CONVERSION OF A MODEL DBS
LORAN INDICATOR TO A FIXED
TIME-BASE OSCILLOSCOPE

by

J KENNETH TROLAN

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APPROVED:

Professor of Physics

In Charge of Major

Head of Department of Physics

Chairman of School Graduate Committee

Dean of Graduate School
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CONVERSION OF A MODEL DDS
LORAN INDICATOR TO A FIXED
TIME-BASE OSCILLOSCOPE

INTRODUCTION

In the past, radio and other communication systems have been the principal users of electronic devices. In such usage, circuits have been designed primarily to accommodate sinusoidal waves. However, because of the development of radar and associated devices, present trends in radio and electronic equipment utilized for physical measurements involve the generation, detection, and transmission of non-sinusoidal waves.

The use of non-sinusoidal waves in electronics necessitates some understanding of the transient response and analysis of networks. The circuits involved include those necessary for the generation of rectangular and square-waves, various types of multivibrators, clipping circuits, frequency multipliers, delay circuits, clamping circuits, timing circuits, and others that are often erroneously referred to as "trick" circuits. It is the purpose of this work to serve as an aid in introducing the student to this branch of electronics. Of the many kinds of one and two-tube circuits available for study, only the more complex ones have been constructed. Most of the circuits are simple enough so that they can
be built up in a rough manner and studied within the time allotted to one or two laboratory periods.
NON-SINUSOIDAL PERIODIC WAVES

In order to understand the effects of combinations of simple electrical components, say a capacitance and resistance or an inductance and resistance, upon a non-sinusoidal wave, one must understand something of the nature of the wave. In general such a wave can be represented by the following Fourier series:

$$f(t) = a_0 + a_1 \cos \omega t + a_2 \cos 2\omega t + \ldots + a_n \cos n\omega t + \ldots + b_1 \sin \omega t + b_2 \sin 2\omega t + b_3 \sin 3\omega t + \ldots + b_n \sin n\omega t + \ldots$$

This series indicates that the wave has an infinite number of components, each component having a frequency that is an integral multiple of the fundamental frequency. The amplitude of each component depends upon the shape of the particular wave represented by the series. If the wave is attenuated, or if the phase of any one component is shifted with respect to the others, the shape of the wave will be altered. Thus to transmit a non-sinusoidal wave without distortion the transmitting device must be able to pass without attenuation, or phase shift, all of the components of the wave. In actual practice, most waves will appear to be undistorted on an oscilloscope if the first ten harmonics are
present, although the number of harmonics required depends upon the wave shape. A wave with high amplitude harmonics is said to have a high harmonic content. The harmonic content of a wave thus depends upon its shape. The smoother the wave the lower the harmonic content; the more sharply the wave shape changes, the higher the content. Thus a sine wave contains only the fundamental while peaked waves and square waves have high harmonic content. Rather thorough discussions of wave analyses are given in a number of books on radio (3, p. 236-259), (7, p. 168-200), as are likewise functions representing various wave shapes (3, p. 245-248), (13, p. 20-23).

If a non-sinusoidal wave is impressed upon a passive circuit containing either inductance or capacitance, the reactance presented to the wave by the circuit is not equal for all the frequency components of the wave. As a result, some of the frequency components will be either attenuated or shifted in phase and the wave shape thus altered. Since it is often desirable to alter the shape of a particular wave, a knowledge of precisely what steps to take to accomplish the desired change is desirable. The reactive circuits used to cause changes in wave shape are classified as either differentiating or integrating circuits.
DIFFERENTIATING AND INTEGRATING CIRCUITS

The terms differentiating circuit and integrating circuit are not exact. However, they are most generally used to describe the four networks in Fig. 1. In a strict mathematical sense a differentiating circuit should produce an output voltage which is accurately proportional to the time derivative of the input voltage. Although this cannot be done exactly by the circuits of Fig. 1, a valuable feature of these circuits is that they produce predictable changes in various wave shapes. A good rule to remember is that differentiation of a wave accentuates its sudden changes while integration tends to smooth them out. This means that differentiation increases the harmonic content of a wave while integration decreases it.

To illustrate that neither differentiation nor integration are accurately accomplished with the simple circuits of Fig. 1, consider the application of a sine-wave to this simple resistance-capacitance network. The derivative of sin x is cos x. Thus the shapes of the input and output waves are similar but are 90° out of phase. A simple vector diagram applied to the voltage relationships in the circuit to which the wave is applied shows that a 90° phase shift is produced only when the output voltage is attenuated to zero.
Fig. 1. Circuits for Differentiation and Integration

Fig. 2. Changes in Wave Shapes Produced by Differentiation and Integration.
Therefore a 90° shift is not attainable in practice. When a sine wave is applied to an integrating circuit a similar phase shift occurs. However, there is no reduction in harmonic content, as called for by the previously stated rule, because only the fundamental is present and cannot be reduced. Thus differentiation and integration in a strict mathematical sense is not accomplished, even in the simplest cases. However the mathematical terminology serves to point out the kind of changes that can be produced by the simple circuits of Fig. 1.

Figure 2 indicates the mathematically predicted changes for five of the most common wave forms upon differentiation or integration. Any particular wave in the group, upon differentiation, is transformed into the wave directly above it, and upon integration into the wave directly below it.
THE NAVY MODEL DBS LORAN RECEIVING EQUIPMENT

The Model DBS is one of several types of Loran indicators employed for navigational purposes on ships or aircraft. Although designed specifically for this purpose, the indicator can be easily modified for use as a laboratory instrument.

A brief discussion of the use of Loran as a navigational instrument, and a summary of the principles upon which the system operates may aid in pointing out possible laboratory uses for it. For a complete discussion of the Loran system and equipment, refer to (2, all pages), (4, p. 94-99), (5, p. 110-115), (6, p. 109-115), and (10, all pages).

Loran is a long range, hyperbolic system of navigation consisting of chains of land-based transmitting stations that transmit short pulses of radio-frequency energy at definite time intervals. For simplification, consider the action of a single pair of stations in the chain. One station of the pair is called the "Master" station and the other the "Slave". Suppose that this pair of stations sends out pulses simultaneously. A navigator on a ship or plane within "listening" range of the two stations measures the difference in the time of arrival of the two pulses. This measured time-difference is utilized to determine from special
tables or charts a "line-of-position" on the earth's surface. A second "line-of-position" can be determined by receiving a different pair of stations. The point of intersection of the two "lines-of-position" establishes a "Loran fix".

The transition from a time-difference measurement to a distance measurement is possible since the radio-frequency pulses travel outward from the transmitter at a constant, known velocity. A Loran "line-of-position", which is a line of constant time-difference, is therefore a spherical hyperbola with the two transmitting stations located at the focal points. The Loran indicator is the device employed by the navigator of a ship or plane for measuring the time difference in the arrival of the transmitted pulses. These pulses have a recurrence rate of 25 cycles per second.

It is necessary that the navigator's reading accuracy be maintained at least as good as one microsecond in fifteen or twenty thousand microseconds. Since the received pulses are viewed on an oscilloscope, the base line must be provided with time markers that permit the required reading accuracy. This is accomplished by a 100 kc crystal-controlled oscillator and a series of frequency dividers. Sharp pips are generated at 100 kc and are caused to appear as 10 microsecond time markers.
upon the sweep trace. The 100 kc frequency is then divided by five to produce 20 kc markers which have periods of 50 microseconds. These in turn are applied to the oscilloscope trace for time measuring purposes. The 20 kc marker frequency is then divided by two to give 10 kc, 100 microsecond, pips. Frequency division is continued in this manner until the pulse recurrence rate of 25 cycles per second is reached. This is the sweep frequency of the indicator oscilloscope.

The indicator can be used in the laboratory as an accurate time scale for measuring time delays, pulse lengths, etc., or it can be used as a precise timing source. Thus, sharp voltage spikes or pips are available at accurately known time intervals for use as markers or as "trigger" sources.
Output Cathode Followers

Five different signal sources have been brought out to banana jacks on the right side of the indicator. The corresponding signals consist of a 100 kc sine-wave, 25 cycle pip, 25 cycle square wave, and 200 and 2000 cycle pips. Figures 3, 4, and 5 indicate completely the modification necessary to make the desired output signals readily available.

Most of the circuits in the indicator have high impedances. Therefore, in order not to disturb their normal operation by the various loads that might be connected to the output terminals, cathode-followers have been added to the outputs of four of them. The impedance of the fifth is already low, having been taken directly from a cathode follower in the indicator. The subject of cathode-followers will be discussed somewhat later.

Vertical Deflection Plates

Another modification consists in bringing out the vertical deflection plates of the oscilloscope tube to banana jacks on the left rear side of the indicator. It will be noticed that one deflection plate is more sensitive to loading by the video amplifier than the other.
Fig. 3. Sub-chassis addition mounted in indicator showing output cathode-follower tubes and output jacks.

Fig. 4. Sub-chassis in unmounted position for component change or check.
FIG. 5. INDICATOR SUB-CHASSIS — OUTPUT CATHODE FOLLOWERS
This appears as a distortion on one end of the slow sweep trace when the sensitive plate is connected to the output of the video amplifier. In nearly all cases the gain of the amplifier is sufficiently great that the push-pull output need not be used. In this case an unbalanced output from the video amplifier should be used and directly connected to the less sensitive deflection plate. The proper polarity for deflection can be found by trying first one output of the amplifier then the other.

**Power Source for Bread Boards**

Several auxiliary bread board circuits have been designed and constructed to operate from power derived from the indicator. These consist of a video amplifier, time delay multi-vibrator, pulsed oscillator, ringing circuit, blocking oscillator frequency divider and sine-wave frequency divider. A four-prong power plug appears at the rear of the right side of the indicator. The laced cable connected to this plug is coded with the following colors:

- **Red** - - - - + 215 volts; d-c regulated
- **Black & white** - 6.3 volt filaments (one side grounded)
- **Black** - - - - - ground
Video Amplifier

In using the indicator as either a trigger source, or as an oscilloscope to view the triggered phenomena, some convenient method must be provided to control the amplitude of the signal viewed. A variable-gain video-amplifier with a step attenuator, shown in Figs. 6, 7 and 8, has been constructed for this purpose. The amplifier together with the indicator is called a fixed time base oscilloscope.

The amplifier is similar in nearly all respects to the one used for vertical gain in the Du Mont Type 224-A Cathode-Ray Oscillograph. The principal difference is that a low capacitance electronic probe, Fig. 9, has been substituted for the ordinary probe. Figure 10 shows the circuits for the amplifier and probe; Fig. 11 the frequency characteristics of the amplifier. The general characteristics of this amplifier are listed below. The operating instructions for the Du Mont Type 224-A Cathode-Ray Oscillograph may be referred to for further details.
General Specifications of Video Amplifier

Input Impedance:

Terminals
2 meg., 30 μF.

Probe
4.7 meg., 12 μF.

Maximum Input Voltage:
600 volts, d.c. or peak.

Amplifier Frequency Response:
Sine-wave response uniform within 3 db.
from 30 c.p.s. to 3.0 Megacycles per second.

Power Supply Source:
115 volts, 60 cycles.
Fig. 6. Front view of Video Amplifier.

Fig. 7. Top view of Video Amplifier Chassis.
Fig. 8. Bottom view of Video Amplifier Chassis.

Fig. 9. Cathode-Follower high impedance probe.
Fig. 10.
FIG. II. FREQUENCY IN CYCLES PER SECOND

VIDEO AMPLIFIER
FREQUENCY RESPONSE
THE CATHODE-FOLLOWER

A cathode-follower, Fig. 12, is a simple electronic device having interesting properties and a wide variety of applications (1, p. 343-356), (11, p. 32, 92, 115, 148). It reproduces on the cathode a signal having a smaller amplitude and the same phase as the grid signal with the important difference that while the grid signal may be from a high impedance source, the cathode-follower serves as a low impedance generator of output voltage. This impedance transforming property is nearly independent of tube choice, cathode resistor, or plate-supply voltage. The circuit employs 100 per cent negative feedback with a resulting gain of less than unity.

Figure 12 shows the basic cathode-follower circuit. A simple circuit analysis (9, p. 18-19) will reveal the principal characteristics of the circuit. In this analysis the following terminology is employed:

\[ e_i = \text{the instantaneous value of the input voltage} \]
\[ e_g = \text{the instantaneous value of the grid cathode voltage} \]
\[ e_o = \text{the instantaneous value of output voltage} \]
\[ i_p = \text{the instantaneous value of the plate current} \]
\[ R_p = \text{the plate resistance of the tube} \]
\[ R_k = \text{the cathode resistance} \]
\[ \mu = \text{the amplification factor of the tube} \]
From Fig. 12,
\[ e_i = e_g + e_0 \]  
and \[ e_0 = i_p R_k \]  

The circuit of Fig. 12 can be replaced by the equivalent circuit of Fig. 13, in which case

\[ i_p = \frac{\mu e_g}{r_p + R_k} \]  

Substituting (3) into (2),
\[ e_0 = \mu e_g \left( \frac{R_k}{r_p + R_k} \right) \]  

If the value of \( e_g \) in (1) is substituted into (4),
\[ e_0 = \left( \frac{\mu R_k}{r_p + R_k} \right) (e_i - e_0) \]  

Rearranging,
\[ e_0 = \frac{\mu R_k e_i}{r_p + R_k} - \frac{\mu R_k e_0}{r_p + R_k} \]  

Gathering the terms involving \( e_0 \),
\[ e_0 \left( 1 + \frac{\mu R_k}{r_p + R_k} \right) = \frac{\mu R_k}{r_p - R_k} e_i \]
The gain of the circuit,

\[
\frac{e_0}{e_1} = \frac{\mu \frac{R_k}{r_p R_k}}{1 + \frac{\mu R_k}{r_p R_k}} \quad (8)
\]

or

\[
\frac{e_0}{e_1} = \frac{\mu R_k}{r_p + R_k (\mu + 1)} \quad (9)
\]

Rearranging,

\[
e_0 = e_1 \left( \frac{\mu}{\mu + 1} \right) \left( \frac{R_k}{\frac{r_p}{\mu + 1} + R_k} \right) \quad (10)
\]
Fig. 12. The Cathode-Follower Circuit.

Fig. 13. Equivalent Voltage-Divider Circuit of the Cathode-Follower.

Fig. 14. Equivalent Voltage-Divider Circuit of the Cathode-Follower.
It can be seen from (10) that the output voltage, $e_0$, is equal to the input voltage, $e_1$, multiplied by two factors each of which is less than unity. Therefore $e_0$ is always less than $e_1$. Consideration of (10) further reveals that it is an expression for the output voltage of the circuit of Fig. 14. An application of Thevenin's theorem to Fig. 14 gives a value for the output impedance, $Z_0$, which is

$$Z_0 = \frac{R_k}{\mu + 1} \frac{r_p}{R_k + \frac{r_p}{\mu + 1}} \cdot$$  \hspace{1cm} (11)

or,

$$Z_0 = \frac{R_k}{\mu R_k + R_k + r_p} \cdot$$  \hspace{1cm} (12)

Dividing numerator and denominator of (12) by $R_k r_p$

$$Z_0 = \frac{1}{\frac{\mu}{r_p} + \frac{1}{r_p} + \frac{1}{R_k}} \cdot$$  \hspace{1cm} (13)

Now $\mu = \varepsilon m r_p$ \hspace{1cm} (14)

and, by substitution of (14) into (13)

$$Z_0 = \frac{1}{\varepsilon m + \frac{1}{r_p} + \frac{1}{R_k}} \cdot$$  \hspace{1cm} (15)
Since $\frac{1}{R_k}$ is usually small compared to $g_m$ and, for values of $R_k$ greater than about 5,000 ohms, $\frac{1}{R_k}$ is also small in relation to the $g_m$,

$$Z_o \approx \frac{1}{g_m}$$

Equation (16) serves as a rough guide in predicting the output impedance of a cathode-follower.

To illustrate the effectiveness of the circuit as an impedance transformer consider the output impedance of types 6SN7 and 6AC7 tubes when used as cathode-followers.

The 6SN7 tube has a transconductance, $g_m$, of 3,000 micromhos, therefore

$$Z_o \approx \frac{1}{3,000 \times 10^{-6} \text{ mhos}} = 333 \text{ ohms}.$$  

The 6AC7 tube has a $g_m$ of 9,000 micromhos, therefore $Z \approx 110 \text{ ohms}$.  

This simple device can transform impedances as high as a million ohms down to hundreds of ohms over a very broad range of frequencies. The limitation at low frequencies is determined only by the ability of the RC input circuits to pass these frequencies. The high frequency limit depends upon how much load capacitance is shunted across the cathode resistor. If the time-constant is too large, the cathode-follower acts as an infinite impedance detector with the result that the cathode is no longer
able to follow the voltage impressed on the grid.

The grid return point has interesting effects on the circuit operation. Normally $R_g$ is returned directly to ground but may, in some cases, be returned to a tap on $R_k$ as shown in two of the circuits of Fig. 5. The current flowing through the tube raises the cathode voltage above ground to a stable point such that the bias is somewhere near, but less than, cut-off. If a positive signal is applied to the grid, more current will flow through the tube and the cathode voltage will rise along with the grid by approximately the same amount. Thus this type of grid return arrangement works well with large positive signals. However, as was mentioned, with no signal applied a near cut-off condition is maintained since the grid is at ground potential and the cathode is positive. When a negative signal is applied to the grid the current flowing through $R_k$ is decreased with a resulting drop in the cathode voltage. The cathode still follows the grid but cannot be reduced below ground potential. Thus when the grid is driven beyond cut-off, the cathode cannot follow and clipping occurs.

Suppose that the grounded end of $R_g$ Fig. 5 D is connected directly to the cathode. The grid is then clamped to the cathode so that, with no signal, the bias is always zero. This causes a large current to flow
through the tube which results in a cathode voltage far above ground. A positive signal on the grid will draw grid current which distorts the signal and biases the tube in the manner of a grid leak. However a negative signal on the grid decreases the current and reduces the cathode voltage. The amount that the cathode may drop is large since it was originally at a high voltage above ground. Therefore this type grid return can accommodate large negative signals.

To accommodate both positive and negative signals $R_g$ should be returned to a tap somewhere along $R_k$ as has been done in two of the circuits of Fig. 5. The exact position should be determined experimentally such that no distortion occurs.
TIME-DELAY MULTIVIBRATOR

Circuit Operation

The time-delay multivibrator is a device used extensively in radar timing circuits. It is also the basic circuit for the microwave communication system known as Pulse-Time Modulation. In Geiger counter work it is often referred to as a "one-shot multivibrator". Another use is as a variable time-delay in Time-of-Flight neutron velocity selectors.

A delay multivibrator, as shown in Fig. 15, consists of two resistance coupled amplifiers with a common cathode resistor. In operation, the circuit alternates between a stable and a semi-stable condition. Let the left half of V1, Fig. 15, be triode number 1 and the right half triode number 2. The signals applied to pin 1 consist of sharp pips widely separated in time. Since the grid of triode 2 is connected to +215v through R9, triode 2 is conducting when no pip is present. The cathodes of the two triodes have a common resistance R11. The current through R11 raises the cathode voltage of both tubes to the same level. However, triode 1 is cut off since its grid is at a low voltage, being determined by the tap on R6. Thus the plate voltage of triode 1 is +215v, while the plate voltage of triode 2 the "on" tube is much lower.
FIG. 15. TIME-DELAY MULTIVIBRATOR "A"

FIG. 16. TIME-DELAY MULTIVIBRATOR "B"
The circuit is now in its stable condition. Suppose next that a sharp positive pip is applied to the grid of triode 1, initiating the semi-stable condition. Triode 1 is then rendered conducting, causing its plate voltage to drop sharply. This sharp voltage drop is transferred through C4 to the grid of triode 2, which is driven sharply negative to cut-off. The plate voltage then suddenly jumps to -215 volts. The grid of triode 2 does not remain below cut-off because its voltage rises along the exponential curve determined by the charging of C4 through R9. When this grid voltage reaches cut-off, triode 2 is suddenly turned on, its plate voltage drops and its cathode rises in potential until it is high enough to again cut off triode 1. The plate voltage of triode 1 thus returns to -215 v. One cycle has now been completed and the circuit remains in the stable condition until triggered again.

Thus we see that the wave shapes at the plates of triode 1 and triode 2 are rectangular with the plate voltage of triode 1 low, and triode 2 high during the semi-stable portion of the cycle. The two plate voltages are 180° out of phase.

The magnitude of the delay is determined by the time that triode 2 is in the semi-stable or "off" condition. This time can be varied by changing the value of
either R9 or C4 since it is proportional to their RC product. However the cut-off point, and hence also the delay time, is determined by the position of the arm of the variable resistance R6. This is the usual method of adjustment.

The delay multivibrator may be used to introduce a delay between two events, provided that the event occurring last can be triggered by the first. This trigger voltage can be developed by differentiating the rectangular wave at the plate of either triode 1 or 2. Each of these waves when differentiated, will produce a sharp positive and a sharp negative pip, one occurring at the start of the delay and the other at the end of it. Since we are interested only in the pip occurring at the end of the delay time it is well to point out that this pip is positive from the plate of triode 1, pin 2, while from triode 2, pin 5, the pip is negative. Thus either a positive or negative pip is available for triggering.

It should be pointed out that although the multivibrator was triggered with a positive pip to pin 1 of triode 1, it could also have been triggered with a negative pip to pin 4 of triode 2 with identical operation of the circuit. The time-delay multivibrator "B", Fig. 16, is triggered with a negative pip applied to pin 4.
The time-delay multivibrator may be studied by using the units of Fig. 17 and Fig. 16 in the arrangement shown in Fig. 27. By connecting the two multivibrators in series and viewing the output with the Model DBS Loran indicator the wave shapes represented in Fig. 16 may be seen. In time sequence, the "A" multivibrator is triggered at the start of the fast sweep trace. (Function switch on the panel of the Loran indicator in positions 2, 3, or 5 for the fast sweep.) However, one cannot view the starting edge of the "A" multivibrator with this arrangement. Viewing the "B" multivibrator permits one to see the actual wave shapes since the "B" multivibrator starts when the "A" stops. To obtain an expanded view of the wave shapes, an auxiliary oscilloscope with a good low and high frequency response, should be used. The DuMont 208-B, for example, is satisfactory.

**Experimental Procedure for Studying the Time-Delay Multivibrator**

The sequence of the following events is not important since each event is complete in itself. Multivibrators, "A" and "B" are in series so that whatever change is made in the delay of unit "A" alters the position of the "B" pip on the scope sweep. However changes in the "B" delay do not affect "A".
The following sequence is suggested for an experiment on multivibrators:

1. View the wave shapes at the various pins on multivibrators "B" and "A" on the fast and slow sweeps of the Loran indicator (Function 1 slow, 2 fast). Compare these with the diagrams.

2. Vary R13 and note, on both slow and fast sweeps, the effect of variation in "B" delay time.

3. Vary R6 and note changes in both "A" and "B" delays.

4. Parallel C5 with a condenser of 200 to 500 \( \mu F \) and note the increased delay time as measured on pin 5 of "B". Also note the change in the pulses on pin 2 and pin 4. The fast sweep should be used.

5. Parallel R16 with a 500 K resistor and note the effect on the delay time. Resistor R16 and capacitor C5 comprise the RC time-constant that determines the delay time.

6. Switch to Function Position 5 on the Loran indicator and view the voltage on pin 5 of multivibrator "B". Determine approximately the rise time of the starting edge and the fall time of the stopping edge. Now connect a 10 to 50 \( \mu F \) condenser from pin 5 to ground and note the effects on the rise and fall time.
Circuit Operation

This experiment is included for two reasons. First, a technique for pulsing an oscillator is shown. Secondly, the damping of an oscillatory system, as a function of its "Q", is well demonstrated.

Figure 19 is a schematic diagram of the bread board model of the pulsed oscillator shown in Fig. 21. A pentode, V4, is used in a conventional Hartley oscillator, excepting that the screen grid is connected to ground through R22, and a resistor, R19, is put in parallel with the resonant circuit. If the end of R22 (opposite to the grid) is connected to +215v the oscillator will be free running; if connected to ground, it is quiescent. If in some manner the screen grid of V4 can be raised to +50 volts or above, the oscillator will perform normally. Thus if a short pulse, say a rectangular wave from the delay multivibrator, is used to raise the screen voltage, the oscillator will produce oscillations that persist during the time that the screen is positive. Such a pulse may be obtained from the plate of the "B" multivibrator. This plate wave, pin 5 V2, Fig. 16, has the proper polarity but by itself cannot deliver enough power to the screen grid of V4 to cause oscillation.
For this reason, the cathode-follower, V5 Fig. 19 is inserted to drive the screen positive during the pulse interval.

**Experimental Procedure**

1. Connect multivibrators "A" and "B", Figs. 15 and 16, in series, to the pulsed oscillator as shown in Fig. 27. View the screen pulse and the RF pulse of the points indicated in Fig. 19.

2. Vary the two delay controls on multivibrators "A" and "B" and note the effect on the pulse. The "A" multivibrator delays the pulsing time; "B" varies the pulse length.

3. After adjusting the "B" multivibrator delay control so that the pulse length is around 100 microseconds (Function switch on the Loran unit in position 5 to determine pulse length), turn the R19 knob clockwise to maximum resistance. The oscillator is now least damped and has a high "Q". Note the number of cycles in rise and decay times.

4. Slowly decrease R19 and note the effect of lowering the circuit "Q" on the rise and decay time.
FIG. 19. PULSED OSCILLATOR

FIG. 20. RINGING CIRCUIT
THE RINGING CIRCUIT

The ringing circuit should be studied in conjunction with the pulsed oscillator since it is also a pulsed oscillator though of a different type.

It was noted, in the discussion of the pulsed oscillator, that although a rectangular shaped pulse was applied to the screen grid, the RF pulse was not rectangular. The latter rose slowly and decayed exponentially. The rise and decay times are functions of the "Q", of the resonant circuit.

In the ringing circuit, however, the RF pulse rises to full amplitude during the first half cycle. This is because the inductance is fully energized by the direct current that is maintained through it during the non-oscillating period. With the application of the negative square wave the direct current is cut off and the magnetic field of the coil collapses, starting the oscillations at full amplitude.

This circuit has considerable practical importance (2, Chapter 2 p. 70-72) as a time-marker source for the oscilloscope. The starting time of the time markers is independent of any continuous action and is therefore convenient to use in the study of transient phenomena.
Circuit Operation

The ringing circuit of Figs. 20 and 22 consists of a conventional triode Hartley Oscillator which is maintained in a non-oscillating condition by the direct current of the cathode-follower half of V3, through R2 and L1. A negative rectangular wave applied to pin 1 of V3 cuts off the cathode-follower, stops the direct current through L1 and permits the oscillator to function normally. The value of R2 has been carefully chosen so that the direct current flowing through L1 is equal to the peak current at maximum amplitude of oscillation.

Experimental Procedure

1. Connect multivibrators "A" and "B" in series exactly as for use with the pulsed oscillator. Connect the ringing circuit as indicated in Fig. 27 for the pulsed oscillator. Note that, in contrast to the pulsed oscillator, a negative instead of a positive rectangular pulse is now needed. This is derived from the first plate of multivibrator "B", pin 2 of V2, Fig. 16. This voltage is 180° out of phase with that on the second plate of multivibrator "B", pin 5, V2.

2. Verify the various wave shapes shown in Fig. 20.
Fig. 21.

Fig. 22.
Circuit Operation

The cathode of V7 Fig. 23 is biased positively by R26 so that the tube is cut off when the grid is at ground potential. The grid of V7 can have its potential changed only by a charge developed on C12. In operation a series of sharp positive and negative pips are applied to C11. The negative pips are shorted to ground through the left half of the dual diode, V6. The positive pips pass through the right half of the dual diode V6 and charge the condenser C12 positively. Each positive pip increases the charge on C12 so that its voltage, and hence the voltage on the grid of V7, appears as a series of ascending steps with time intervals equal to those of the incoming positive pips. When the grid of V7 reaches cut-off, plate current starts to flow. The pulse transformer, T1, is so connected that the grid voltage increases with increasing plate current. This further increases the plate current which drives the grid further positive. Finally the plate reaches saturation, the field collapses causing the grid to be driven negatively. This regenerative action cuts off the tube. Condenser C12 is negatively charged because of the current drawn while the grid was positive, and the cycle is ready to
be repeated. As represented by the wave forms in Fig. 23, it takes five input pips to get one pip out of the plate circuit so that the frequency is divided by five. The counting range, or dividing factor, can be varied by adjusting R26. High counts, division by 10 or higher, are unstable and are to be avoided.

Experimental Procedure

1. Connect the Blocking Oscillator bread board, Fig. 25, as shown in Fig. 23. Verify the wave shapes of the figure by viewing with the amplifier and oscilloscope.

2. Vary the count by adjusting R26.

3. Vary separately the values of C11 and C12 by a factor of say 2 by connecting condensers in parallel. Note the effects on the counting rate.
Fig. 23. Blocking Oscillator Divider

Fig. 24. Sine-Wave Divider
THE SINE WAVE FREQUENCY DIVIDER

This type of divider is very stable and performs well. It is included here primarily to illustrate, by simple means, various ways of using conventional circuits. For example, this two-tube circuit may be used to illustrate frequency division, frequency multiplication, frequency addition, and frequency subtraction.

Circuit Operation

The function of the circuit of Fig. 24 is to transform a 100 kc into a 20 kc sine wave. Thus the frequency is to be divided by five. The 100 kc sine wave derived from the Loran indicator is applied to one of the control grids, pin 8, of a conventional mixer tube, V8. If an 80 kc sine wave is impressed on the other control grid, pin 5, this wave and the 100 kc wave will combine to give the sum and difference frequencies of the two waves. The difference frequency is selected by tuning the plate load of V8 to 20 kc. This 20 kc wave is then impressed on the grid, pin 4, of V9. If the grid is driven hard enough to draw grid current, or to cut off the tube, distortion is introduced into the grid signal. This is just one way of saying that harmonics are added to the wave. The plate load of V9 is tuned to 80 kc. This
tube selects, and amplifies the fourth harmonic of the 20 kc signal and provides the 80 kc signal which is impressed on pin 5 of V8.

The starting point for this analysis is that when the circuit is first turned on, the initial pulse of current through V8 shock-excites the 20 kc resonant circuit. This circuit rings at 20 kc long enough for V9 to amplify the fourth harmonic giving 80 kc. This 80 kc signal is fed to V8 where it beats with the 100 kc to sustain the 20 kc oscillations.

By altering the resonant frequency of the plate loads division by any integral can be attained provided the rules of multiplication, division, addition, and subtraction are adhered to.

**Experimental Procedure**

1. Connect the sine wave divider, Fig. 26, as shown in Fig. 24. Note and verify the various wave shapes as pictured in the figure.

2. Observe the distortion to the 20 kc wave at pin 4, V8.

3. Observe the distortion to the 80 kc wave at pin 8, V9.

4. Note that the amplitude of every fourth cycle of the 80 kc wave is larger than the others. This occurs
because the 20 kc signal pulses the grid only once during four oscillations of the 80 kc circuit.

5. Show by viewing the 20 kc signal on the scope that the input frequency is divided by five. The appearance of five 10 micro second markers for each cycle of the sine wave verifies that the output frequency is 20 kc.
Video Amplifier

Loran Indicator

Fig. 28.
INDICATOR OPERATION

Complete operation and maintenance instructions for the Model DBS indicator are given in the Loran Instruction Book, (2, all pages).

The following instructions are for its use in combination with the video amplifier as a fixed time-base oscilloscope.

All necessary indicator controls are on the front panel. The on-off switch is combined with the receiver gain control. Do not turn up the gain. If the gain is too high, noise voltages will appear on the scope trace.

The R. F. Channel selector has no effect in this operation and can be left in any position.

The Amplitude Balance is of no importance in this application. Any position is satisfactory.

The Station Selector should be left on zero.

The Drift and Left-Right controls change the 100 kc crystal frequency slightly but can be used in any position.

The PRR (pulse recurrence rate) is 25 cycles per second when the switch is on L (low) or 33 1/3 cycles per second when on H (high). Operate on L normally.

The only controls having any effect are the Coarse Delay, Fine Delay and Function Selector. Of these only
the Function Selector is of great importance.  
Most viewing will be done with the Function Switch at position 1, 2, or 5.

The various Function positions are:
1. Slow sweep. Total sweep time presented is 40,000 micro seconds.
2. Fast sweep, traces separated.
3. Fast sweep, traces superimposed.
4. 1000 microsecond marker check.
5. Slow sweep with time markers. Shortest marked interval is 10 microseconds. Every fifth marker is raised to mark off the 50 microsecond intervals. Every tenth interval is still higher for the 100 microsecond markers. Every one hundredth 10 microsecond marker or every tenth 100 microsecond marker is a double marker to indicate 1000 microsecond time intervals.

With the Function switch at position 1 the slow sweep is presented. A notch appears on the right hand end of the lower trace. This notch is the starting time for the fast sweep, and is the source of the 25 cps pip. The position of the notch on the slow sweep is controlled by the Coarse and Fine Delay controls. The Fine Delay has a small range but is continuous. The Coarse Delay is locked at 500 microsecond intervals so that the notch appears to jump when the control is moved. If the 25 cps
output source is used for triggering and the signal being viewed appears to jump, make a slight adjustment of the coarse delay control to stop the erratic effect.

Warning

There are many front panel and side-of-chassis adjustments. **Under no circumstances should anyone adjust any of these** before consulting the instruction book and thoroughly understanding precisely what effect each control has and what comprises satisfactory adjustment.

Quite likely these controls will never need readjustment.
SUGGESTED CIRCUITS FOR STUDY

Many simple circuits other than those discussed can be easily studied by utilizing the Model DBS as a trigger source and for viewing.

The principles and techniques involved in the operation of these circuits can often be carried over to other applications. The following list of circuits is suggested for study:

3. Sweep Circuit Generators. (11, Chapters 5, 6, 7).
4. Trigger Circuits. (11, Chapter 4).
6. Square-wave generator circuits and peaking circuits. (1, Chapter 11).
7. Study of pulse transformers. (12, Chapter 2, p. 73-88).
8. Trapezoidal Generator. (12, Chapter 3, p. 47).
BIBLIOGRAPHY


