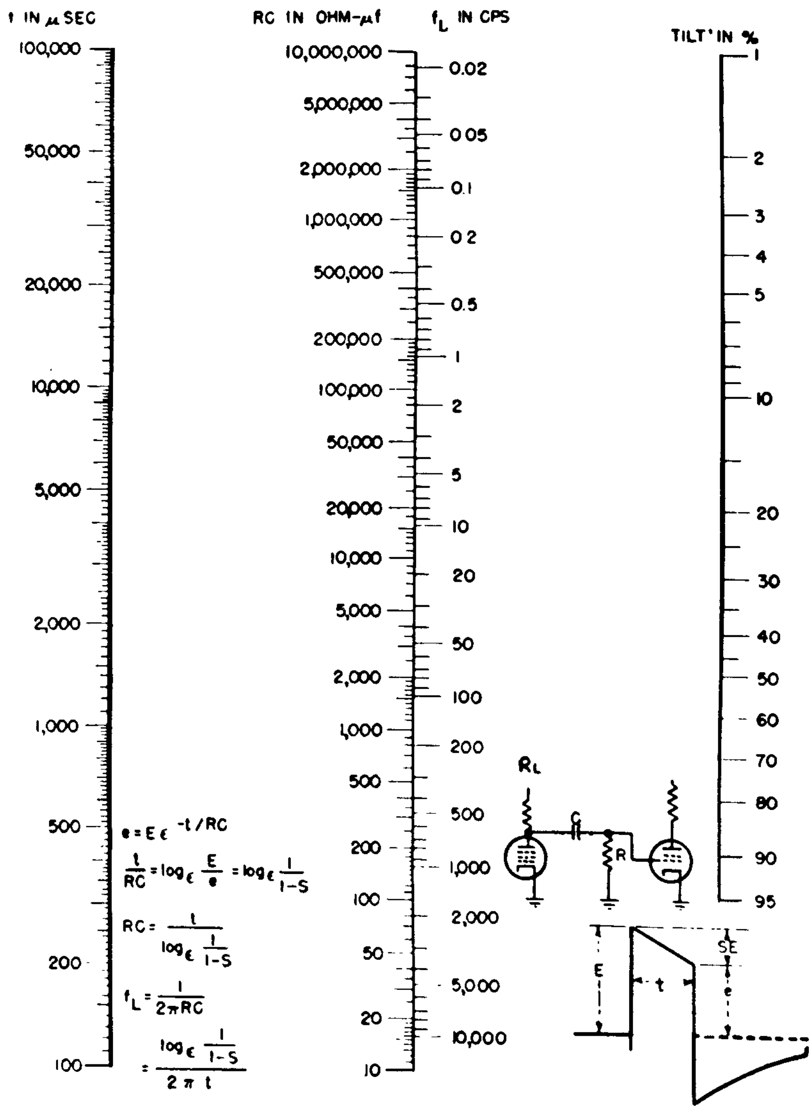
SQUARE-WAVE RESPONSE NOMOGRAPH

Correlates tilt of Square Wave after passage through uncompensated RC-coupled video or audio amplifier with low-frequency response of amplifier and time constant of coupling circuit.

By A. J. Baracket
Dept. Head, TV: Federal Telecommunication Laboratories

When using rectangular or Square Waves for testing audio and video amplifiers, the output of the amplifier is compared with the input on an Oscilloscope. The degree or percent of tilt of the top of the Square Wave represents the amplifier's deterioration of the lower frequencies.

In the uncompensated RC-coupled amplifier stage shown, the effect of the amplifier on low frequencies is almost completely a function of the value of the RC time constant in the grid coupling circuit. The smaller the time constant, the poorer the low-frequency response and consequently the greater the percent tilt "S" of a rectangular wave (referred to the peak voltage value "E" as indicated on the waveform diagram).



The accompanying nomograph is useful in computing the RC value required to give a maximum specified Tilt "S" (expressed as a decimal part of "E") for a rectangular wave having a duration "T"or, conversely, it may be used to determine the tilt that will be obtained from a given time constant. The chart also gives the relationship between tilt and low-frequency cutoff of an amplifier coupling circuit (the frequency Fl at which the amplitude-frequency response characteristic is down 3 DB).

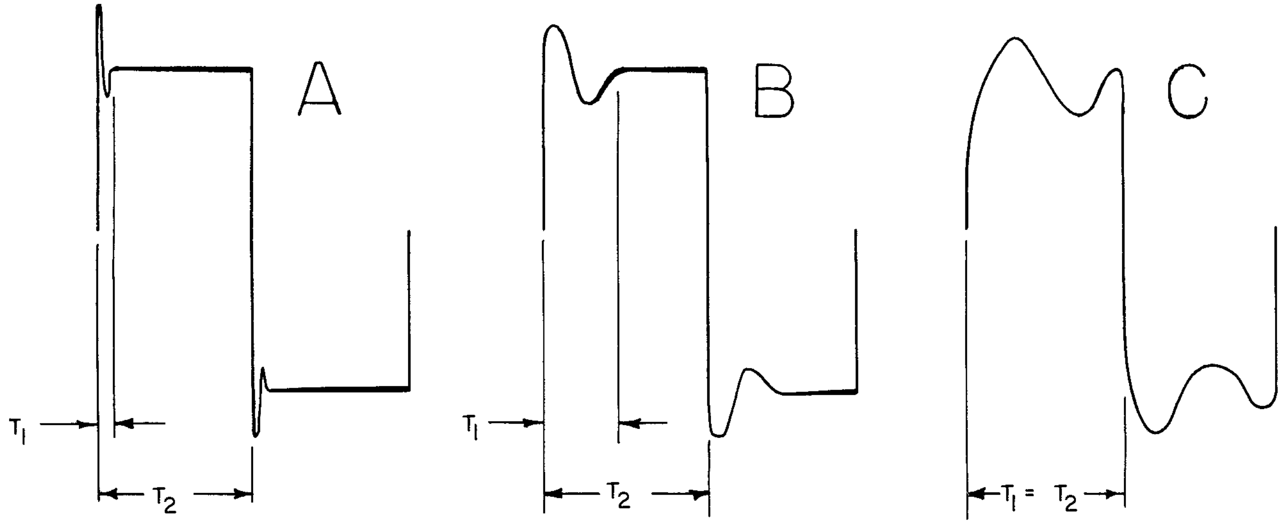
Example of Use

The percent tilt of an uncompensated video amplifier stage is specified as 2 percent maximum on a 60-cycle Square Wave. What will be the required time constant of the coupling circuit and the corresponding low cutoff frequency?

By means of a straightedge, connect the 2 percent point on the tilt scale with the 8,300 usec point (corresponding to the half-cycle duration of a 60-cycle Square Wave) on the "T" scale. The straightedge will cross the RC scale at approximately 410,000 ohm-uf. The corresponding low cutoff frequency Fl is found to be 0.4 cycle.

Reprinted from ELECTRONICS, August 1947

FIG 17



THE THREE SQUARE WAVE PATTERNS IN A, B, C ABOVE INDICATE A DAMPED RESONANT ELEMENT IN THE CIRCUIT OR AMPLIFIER UNDER TEST.

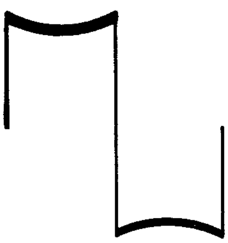
THE SHORT TIME DURATION OF THE DAMPED OSCILLATION IN FIG.A INDICATES THAT THE FUNDAMENTAL FREQUENCY OF THE SQUARE WAVE IS APPROXIMATELY 1/10 THAT OF THE DAMPED OSCILLATION. (T_1 APPROX. = $.1 x T_2$).

FIG. B IS A SQUARE WAVE SHAPE OBTAINED BY APPLYING A HIGHER FREQUENCY SQUARE WAVE TO THE SAME CIRCUIT OR AMPLIFIER REPRESENTED BY FIG. A. THE LONGER TIME DURATION OF THE DAMPED OSCILLATION INDICATES THAT IN THIS CASE THE FUNDAMENTAL OF THE SQUARE WAVE IS CLOSER TO THAT OF THE DAMPED OSCILLATION AS COMPARED TO FIG. A.

IN THIS CASE THE FUNDAMENTAL FREQUENCY OF THE SQUARE WAVE IS APPROXIMATELY 1/2 THAT OF THE DAMPED OSCILLATION. (T_1 APPROX. = $.5 x T_2$).

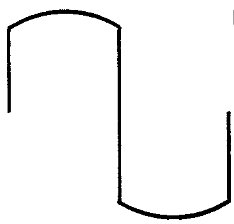
FIG. C ABOVE INDICATES THE WAVE-FORM PATTERN WHEN THE FUNDAMENTAL FREQUENCY OF THE SQUARE WAVE EQUALS THAT OF THE DAMPED OSCILLATION.

FIG 18



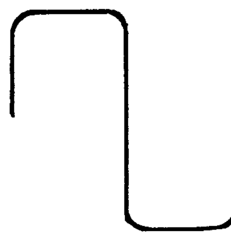
FREQUENCY DISTORTION, (AMPLITUDE REDUCTION OF LOW FREQUENCY COMPONENT)-NO PHASE SHIFT.

FIG 19



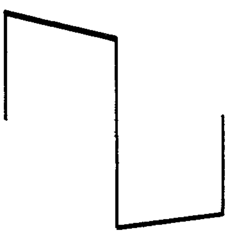
LOW FREQUENCY BOOST (ACCENTUATED FUNDAMENTAL).

FIG 20



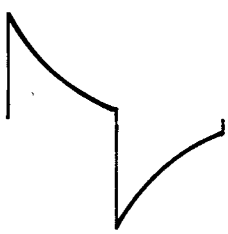
HIGH FREQUENCY LOSS -NO PHASE SHIFT.

FIG 21



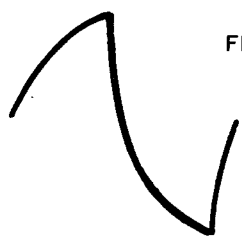
LOW FREQUENCY PHASE SHIFT.

FIG 22



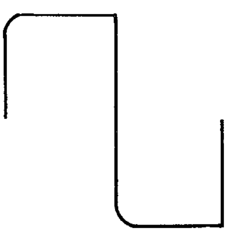
LOW FREQUENCY LOSS AND PHASE SHIFT.

FIG 23



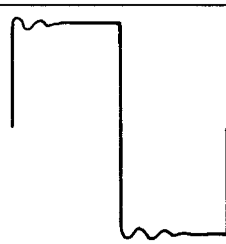
HIGH FREQUENCY LOSS AND LOW FREQUENCY PHASE SHIFT.

FIG 24



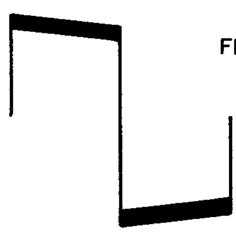
HIGH FREQUENCY LOSS AND PHASE SHIFT.

FIG 25



DAMPED OSCILLATION.

FIG 26



LOW FREQUENCY PHASE SHIFT, (TRACE THICKENED BY HUM-VOLTAGE).

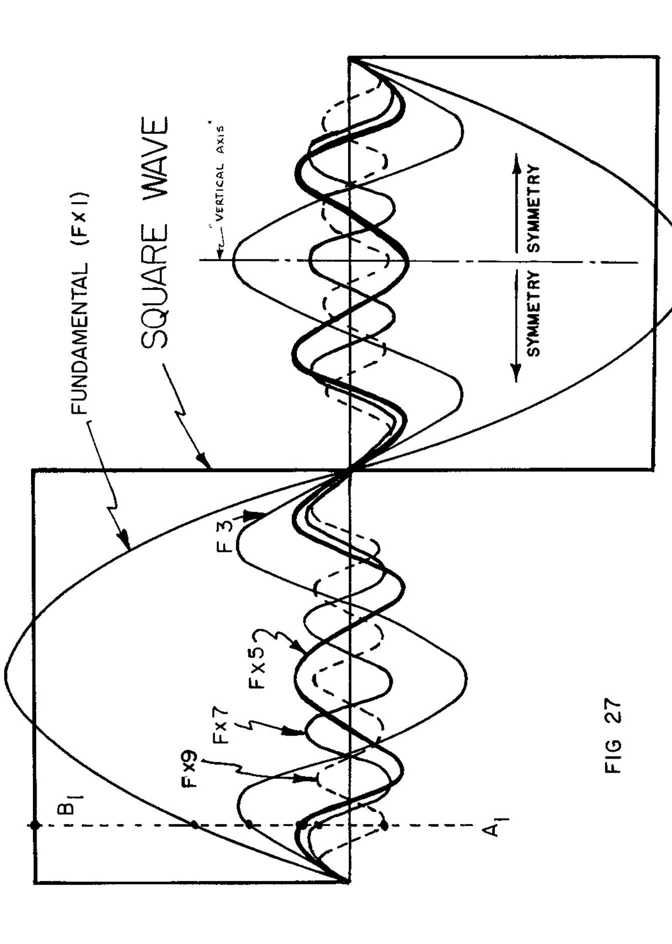


FIG 27

ALL ELEMENTS IN-PHASE

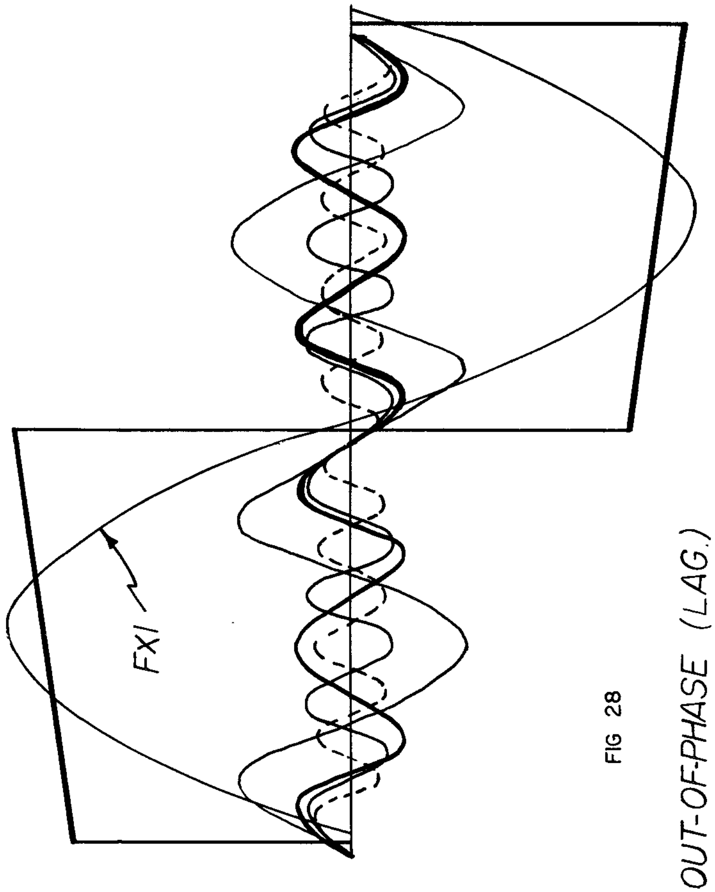


FIG 28

Fx1 OUT-OF-PHASE (LAG.)

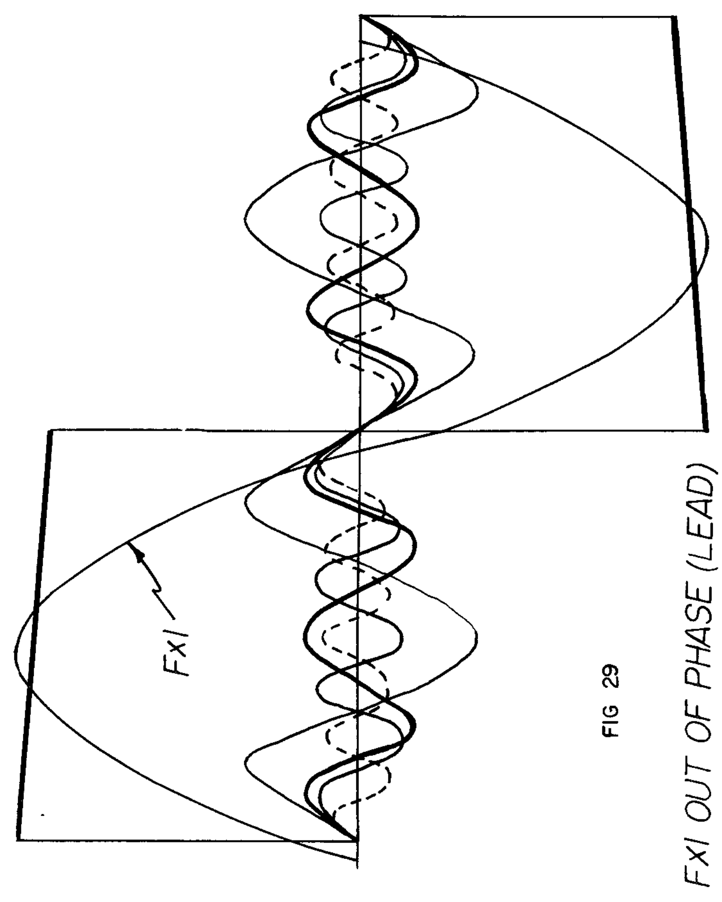


FIG 29

Fx1 OUT OF PHASE (LEAD)

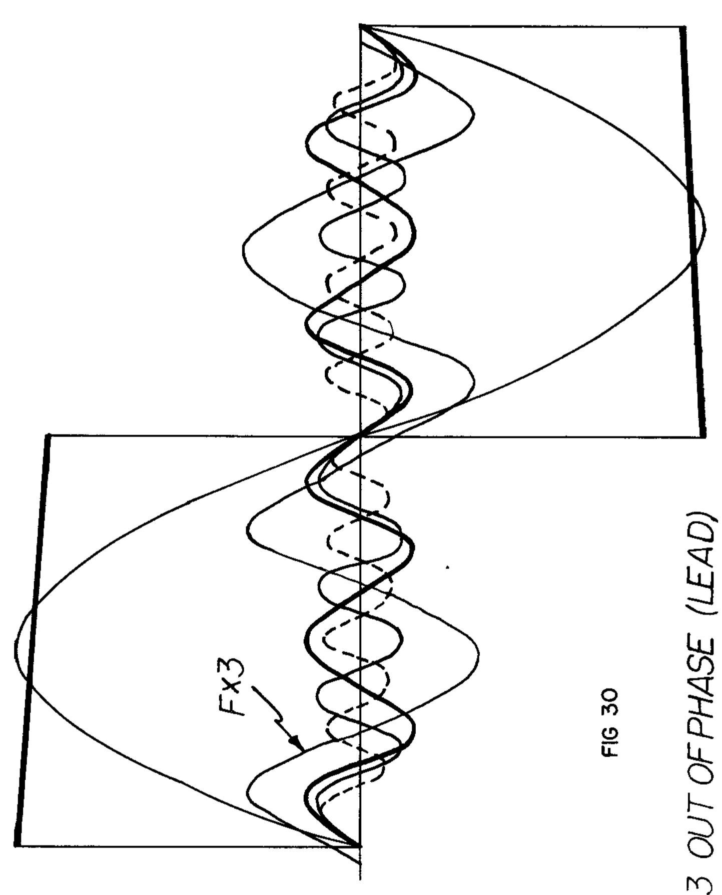
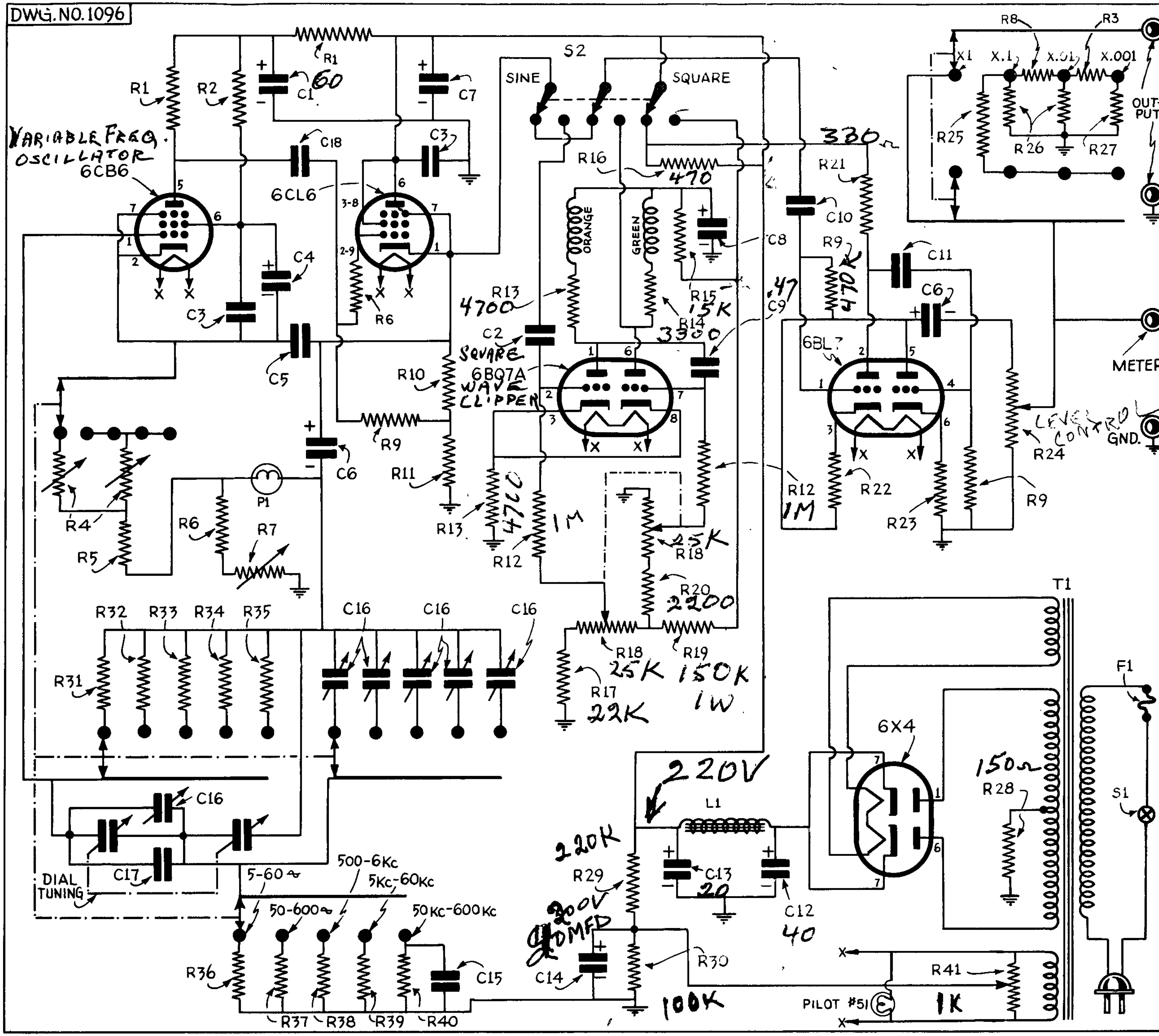


FIG 30

Fx3 OUT OF PHASE (LEAD)

DWG. NO. 1096



PART NO.	SPECIFICATION
R41	1KΩ HUM CONT. (INT.)
R40	3KΩ
R39	30KΩ
R38	300KΩ
R37	3 MEG. Ω
R36	30 MEG. Ω
R35	15KΩ
R34	150KΩ
R33	1.5 MEG. Ω
R32	15 MEG. Ω
R31	150 MEG. Ω
R30	100KΩ
R29	220KΩ
R28	150Ω-5W
R27	200Ω
R26	2400Ω EACH
R25	18KΩ
R24	2KΩ LEVEL CONT.
R23	22Ω
R22	56Ω
R21	330Ω
R20	2200Ω
R19	150KΩ-1W.
R18	25KΩ (INT.) SYMMETRY CONT.
R17	22KΩ
R16	470Ω
R15	15KΩ-2W.
R14	3300Ω
R13	4700Ω EACH
R12	1 MEG. Ω EACH
R11	5KΩ-5W.
R10	220Ω
R9	470KΩ EACH
R8	10KΩ
R7	1KΩ AMP. CONT. (INT.)
R6	1KΩ EACH
R5	100Ω
R4	100Ω EACH
R3	1800Ω
R2	8200Ω
R1	4700Ω-1W. EACH
P1	3 WATT LAMP
L1	FILTER CHOKE 3-125
S2	SINE-SQUARE SW.
S1	OFF-ON SWITCH
T1	POWER TRANSFORMER
F1	1 AMP FUSE
C18	.47MFD-200V
C17	20MMFD.
C16	4-30MMFD. EACH
C15	15MMFD.
C14	20MFD.-200V.
C13	20MFD.-350V.
C12	40MFD.-350V.
C11	0.5MFD.-400V.
C10	1.0MFD-200V.
C9	0.47MFD.-200V.
C8	60MFD.-200V.
C7	30MFD.-350V.
C6	250MFD.-200V. EA.
C5	40MMFD.
C4	40MFD-150V
C3	.02MFD (CER) EACH
C2	0.1MFD.-200V.
C1	60MFD.-350V.

PRECISION APPARATUS Co. INC.
GLENDALE 27 L.I.N.Y.

TITLE: MODEL E310 – SINE-SQUARE WAVE GENERATOR

DRAWN BY: WM. KADLECEK Jr.

CHECKED [illegible] DATE: 8-18-58

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TEST EQUIPMENT

Standard of Accuracy

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