OPERATING INSTRUCTIONS FOR

PRECISION

MODEL E-300

SINE-SQUARE WAVE SIGNAL GENERATOR

(AUDIO-VIDEO RANGE)

PRECISION
TEST EQUIPMENT
Standard of Accuracy

PRECISION APPARATUS COMPANY, INC.

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INTRODUCTION

THE SERIES E-300 SINE-SQUARE WAVE SIGNAL GENERATOR WAS ESPECIALLY DEVELOPED TO ANSWER MANY MODERN ELECTRONIC AMPLIFIER CIRCUIT TESTING PROBLEMS WHICH CANNOT BE HANDLED WITH JUST A ROUTINE COMPLEMENT OF TEST INSTRUMENTS.

SPECIALLY NOTE THE "PERFORMANCE TESTING" REQUIREMENTS FOR HIGH FIDELITY AUDIO SYSTEM, TV VIDEO AMPLIFIERS AND OTHER WIDE BAND DEVICES!

AN UP-TO-DATE TEST EQUIPMENT INSTALLATION CAN NO LONGER BE CONSIDERED COMPLETE, FOR COMPREHENSIVE USE, UNTIL AN INSTRUMENT SUCH AS THE SERIES E-300 HAS BEEN ACQUIRED.

FOR THOSE WHO MAY NOT BE FAMILIAR WITH SINE AND SQUARE WAVE TESTING TECHNIQUES, A PORTION OF THIS MANUAL HAS BEEN ESPECIALLY PREPARED. A FOUNDATION IS ESTABLISHED AS WILL PERMIT THE OPERATOR TO INTERPRET OSCILLOGRAPHIC WAVEFORMS IN TERMS OF FREQUENCY RESPONSE, DISTORTION, ETC.

PRACTICAL EXPERIENCE IN THE USE OF SINE AND SQUARE WAVES WILL DEVELOP RECOGNITION OF MORE SUBTLE DIFFERENCES IN WAVEFORM INDICATIONS VERSUS CIRCUIT CONDITIONS.

IT WILL BE FOUND THAT CERTAIN CIRCUITS CAN APPARENTLY TOLERATE SIZEABLE DEGREE OF DISTORTION AND DEPARTURE FROM "FLATNESS", - - - WHEREAS SUCH MAY NOT BE THE CASE FOR OTHER AND MORE CRITICAL TYPES OF CIRCUITS. IT IS THEREFORE ESSENTIAL THAT ONE BECOME FAMILIAR WITH WHAT IS TO BE EXPECTED OF THE AMPLIFIER OR EQUIPMENT UNDER TEST BEFORE WAVEFORM ANALYSIS IS STARTED. THE BASIS OF COMPARISON IS USUALLY THE MANUFACTURER'S SPECIFICATIONS OR THE OPERATOR'S OWN EXPERIENCE WITH THE PARTICULAR AMPLIFIER WHOSE PERFORMANCE IS TO BE ANALYZED AND/OR ADJUSTED.

APPROPRIATELY APPLIED, THE SERIES E-300 SINE-SQUARE WAVE SIGNAL GENERATOR WILL AFFORD CONSIDERABLE STREAMLINING OF AMPLIFIER TEST PROCEDURES WITH RESULTANT SAVINGS IN TIME AND EFFORT - - - AND WITH MORE UNIFORMLY HIGH STANDARDS OF APPARATUS PERFORMANCE.

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GENERAL SPECIFICATIONS

VARIABLE-FREQUENCY SINE WAVE RANGES:- FOR TESTING AUDIO AMPLIFIERS, WIDE RANGE AMPLIFIERS, LOW FREQUENCY RF AMPLIFIERS, ETC.

CONTINUOUS COVERAGE FROM 20 CYCLES TO 200 KILOCYCLES IN FOUR BANDS.

BAND 1 - 20 CYCLES TO 200 CYCLES (DIRECT READING)

BAND 2 - 200 CYCLES TO 2000 CYCLES

BAND 3 - 2000 CYCLES TO 20,000 CYCLES

BAND 4 - 20 KILOCYCLES TO 200 KILOCYCLES

VARIABLE-FREQUENCY SQUARE WAVE RANGES:- FOR ANALYZING PERFORMANCE OF AUDIO AMPLIFIERS, WIDE BAND AMPLIFIERS AND SIMILAR DEVICES.

20 CYCLES THROUGH 20,000 CYCLE COVERAGE IN THREE BANDS.

BAND 1 - 20 CYCLES TO 200 CYCLES (DIRECT READING)

BAND 2 - 200 CYCLES TO 2000 CYCLES

BAND 3 - 2000 CYCLES TO 20,000 CYCLES

FIXED, HIGH-FREQUENCY SQUARE WAVES:- FOUR SELECTED FREQUENCIES FOR PERFORMANCE ANALYSIS OF VIDEO AMPLIFIERS AND OTHER VERY WIDE BAND AMPLIFIERS UP TO 20 MC BAND-WIDTH.

1 - 50 KILOCYCLES SQUARE WAVE

2 - 100 KILOCYCLE SQUARE WAVE

3 - 250 KILOCYCLE SQUARE WAVE

4 - 500 KILOCYCLE SQUARE WAVE

OUTPUT CHARACTERISTICS:-

VARIABLE FREQUENCY RANGES:- 0-10 V. RMS, FLAT WITHIN ±1 DB
ACCURACY:- ±2% FROM 50 CYCLES TO 200 KILOCYCLES

± 1 CYCLE FROM 20 CYCLES TO 50 CYCLES

DISTORTION:- LESS THAN 1% TOTAL, FROM 20 CYCLES THROUGH 200 KILOCYCLES

SQUARE WAVE RISE TIME:- .5 MICROSECOND AT 20 KC

FIXED, HIGH FREQUENCY SQUARE WAVES:- 0-5 VOLTS PEAK TO PEAK, AT TERMINATED COAXIAL OUTPUT CABLE

RISE TIME:- BETTER THAN .05 MICROSECOND

OVERSHOOT:- NEGLIGIBLE

TUBE COMPLEMEMT AND FUNCTIONS:-

1 - #5879 VARIABLE FREQUENCY OSCILLATOR

1 - #6CL6 CATHODE FOLLOWER FOR #5879; ALSO USED AS HIGH FREQUENCY SQUARE WAVE OUTPUT AMPLIFIER

1 - #6J6 VARIABLE FREQUENCY SQUARE WAVE CLIPPER

1 - #6AU6 AMPLIFIER, VARIABLE FREQUENCY RANGES; ALSO USED AS 1/2 OF HIGH FREQUENCY SQUARE WAVE MULTI-VIBRATOR.

1 - #6AU6 PHASE SPLITTER, VARIABLE FREQUENCY RANGES; ALSO USED AS 1/2 OF HIGH FREQUENCY SQUARE WAVE MULTI-VIBRATOR

1 - #6BL7 OUTPUT AMPLIFIER, VARIABLE FREQUENCY RANGES

1 - TYPE #6AH6 HIGH FREQUENCY SQUARE WAVE AMPLIFIER

1 - TYPE 6X4 POWER RECTIFIER

DUAL OUTPUT CIRCUITS: COMPLETELY SEPARATE OUTPUT NETWORKS FOR THE VARIABLE AND FIXED-FREQUENCY RANGES. EACH NETWORK SPECIFICALLY DESIGNED TO PERFORM ITS INTENDED FUNCTION WITH UTMOST EFFICIENCY AND FACILITY.

DUAL OUTPUT SIGNAL INDICATORS:- TWO DISTINCTLY SEPARATE PILOT LIGHT CIRCUITS AUTOMATICALLY INDICATE THE VARIABLE FREQUENCY AND FIXED HIGH FREQUENCY OUTPUT JACKS, COINCIDENT WITH RANGE SELECTION.

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-300.

TERMINATED, LOW-LOSS, HIGH FREQUENCY COAXIAL OUTPUT CABLE ASSURES ABILITY OF THE SERIES E-300 TO TRANSMIT THE CAREFULLY GENERATED H.F. SQUARE WAVES TO THE CIRCUITS UNDER TEST, WITHOUT DISTORTION.

EXTERNAL "SYNC" TERMINAL POST PROVIDES DIRECT AND CONVENIENT MEANS OF SYNCHRONIZING OSCILLOGRAPH HORIZONTAL SWEEP TO H.F. SQUARE WAVE.

ETCHED-ANODIZED TUNING DIAL AND PANEL BOTH OF HEAVY GAUGE ALUMINUM, RESISTANT TO MOISTURE AND ABRASION. NO-GLARE, ENGINE-TURNED DIAL FINISH AND SOFT-BLACK PANEL FIELD, AFFORD UTMOST VISIBILITY AND EASE OF READING.

EXTRACTOR FUSE POST, AT FRONT OF PANEL, PROVIDES CONVENEIENT FUSE REPLACEMENT FACILITY AND UTMOST CIRCUIT COMPONENT PROTECTION.

FULLY LICENSED UNDER PATENTS OF RCA, WESTERN ELECTRIC AND AT AND T.

FULL ONE YEAR WARRANTY:- SERIES E-300, 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.

DESCRIPTION AND FUNCTIONS OF E-300 PANEL CONTROLS AND SWITCHES

THE SERIES E-300 CAN BE CONSIDERED AS TWO DISTINCTLY SEPARATE INSTRUMENTS INSOFAR AS OPERATION FROM THE FRONT PANEL IS CONCERNED:-

1. VARIABLE SINE-SQUARE

   WHEN THE FUNCTION SELECTOR SWITCH (RIGHT HAND KNOB UNDER THE TITLING "SIGNAL-FREQUENCY SELECTORS") IS SET TO ITS FIRST POSITION ("VARIABLE SINE-SQUARE"), THE VARIABLE FREQUENCY OUTPUT OF THE GENERATOR APPEARS AT THE TWO BINDING POSTS AT THE LEFT OF THE INSTRUMENT PANEL.

   THE "LEVEL CONTROL" FUNCTIONS AS THE OUTPUT FOR ALL VARIABLE SINE-SQUARE WAVE RANGES.

2. FIXED HIGH-FREQUENCY SQUARE WAVE

   WHEN THE FUNCTION SWITCH IS SET TO ANY ONE OF THE FOUR POSITIONS MARKED 50 KC - 100 KC - 250 KC - 500 KC., THE OUTPUT OF THE GENERATOR APPEARS ONLY AT THE TERMINATION BOX AT THE END OF THE COAXIAL OUTPUT CABLE EXTENDING FROM THE RIGHT HAND SIDE OF THE INSTRUMENT PANEL.

   THE CONTROL IN THE TERMINATION BOX AT THE END OF THE CO-AXIAL CABLE IN THIS CASE FUNCTIONS AS THE OUTPUT CONTROL OR ATTENUATOR FOR THE FOUR FIXED FREQUENCY SQUARE WAVE SIGNALS.

   THE GREEN PILOT LIGHTS AT EITHER SIDE OF THE PANEL AUTOMATICALLY INDICATE THE SELECTION OF OUTPUT SIMULTANEOUSLY WITH SELECTION OF THE FUNCTION SWITCH POSITION.

   NOTE: EITHER THE VARIABLE RANGES OR THE FIXED SQUARE-WAVE RANGES ARE OPERATING AT ONE TIME. AFTER SELECTION OF FUNCTION, USE THE OUTPUT INDICATED BY THE ILLUMINATED PILOT LIGHT.

   SELECT VARIABLE RANGES FROM 20 CPS SINE TO 200 KC SINE BY ROTATING THE RANGE SELECTOR SWITCH TO ANY ONE OF THE FIRST DISTINCTLY SEPARATE FOUR POSITIONS OF THE SWITCH.

   SELECT VARIABLE RANGES FROM 20 CPS SQUARE WAVE, TO 20 KC SQUARE WAVE BY ROTATING THE RANGE SELECTOR SWITCH TO THE LOWER THREE SQUARE-WAVE POSITIONS OF THE SWITCH, INDICATED ON THE PANEL BY A BORDER OUTLINE AROUND THE IDENTIFICATION.

   SELECT FIXED FREQUENCY SQUARE WAVE OUTPUT AS REQUIRED BY ROTATING "HIGH FREQUENCY SQUARE WAVE" SWITCH TO ONE OF ITS FOUR INDICATED POSITIONS.

   THE INSTRUMENT TUNING DIAL IS USED FOR ALL VARIABLE RANGES AND IS CALIBRATED IN THE BASIC LOW RANGE OF THE INSTRUMENT. INASMUCH AS RANGE MULTIPLICATION OCCURS IN MULTIPLES OF TEN, THE DIAL READS SIMPLY FOR ALL VARIABLE RANGES, AS FOLLOWS:-

20 CPS TO 200 CPS	. . . . READ DIRECTLY
200 CPS TO 2KC	. . . . MULTIPLY ALL READINGS BY 10
2 KC TO 20 KC	. . . . MULTIPLY ALL READINGS BY 100
20 KC TO 200 KC	. . . . MULTIPLY ALL READINGS BY 1000

THE SYNC. OUTPUT JACK DELIVERS A SMALL MAGNITUDE OF FIXED SQUARE WAVE OUTPUT, FOR EXTERNAL SYNCHRONIZATION PURPOSES. IN PRACTICE, THE OUTPUT FROM THIS JACK WILL BE APPLIED TO THE EXTERNAL SYNC POST OF THE OSCILLOSCOPE BEING USED, FOR OPTIMUM SYNCHRONIZATION.

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SET-UP AND TYPICAL APPLICATION

1. INSERT THE LINE PLUG INTO A SOURCE OF 110/120 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 10 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.

3. Set the Controls and Switches of the E-300 as follows:-

Function Switch to "VARIABLE SINE-SQUARE"

Range Switch to "20-200"

Level Control between 0 and 2

4. Connect the "GND" binding post of the E-300 to ground of the amplifier; connect the "OUTPUT" post of the E-300 to the input of the amplifier.

5. 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 Series EV-10A or EV-20 equipped with RF-10A Probe 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 Series ES-500A or ES-520 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.)

6. Set the E-300 Tuning Dial to 60 cps, for example and adjust the gain of the 'scope and the output of the E-300 to obtain a good sized sine pattern on the 'scope screen, always keeping in mind the caution that the output of the E-300 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.

7. With the "Level Control" of the E-300 adjusted, 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).

8. Now, without touching any other controls or switches, merely rotate the tuning dial of the E-300 to 200, and note the difference, if any in the height of the sine pattern on the 'scope.

9. 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-300 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.

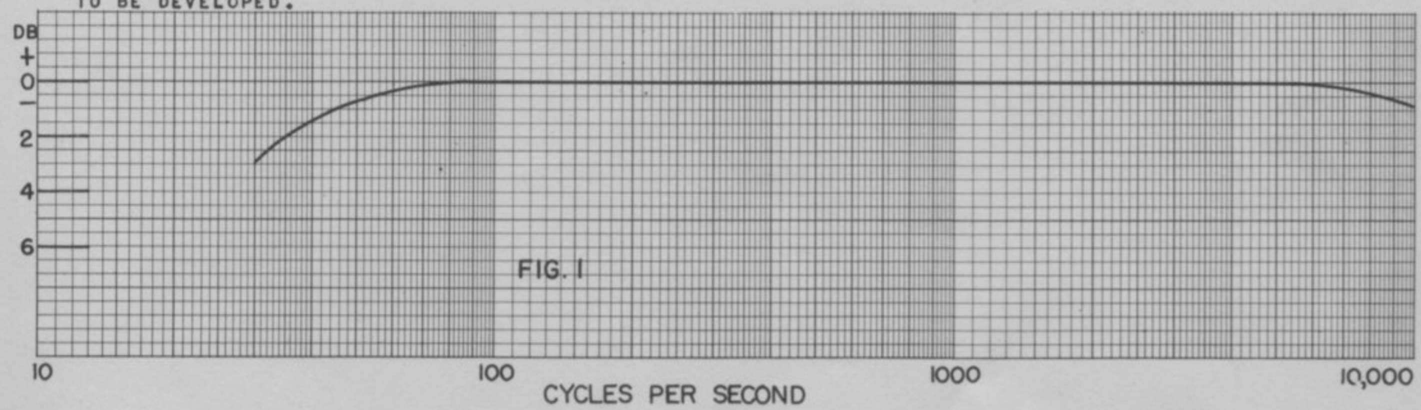


FIG. 1

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 5000 CPS.

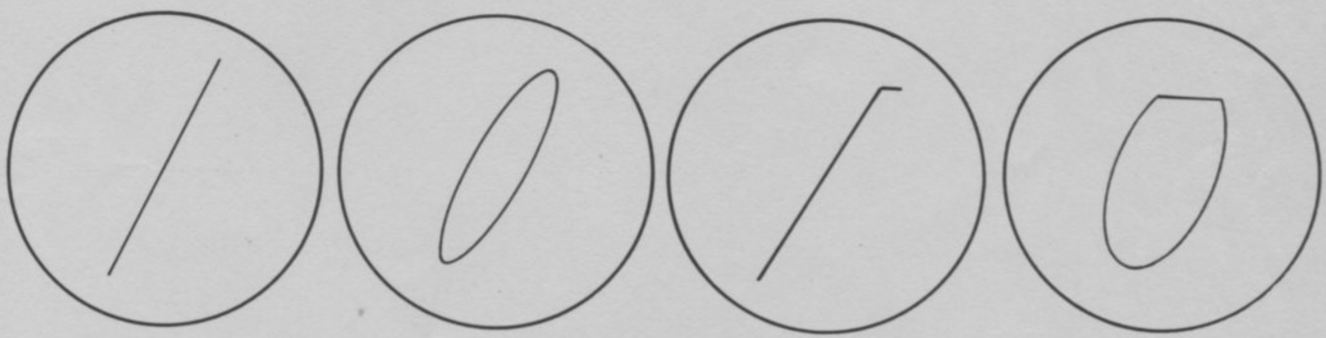
IN THIS CASE THE GENERATOR IS BEING USED TO INDICATE THE NATURE OF THE TROUBLE. FROM THEN ON THE EXPERIENCE AND BACKGROUND OF THE TECHNICIAN WILL ASSIST IN LOCATING THE EXACT TROUBLE SPOT ITSELF.

THE SINE OUTPUT OF THE E-300 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 .



IN-PHASE, OR 180° OUT OF PHASE; NO OVERLOAD DISTORTION. — PHASE SHIFT, NO OVERLOAD DISTORTION. — IN PHASE; OVERLOAD DISTORTION. — PHASE SHIFT AND OVERLOAD DISTORTION

FIG. 2

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-570 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-300 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-300 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 17 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 WAVESHAPE 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.

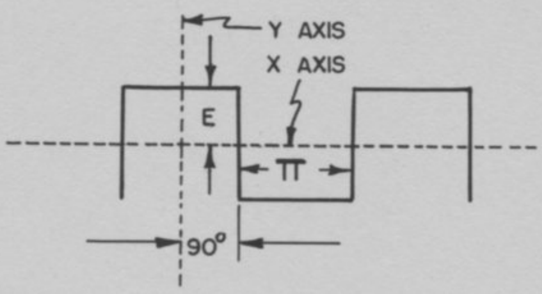
IF ALL SINE COMPONENTS OF THE SQUARE WAVE ARE BEGINNING THE 1/2 CYCLE AT ZERO AMPLITUDE, THEY ARE OF COURSE IN-PHASE. IN A WELL PROPORTIONED AND SHAPED SQUARE WAVE WE THEN HAVE A WHOLE SERIES OF SINE WAVES, VARYING IN FREQUENCY FROM LOW TO VERY HIGH, ALL IN PHASE AND ALL IN A RELATED AMPLITUDE. (THE 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 ON THE FOLLOWING PAGE:

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

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

$$\dots\left(\cos x - \frac{1}{3}\cos 3x + \frac{1}{5}\cos 5x \dots\right)$$



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.

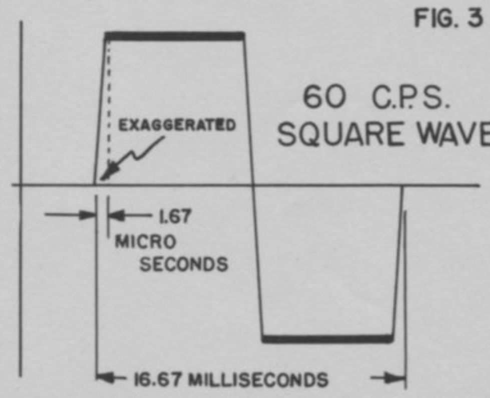
FIG.27 CANNOT OF COURSE BEGIN TO ILLUSTRATE THE PRACTICALLY INFINITE NUMBER OF HARMONICS WHICH CONSTITUTE A SHARP SQUARE WAVE. BUT IF ONE TAKES LINE "A_1" OF FIG.27 AND IMAGINES THE PRESENCE OF IN-PHASE HARMONICS AS HIGH AS THE 100TH OR 500TH AND IF WE UNDERSTAND THAT WE ARE TO ADD ALL COMPONENTS UP 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.

FIG. 3



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 PG. 16).

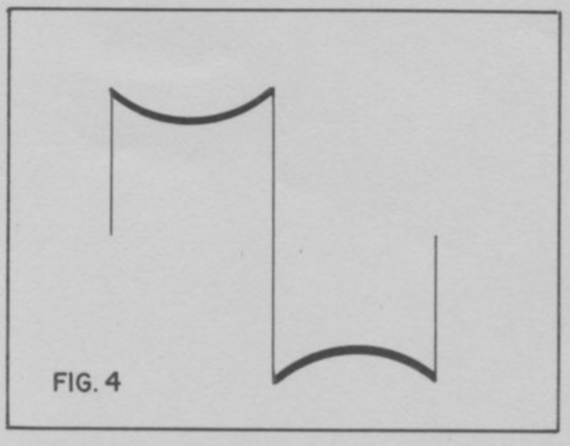


FIG. 4

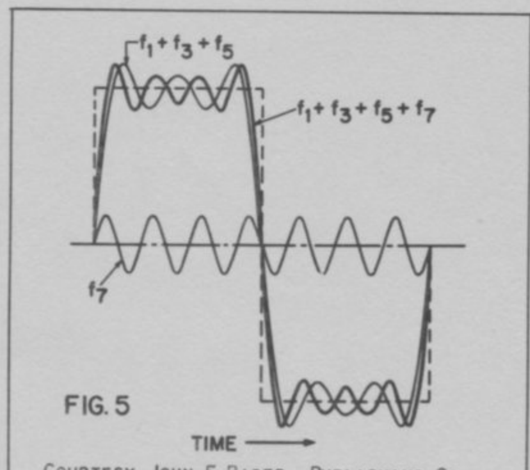


FIG. 5

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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.

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-HUNDRETH 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 A 80 CPS FUNDAMENTAL SQUARE WAVE FREQUENCY.

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 MICROSEOND 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.

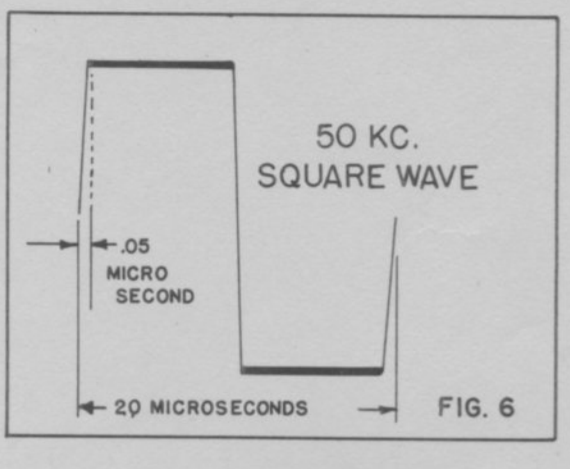


FIG. 6

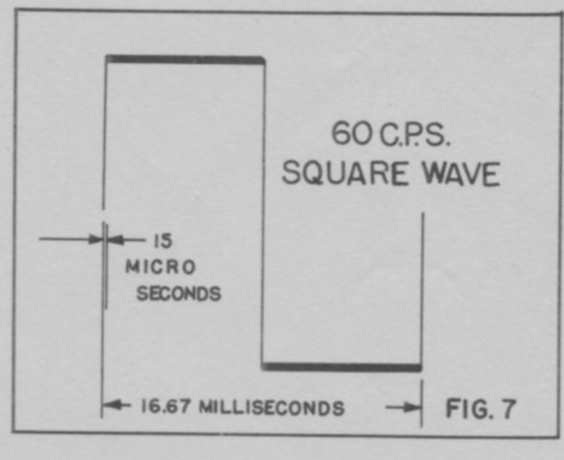


FIG. 7

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.

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

OR

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

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.

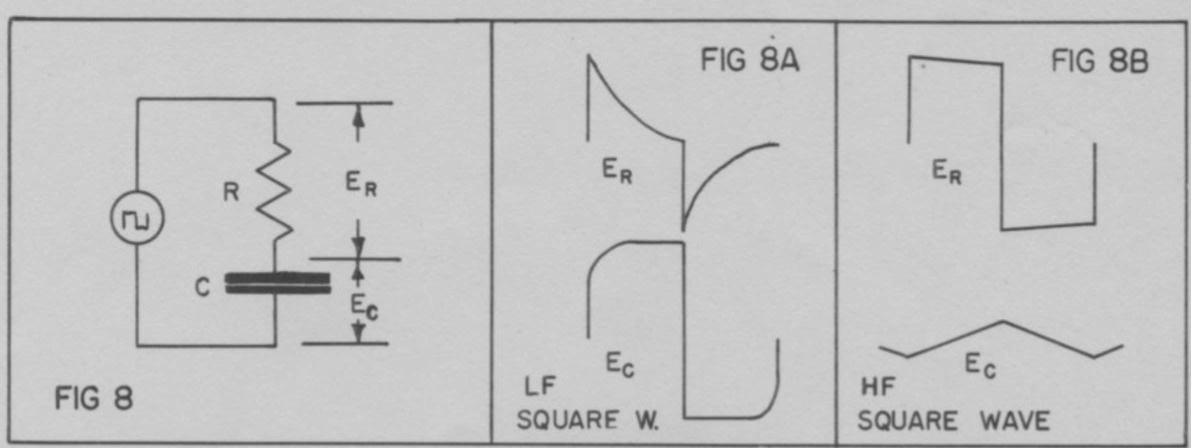
IT IS SIGNIFICANT TO NOTE THAT THE RISE TIME PORTION OF THE SQUARE WAVE DETERMINES THE BANDWIDTH REQUIRED TO FAITHFULLY REPRODUCE THE SQUARE WAVE. SHOULD ONE SQUARE WAVE BE TWICE THE FUNDAMENTAL FREQUENCY OF ANOTHER, BUT BOTH HAVE THE SAME RISE TIME, THEN THE SAME BANDWIDTH (DETERMINED BY THE RISE TIME) 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.

* * * * *

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.

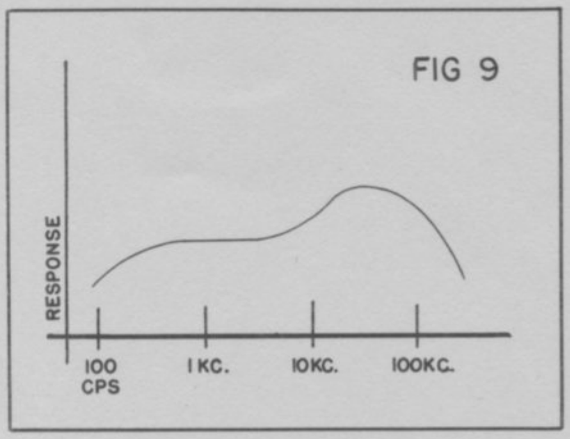
Therefore in Square Wave testing of practical circuitry we will usually find that the distorted Square Wave includes a COMBINATION of Amplitude AND Phase distortion clues.

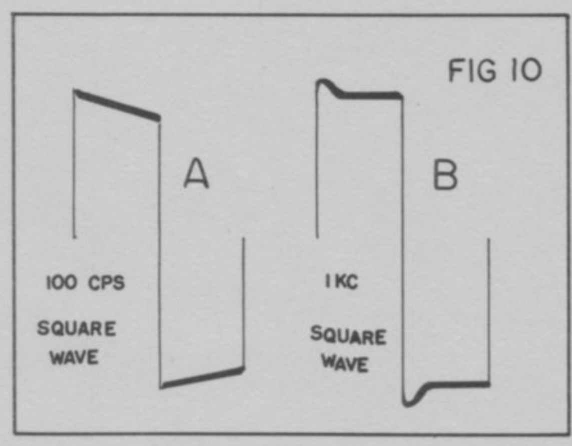
If we now proceed to the application of Square Waves to a typical wide band amplifier we find that a Square Wave check accurately reveals many distortion characteristics of the circuit:-

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 17 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.

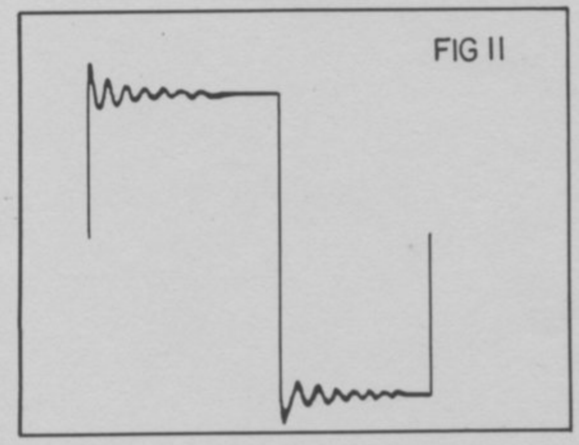
Fig. 29 indicates the tilt in Square Wave shape produced by a 10° phase shift of a low frequency element in a leading direction. The tilting shape of the resultant wave results from the simple algebraic addition of all components along a vertical line as has been previously noted in this discussion.

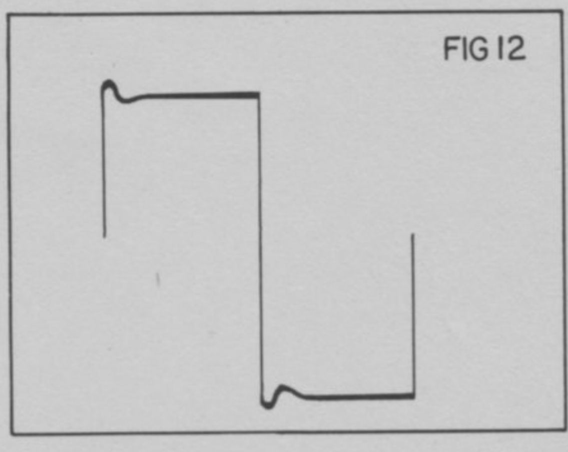
Fig. 28 also indicates a 10° phase shift in a low frequency component in a lagging direction. The tilts are opposite in the two cases because of the difference in polarity of the phase angle in the two cases as can be checked through algebraic addition of components.

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 characterisitic relationship is explained by remembering that in a normal well shaped Square Wave, the sharp rise at "O" is created by the summation of a practically infinite number of harmonic components rising in amplitude from "O". 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.





VIDEO AMPLIFIER TESTING

ONE OF THE MOST USEFUL APPLICATIONS OF THE 50 KC TO 500 KC FIXED SQUARE WAVE OUTPUT OF THE E-300 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 THE VIDEO AMPLIFIER IS AS FOLLOWS:

1. SET UP THE E-300 FOR 250 KC FIXED FREQUENCY SQUARE WAVE OUTPUT. CONNECT THE "HIGH" POST OF THE TERMINATION BOX TO THE GRID OF THE 1ST VIDEO AMPLIFIER THRU A .01 MFD CAPACITOR.

2. DETUNE THE FRONT END OR DISABLE THE LOCAL OSCILLATOR TO PREVENT STATION INFORMATION TO INTERFERE WITH THE TEST WAVEFORM.

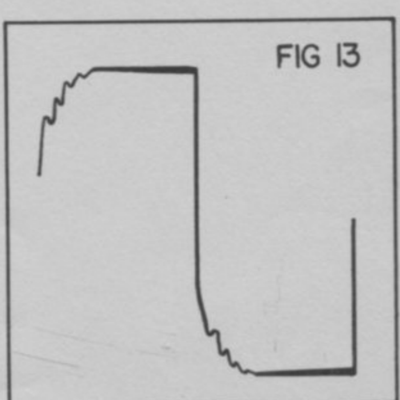
3. CONNECT THE OUTPUT OF THE VIDEO AMPLIFIER (INPUT OF THE CR TUBE) DIRECTLY TO THE VERTICAL PLATES OF THE 'SCOPE (UNLESS A WIDE BAND 'SCOPE SUCH AS PRECISION ES-570 IS BEING USED. IF AN ES-570 IS USED, THEN THE OUTPUT OF THE VIDEO AMPLIFIER MAY BE CONNECTED TO THE "SCOPE'S AMPLIFIER).

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.



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, SWITCH THE E-300 FUNCTION SWITCH TO "VARIABLE SINE-SQUARE", AND ROTATE THE RANGE SWITCH TO "20-200 SQUARE".

7. DISCONNECT THE OUTPUT OF THE TERMINATION BOX FROM THE INPUT OF THE VIDEO AMPLIFIER, AND CONNECT LEADS FROM THE "OUTPUT" AND "GND" POSTS AT THE LEFT OF THE PANEL TO THE INPUT OF THE VIDEO AMPLIFIER.

8. SET THE TUNING DIAL TO APPROXIMATELY 70 CPS, AND SET THE "LEVEL CONTROL" 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.

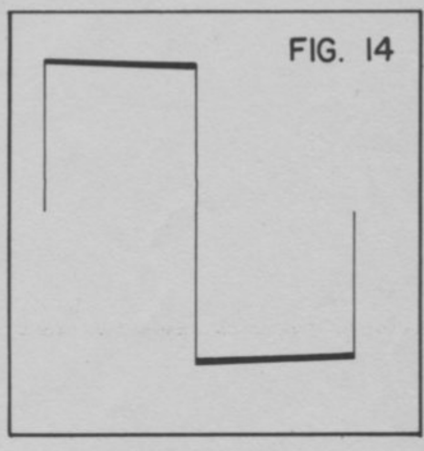


FIG. 14

HOWEVER IF THE FREQUENCY RANGE OF THE E-300 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 (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.

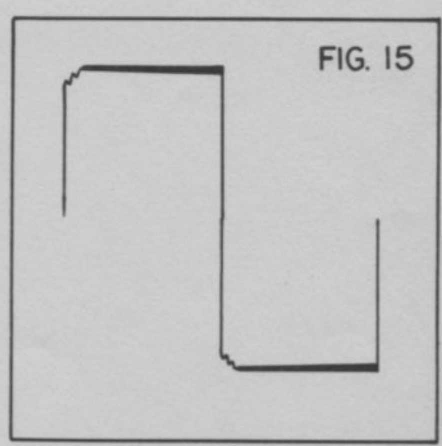


FIG. 15

WE CAN THEREFORE EXPECT HIGH FREQUENCY DISTORTION TO APPEAR AS A PROGRESSIVELY LARGE 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).

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.

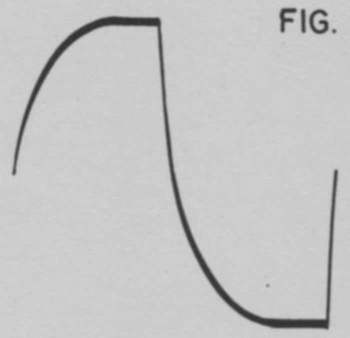


FIG. 16

THE SHARP RISE TIME OF THE SQUARE WAVE GENERATED BY THE E-300 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 T.V. 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-300 AS A PATTERN LINEARITY CHECKER:

WE HAVE NOTED PREVIOUSLY THAT THE ABRUPT RISE OF A SQUARE WAVE FROM 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 250 KC. WILL THEREFORE PRODUCE 16 VERTICAL PAIRS OF BLACK AND WHITE LINES. EVEN THOUGH 250 KC IS NOT AN EXACT MULTIPLE OF 15.75 KC IT IS CLOSE ENOUGH TO "PULL IN" AND SYNCHRONIZE SATISFACTORILY ENOUGH THRU ADJUSTMENT OF THE HOLD CONTROL. A 500 KC SQUARE WAVE WILL PRODUCE 32 PAIRS OF LINES: THE TECHNICIAN MAY CHOOSE EITHER 250 KC OR 500 KC WHICHEVER SEEMS TO PROVIDE BEST SYNCHRONIZATION.

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 MUTLTIPLE OF 60 CPS INTO THE VIDEO AMPLIFIER. THE E-300 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.

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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:-

ATT: SERVICE DEPARTMENT

IMPORTANT NOTE: THE ORIGINAL CARTON AND FILLERS OF THE SERIES E-300 ARE ADMIRABLY SUITED FOR THIS PURPOSE.

IMPORTANT!!!

IF EVER THE SERIES E-300 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-300 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.

*   *   *   *   *

ACCESSORIES SUPPLIED:

(A) HIGH FREQUENCY FIXED FREQUENCY SQUARE WAVE OUTPUT CABLE.

(B) INSTRUCTION MANUAL.

BIBLIOGRAPHY

1. ENCYCLOPEDIA ON CATHODE RAY OSCILLOSCOPES
JOHN RIDER, PUBLISHER

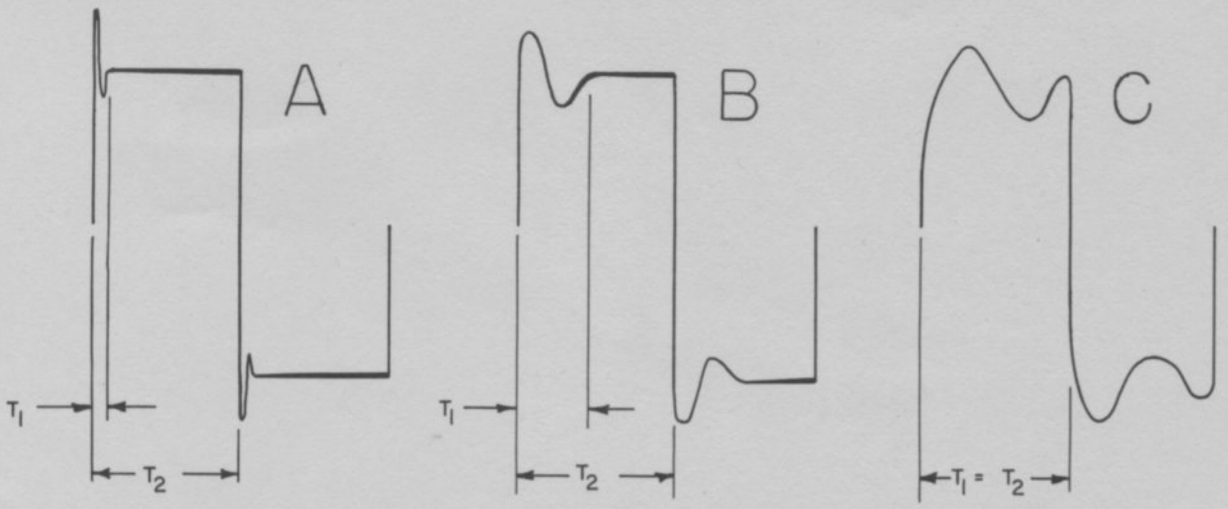
2. ELECTRONIC CIRCUITS AND TUBES
McGRAW-HILL PUBLISHER

3. OBTAINING AND INTERPRETING TEST SCOPE TRACES
JOHN RIDER, PUBLISHER

4. RADIO ENGINEERING, TERMAN
McGRAW-HILL PUBLISHER

5. ARGUIMBAU, L.B., VACUUM-TUBE CIRCUITS
JOHN WILEY AND SONS, INC., PUBLISHERS

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.

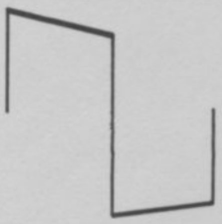
FIG 19

LOW FREQUENCY BOOST, (ACCENTUATED FUNDAMENTAL).

FIG 20

HIGH FREQUENCY LOSS, NO PHASE SHIFT.

FIG 21

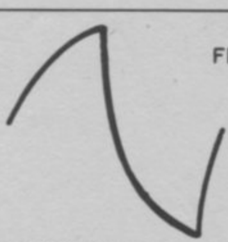


LOW FREQUENCY PHASE SHIFT.

FIG 22

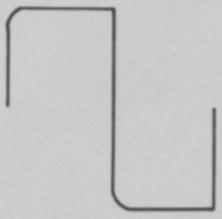
LOW FREQUENCY LOSS AND PHASE SHIFT.

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.

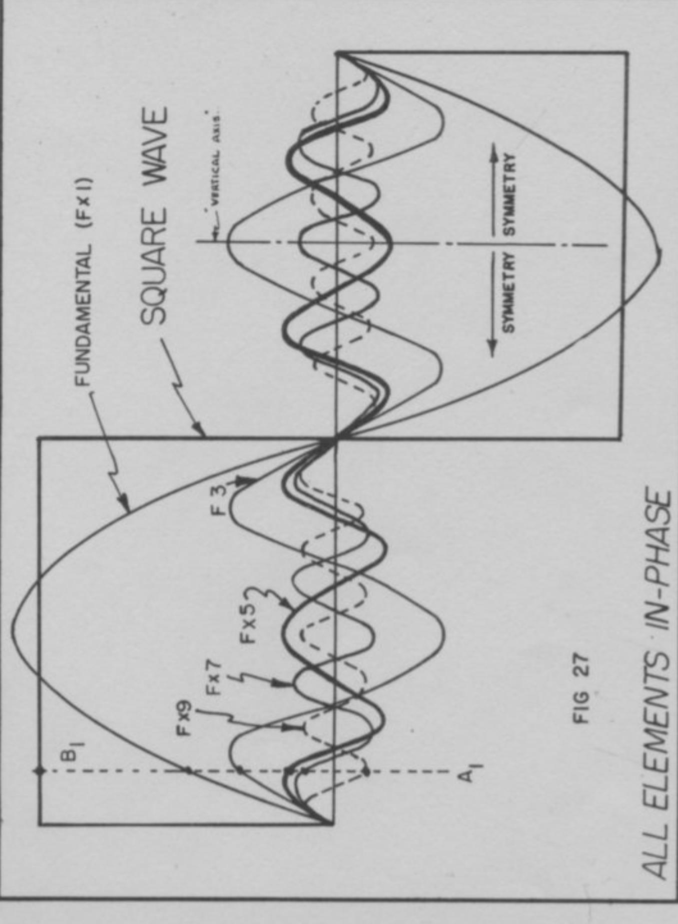


FIG 27

ALL ELEMENTS IN-PHASE

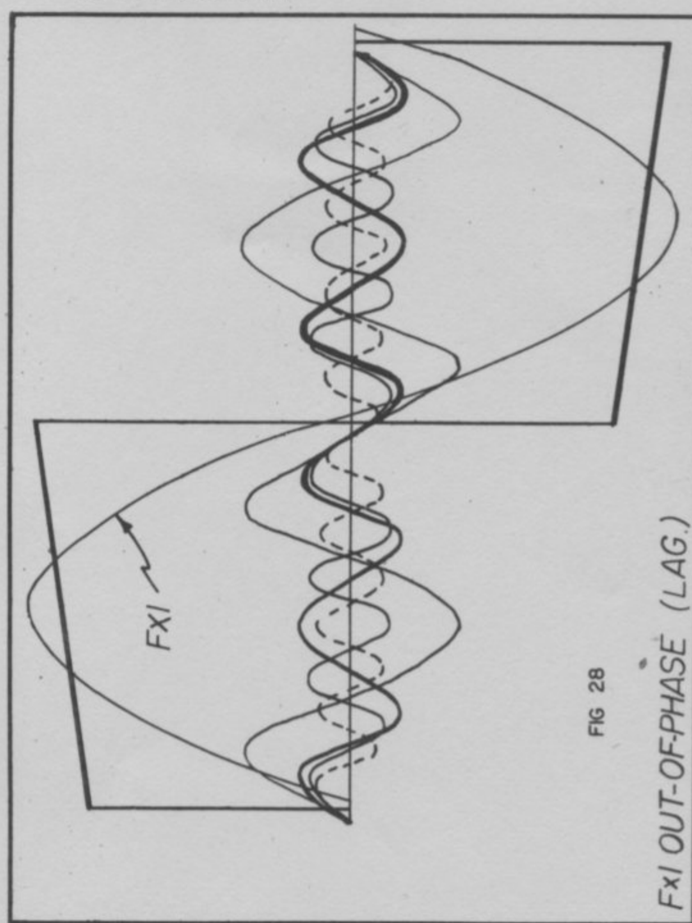


FIG 28

FxI OUT-OF-PHASE (LAG.)

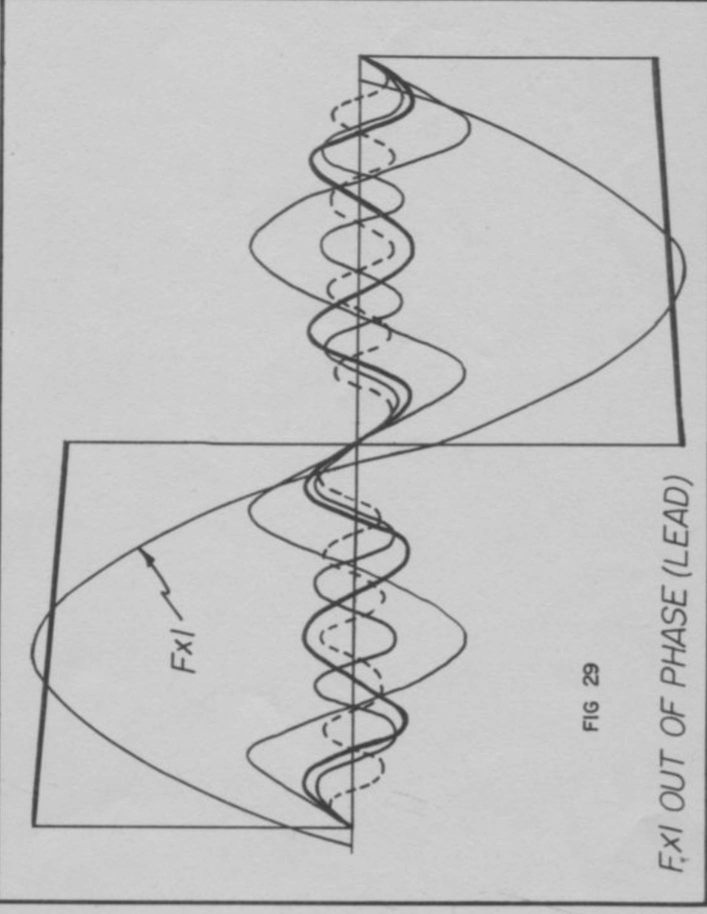


FIG 29

FxI OUT OF PHASE (LEAD)

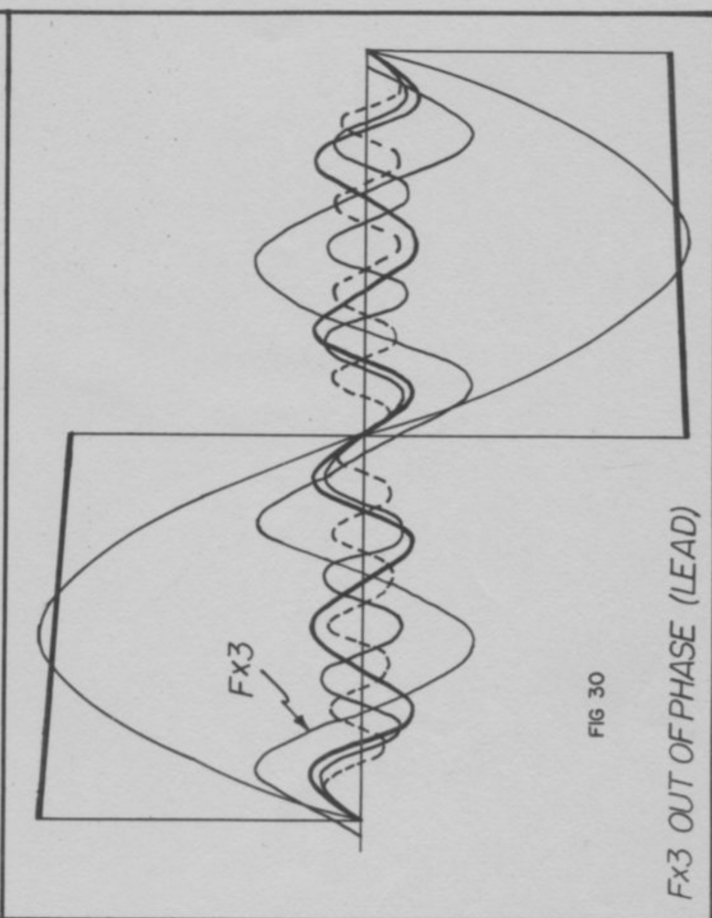


FIG 30

Fx3 OUT OF PHASE (LEAD)

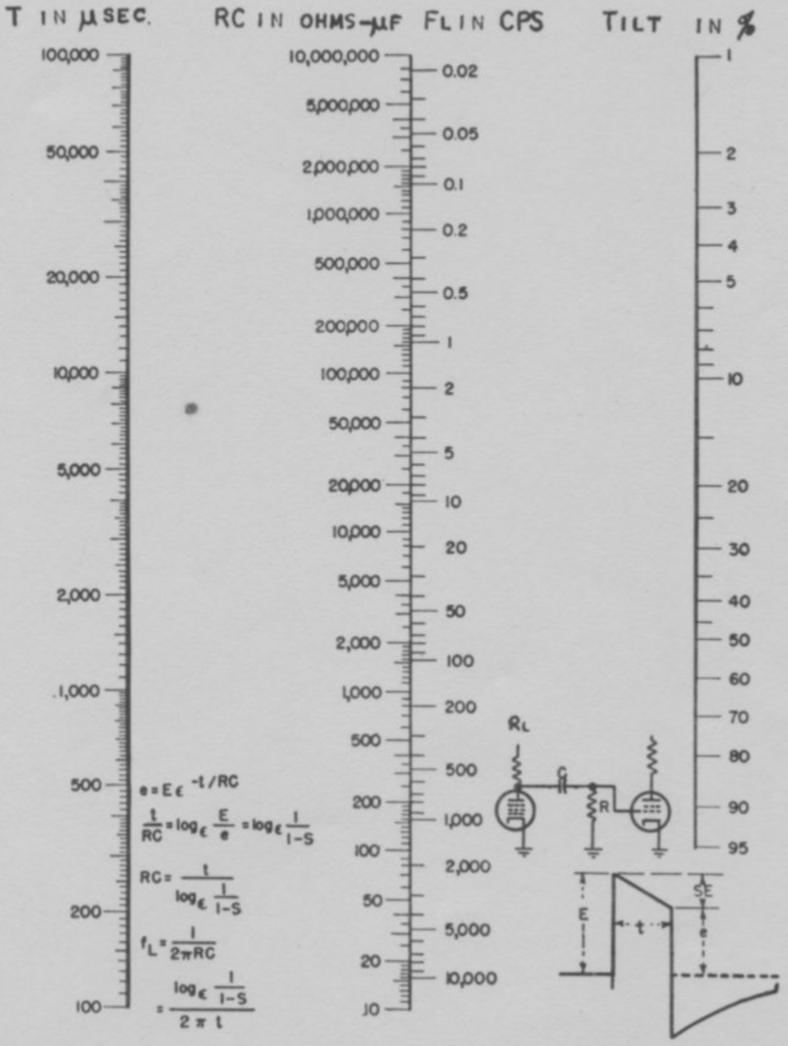
SQUARE-WAVE RESPONSE NOMOGRAPH

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 STAGESHOWN, 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 WAVE-FORM 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 µSEC 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-µF. THE CORRESPONDING LOW CUTOFF FREQUENCY FL IS FOUND TO BE 0.4 CYCLE.

FORM DBC-1

DECIBEL CHART

NEG.			POS.	
Voltage Ratio	Power Ratio	-Db+	Voltage Ratio	Power Ratio
1.0000	1.0000	0	1.000	1.000
.9772	.9550	.2	1.023	1.047
.9550	.9120	.4	1.047	1.096
.9333	.8710	.6	1.072	1.148
.9120	.8318	.8	1.096	1.202
.8913	.7943	1.0	1.122	1.259
.8710	.7586	1.2	1.148	1.318
.8511	.7244	1.4	1.175	1.380
.8318	.6918	1.6	1.202	1.445
.8128	.6607	1.8	1.230	1.514
.7943	.6310	2.0	1.259	1.585
.7762	.6026	2.2	1.288	1.660
.7586	.5754	2.4	1.318	1.738
.7413	.5495	2.6	1.349	1.820
.7244	.5248	2.8	1.380	1.905
.7079	.5012	3.0	1.413	1.995
.6918	.4786	3.2	1.445	2.089
.6761	.4571	3.4	1.479	2.188
.6607	.4365	3.6	1.514	2.291
.6457	.4169	3.8	1.549	2.399
.6310	.3981	4.0	1.585	2.512
.6166	.3802	4.2	1.622	2.630
.6026	.3631	4.4	1.660	2.754
.5888	.3467	4.6	1.698	2.884
.5754	.3311	4.8	1.738	3.020
.5623	.3162	5.0	1.778	3.162
.5495	.3020	5.2	1.820	3.311
.5370	.2884	5.4	1.862	3.467
.5248	.2754	5.6	1.905	3.631
.5129	.2630	5.8	1.950	3.802
.5012	.2512	6.0	1.995	3.981
.4898	.2399	6.2	2.042	4.169
.4786	.2291	6.4	2.089	4.365
.4677	.2188	6.6	2.138	4.571
.4571	.2089	6.8	2.188	4.786
.4467	.1995	7.0	2.239	5.012
.4365	.1905	7.2	2.291	5.248
.4266	.1820	7.4	2.344	5.495
.4169	.1738	7.6	2.399	5.754
.4074	.1660	7.8	2.455	6.026
.3981	.1585	8.0	2.512	6.310
.3890	.1514	8.2	2.570	6.607
.3802	.1445	8.4	2.630	6.918
.3715	.1380	8.6	2.692	7.244
.3631	.1318	8.8	2.754	7.586
.3548	.1259	9.0	2.818	7.943
.3467	.1202	9.2	2.884	8.318
.3388	.1148	9.4	2.951	8.710
.3311	.1096	9.6	3.020	9.120
.3236	.1047	9.8	3.090	9.550

NEG.			POS.	
Voltage Ratio	Power Ratio	-DB+	Voltage Ratio	Power Ratio
.3162	.1000	10.0	3.162	10.000
.3090	.09550	10.2	3.236	10.47
.3020	.09120	10.4	3.311	10.96
.2951	.08710	10.6	3.388	11.48
.2884	.08318	10.8	3.467	12.02
.2818	.07943	11.0	3.548	12.59
.2754	.07586	11.2	3.631	13.18
.2692	.07244	11.4	3.715	13.80
.2630	.06918	11.6	3.802	14.45
.2570	.06607	11.8	3.890	15.14
.2512	.06310	12.0	3.981	15.85
.2455	.06026	12.2	4.074	16.60
.2399	.05754	12.4	4.169	17.38
.2344	.05495	12.6	4.266	18.20
.2291	.05248	12.8	4.365	19.05
.2239	.05012	13.0	4.467	19.95
.2188	.04786	13.2	4.571	20.89
.2138	.04571	13.4	4.677	21.88
.2089	.04365	13.6	4.786	22.91
.2042	.04169	13.8	4.898	23.99
.1995	.03981	14.0	5.012	25.12
.1950	.03802	14.2	5.129	26.30
.1905	.03631	14.4	5.248	27.54
.1862	.03467	14.6	5.370	28.84
.1820	.03311	14.8	5.495	30.20
.1778	.03162	15.0	5.623	31.62
.1738	.0320	15.2	5.754	33.11
.1698	.02884	15.4	5.888	34.67
.1660	.02754	15.6	6.026	36.31
.1622	.02630	15.8	6.166	38.02
.1585	.02512	16.0	6.310	39.81
.1549	.02399	16.2	6.457	41.69
.1514	.02291	16.4	6.607	43.65
.1479	.02188	16.6	6.761	45.71
.1445	.02089	16.8	6.918	47.86
.1413	.01995	17.0	7.079	50.12
.1380	.01905	17.2	7.244	52.48
.1349	.01820	17.4	7.413	54.95
.1318	.01738	17.6	7.586	57.54
.1288	.01660	17.8	7.762	60.26
.1259	.01585	18.0	7.943	63.10
.1230	.01514	18.2	8.128	66.07
.1202	.01445	18.4	8.318	69.18
.1175	.01380	18.6	8.511	72.44
.1148	.01318	18.8	8.710	75.86
.1122	.01259	19.0	8.913	79.43
.1096	.01202	19.2	9.120	83.18
.1072	.01148	19.4	9.333	87.10
.1047	.01096	19.6	9.550	91.20
.1023	.01047	19.8	9.772	95.50
.1000	.01000	20.0	10.000	100.00

VOLTAGE RATIOS BEYOND THE RANGE OF THE TABLES.

A. Ratios less than those in tables: Multiply ratio by 10 successively until the result can be found in the tables. From the decibel value found from the table subtract +20Db for each time the multiple of 10 was used.

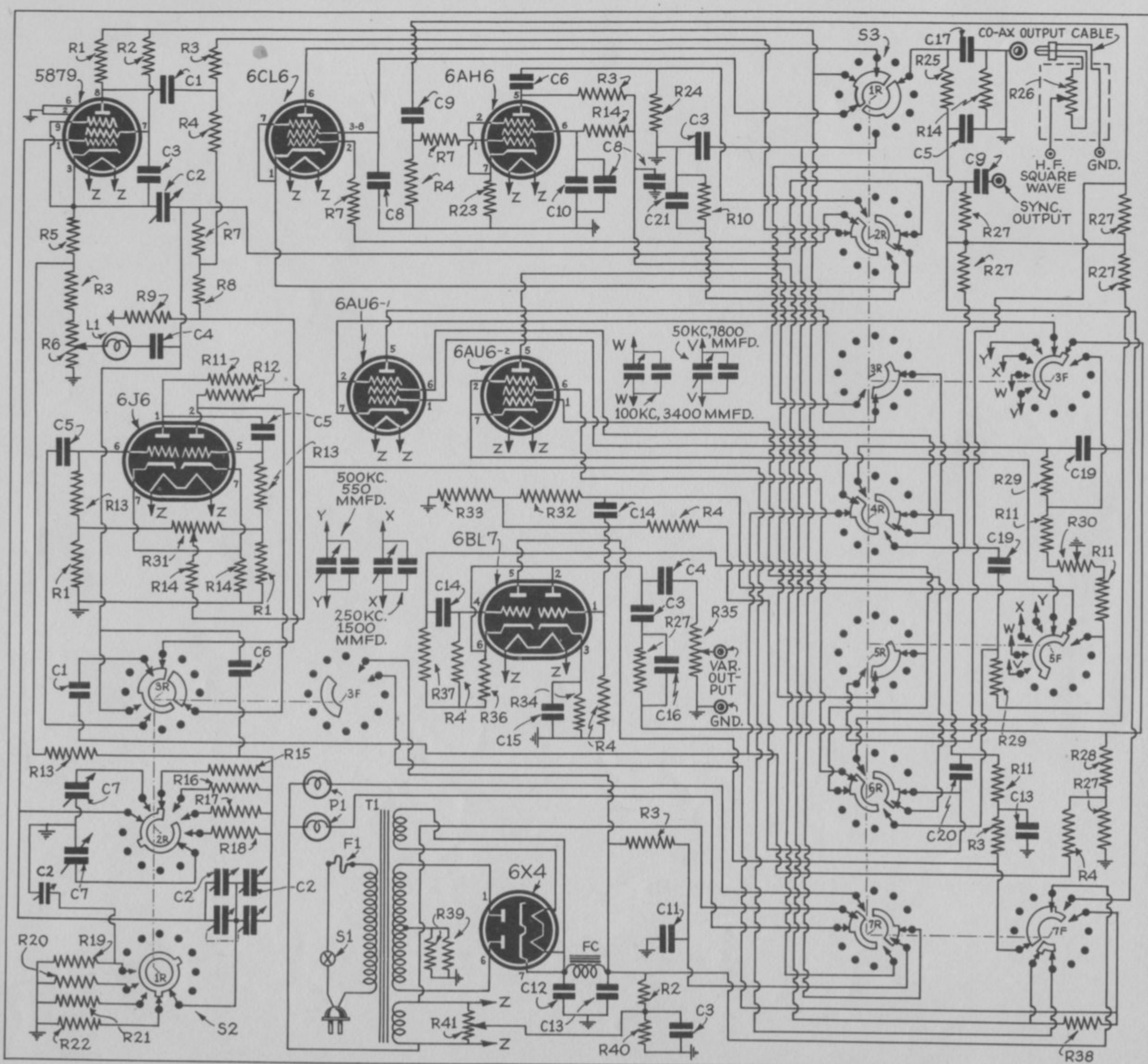
Example:- Voltage Ratio of 0.02042 - find Db value:-
.02042 x 10 x 10 = 2.042 from the table:- Voltage ratio of 2.042 = 6.2 Db
6.2 Db - 20 Db - 20 Db = -33.8 Db.

B. Ratios greater than those in tables: Divide ratio by 10 successively until the result can be found in the tables. To the Db value found from the table add +20Db for each time the divisor of 10 was used.

Example:- Voltage Ratio of 407.4 - find Db value:-
407.4 ÷ 10 ÷ 10 = 4.074 from the table:- Voltage ratio of 4.074 = 12.2 Db
12.2 Db + 20 Db + 20 Db = 52.2 Db.

PRECISION APPARATUS COMPANY, INC.
92-27 HORACE HARDING BLVD. • ELMHURST, NEW YORK

DWG. № 1062



ITEM	PART №	SPECIFICATION
70	C21	300 MMFD.
69	C20	0.5 MFD.
68	C19	.005 MFD. EACH
67	C18	.001 MFD. EACH
66	C17	4 MFD.
65	C16	56 MMFD.
64	C15	20 MFD.
63	C14	0.47 MFD. EACH
62	C13	20 MFD. EACH
61	C12	40 MFD.
60	C11	60 MFD.
59	C10	10 MFD.
58	C9	100 MMFD.
57	C8	.02 MFD. EACH
56	C7	4-30 MMFD. EACH
55	C6	.04 MFD. EACH
54	C5	0.1 MFD. EACH
53	C4	250 MFD. EACH
52	C3	40 MFD. EACH
51	C2	7-45 MMFD. EACH
50	C1	1 MFD. EACH
49	R41	600 Ω
48	R40	100K Ω
47	R39	300 Ω EACH
46	R38	15K Ω
45	R37	3900 Ω
44	R36	1600 Ω
43	R35	2500 Ω LEVEL CONT.
42	R34	270 Ω
41	R33	4300 Ω
40	R32	1300 Ω
39	R31	5K Ω L.F. SYMMETRY CONT.
38	R30	5K Ω H.F. SYMMETRY CONT.
37	R29	10 MEG. Ω
36	R28	390 Ω
35	R27	2200 Ω EACH
34	R26	250 Ω OUTPUT CONT.
33	R25	160 Ω
32	R24	56K Ω
31	R23	200 Ω
30	R22	4 MEG. Ω
29	R21	400K Ω
28	R20	40K Ω
27	R19	4K Ω
26	R18	49.99K Ω
25	R17	499.9K Ω
24	R16	4.999 MEG. Ω
23	R15	49.99 MEG. Ω
22	R14	22K Ω EACH
21	R13	1 MEG. Ω EACH
20	R12	6800 Ω
19	R11	10K Ω EACH
18	R10	56 Ω
17	R9	3500 Ω
16	R8	1500 Ω
15	R7	100 Ω EACH
14	R6	1K Ω
13	R5	560 Ω
12	R4	470K Ω EACH
11	R3	1K Ω EACH
10	R2	220K Ω
9	R1	27K Ω EACH
8	T1	POWER TRANSFORMER
7	S3	OUTPUT WAVE SWITCH
6	S2	BAND SWITCH
5	S1	ON-OFF SWITCH
4	FC	F. CHOKE
3	P1	#47 PILOT LIGHT
2	L1	3W. INCANDESCENT LAMP
1	F1	1 AMP. FUSE

PRECISION APPARATUS CO. INC.

TITLE: SINE & SQUARE WAVE SIGNAL GENERATOR SCHEMATIC SERIES E-300

DRAWN BY: DATE: 6-30-54
CHECKED BY: DATE: 7-6-54