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A TUNING-FORK AUDIO OSCILLATOR

By CHARLES E. WORTHEN*

FOR a variety of measurements in the communication laboratory, and for bridge measurements in particular, a fixed frequency oscillator is an indispensable instrument. Among the requirements which such an instrument should meet are good waveform, simplicity of construction, and low cost.

These requirements may be met by an oscillator using a tuning fork as the frequency-controlling element. The electrical circuit of such an oscillator is shown in Figure 1. Referring to this diagram, F is a tuning fork which serves as a frequency-controlling device. When this fork is set in motion, it vibrates at its natural frequency (depending on its dimensions), and causes the diaphragm of the microphone button M , which is mechanically coupled to the fork, to vibrate at the same frequency. The resistance of the microphone button varies in accordance with the motion of its diaphragm, and causes a corresponding variation in the current which flows in a circuit consisting of the microphone button M , the battery B , and the primary of the output transformer T_1 . An alternating voltage of the fork frequency is then produced at the secondary terminals of T_1 , and alternating current flows

around the circuit consisting of the secondary of T_1 , the drive coil D , the condenser C_1 , and the primary of the output transformer T_2 . A portion

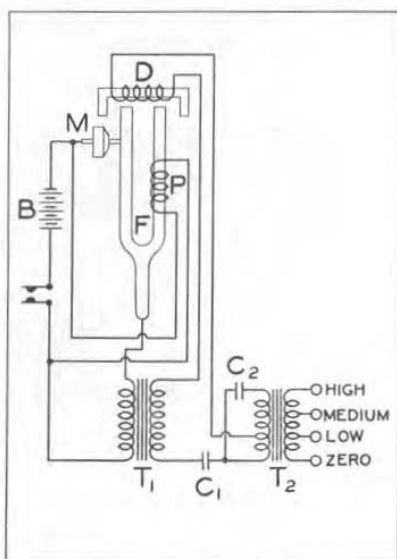


FIGURE 1

of the available energy is fed back through the drive coil to keep the fork in motion, and the rest is supplied to the load at the secondary terminals of the output transformer T_2 . The condenser C_1 is used to shift the

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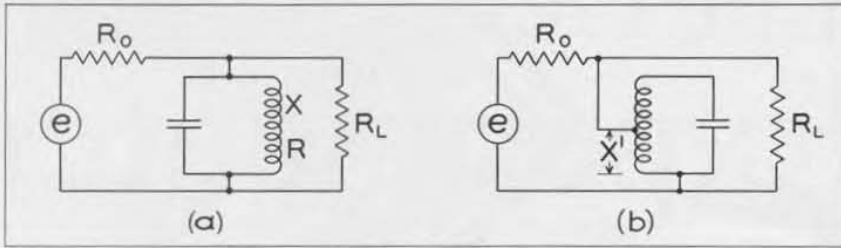


FIGURE 2

phase of the current through the drive coil to the value necessary to drive the fork. Since the fork is not permanently magnetized, a polarizing coil P is necessary to supply a constant magnetic bias. Without this, the fork would be driven at twice its natural frequency.

The circuit elements of Figure 1 exclusive of the output transformer can readily be adjusted for maximum output. When such a condition is reached, the output voltage contains a

large number of harmonics of considerable magnitude, and to get good waveform, some method of filtering is necessary.

This can be accomplished by the arrangement shown at the right of Figure 1. This is, in effect, a parallel tuned circuit placed across the output.

If the output transformer (which is merely a means of matching impedances) is disregarded, the oscillator circuit may be represented as shown in



FIGURE 3. TYPE 213-C Audio Oscillator. TYPE 213-B Audio Oscillators are the same except that they have somewhat shallower cabinets

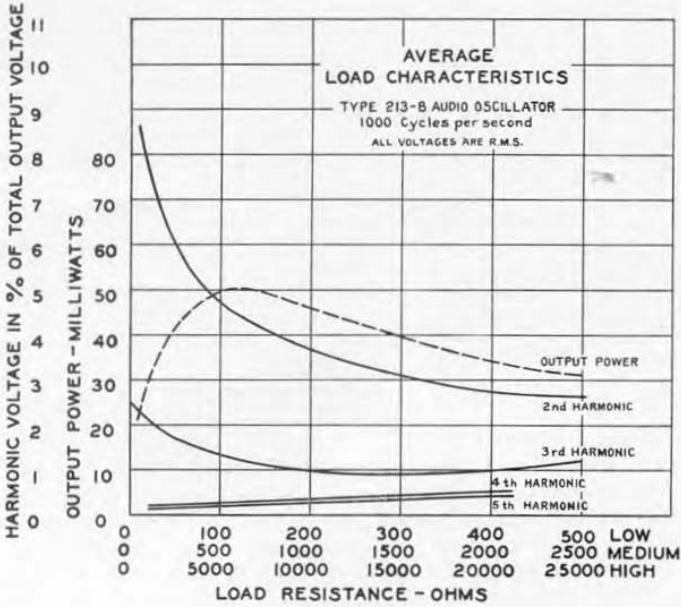


FIGURE 4. Average load characteristics: Upper left—TYPE 213-B Audio Oscillator, 1000 cycles per second; Lower right—TYPE 213-C Audio Oscillator, 400 cycles per second

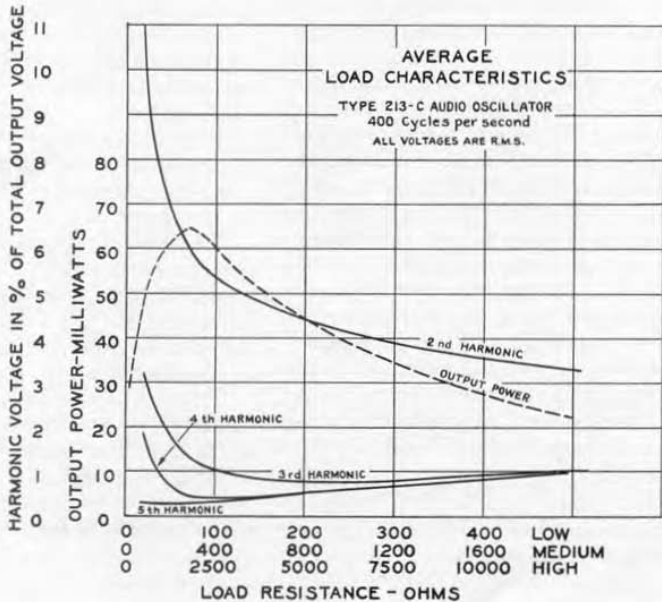


Figure 2a, where R_0 is the internal impedance of the oscillator, R_L is the load resistance, and R and X are, respectively, the resistance of the tuned circuit and the reactance of one of its branches. The resonant impedance of the tuned circuit is a pure resistance and is equal to $\mathcal{Q}X$ where $\mathcal{Q} = \frac{X}{R}$.

Its impedance at a harmonic frequency which is n times the fundamental is $\frac{n}{n^2-1} X$. The ratio of the fundamental impedance to the harmonic

impedance is then $\frac{n^2-1}{n} \mathcal{Q}$, which is

a measure of the filtering action of the tuned circuit. When this ratio is large, the harmonics are bypassed by the tuned circuit, and do not reach the load. This selective action is modified by the load resistance, and as R_L becomes large compared with $\mathcal{Q}X$, the ratio of fundamental to harmonic impedance approaches $\frac{n^2-1}{n} \mathcal{Q}$ for

the parallel combination of tuned circuit and load resistance. This means that as the load resistance increases, the waveform improves, which is shown by the curves of Figure 4.

Since, for proper operation, a low-impedance tuned circuit is required, the arrangement shown in Figure 2a would require a prohibitively large value of condenser. This difficulty can be overcome by using a high-impedance circuit and tapping the inductive branch at a point which gives the desired value of impedance. If X and R are the reactance and resistance of the whole coil and X' (see Figure 2b) is the reactance of the tapped portion, the resonant impedance can be shown to be $X' \frac{X}{R} = X' \mathcal{Q}$ for values of coupling approaching unity. The coil acts as an auto-transformer to step down the impedance.

In order to save both space and material, the primary of the output transformer can be used as the inductive branch of the tuned circuit, as shown in Figure 1. As transformers are ordinarily used, where the winding reactances are large compared to the impedances between which they work, the primary cannot be tuned because the reactance seen on the primary side is extremely small. This difficulty is avoided by making the transformer reactances very small in comparison to the impedances to which they are connected, so that the load may be varied over wide limits without an appreciable change in the apparent primary reactance. If unity coupling is assumed and winding resistances are neglected, the impedance looking into the primary of a transformer is the primary reactance in parallel with the reflected load impedance. If, then, the reflected load impedance is large compared with the primary reactance, the impedance looking into the primary is approximately equal to its reactance. Under this condition, tuning of the primary will hold for a wide range of loads.

Output characteristics showing both power and waveform are given in Figure 4 for a 400-cycle and a 1000-cycle oscillator. Since \mathcal{Q} for the coils used is lower at 400 than at 1000 cycles, a slightly better waveform is obtained for the latter.

For several years the General Radio Company has been manufacturing a 1000-cycle tuning-fork oscillator, the TYPE 213 Audio Oscillator. This has been redesigned to include the filtering arrangement we have just discussed.

The new output circuit makes it a relatively easy matter to build these oscillators for operation on other frequencies, and, in addition to the 400-cycle and the 1000-cycle models regularly carried in stock, instruments for any 100-cycle multiple in the 400-1500-cycle range can be built to order.



FIGURE 1

AN AUDIO AMPLIFIER FOR THE LABORATORY

By ARTHUR E. THIESSEN *

THE TYPE 645 Laboratory Amplifier illustrated in Figure 1 has been designed to fill the need for a two-stage audio amplifier of the greatest possible flexibility to be used for general experimenting. Because of the widely varying requirements of different experimenters and since the needs of every experimenter change from day to day, it is almost impossible to design one amplifier to serve all purposes.

By utilizing the plug-in principle for the input and interstage coupling units, the widest variety of circuit requirements may be met. The amplifier is supplied with jack plates, properly drilled to receive the TYPE 274-EP Transformer Mounting Base to which any type of coupling unit may be attached. Or, if it is necessary to use only a part of the amplifier, any standard TYPE 274 two-element plug may be plugged in at the desired point in the circuit; for example, across the

grid of the output tube. The convenience of such flexibility is at once apparent to experimenters who have tried to adapt an amplifier to some purpose by the use of a soldering iron and clips.

Each amplifier is sold with two of the standard TYPE 274-EP Transformer Mounting Bases which fit the jack plates on the amplifier base and to which any form of transformer or coupling device may be attached. The bases are drilled especially to fit the General Radio TYPE 585 Transformers and the TYPE 573-A Resistance-Impedance Coupler.

Figure 2 shows the circuit diagram. The power transformer, filter, and grid-bias units are each in separate containers, all of which are connected together and grounded. The can covers for the removable units may also be grounded by means of the center jacks on the mounting jack plates. All of the wiring is done under the base, but is exposed so that changes can be made readily if necessary.

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The circuit is similar to the usual two-stage amplifier circuit, except that the filament center tap rather than the negative plate-battery terminal is grounded. This is done so that the output terminal can be connected directly back to filament and to ground at the same time.

The output circuit consists of a 40-henry inductance and a 4-microfarad condenser. At 50 cycles, this circuit has an inductive reactance of over 12,000 ohms, and a capacitive reactance of 800 ohms in series with the output terminals. These values are large enough so that, at frequencies above 50 cycles, the practically constant tube impedance of 2,000 ohms is seen, looking back from the output. This impedance may then be matched to any sort of a load by a suitable impedance-matching transformer or network.

Numerous tests have been conducted on this amplifier, one of which may be regarded as typical. Figure 3 indicates the frequency-response char-

acteristic of the amplifier using two General Radio TYPE 585-D Transformers which have a 1:2 voltage step-up ratio and are designed to work out of about 10,000 ohms. The curve was taken with the amplifier working out of 10,000 ohms and into 5,000 ohms. The curve shows the gain of the amplifier to be approximately 40 decibels over its flat portion — from 90 to 6,000 cycles — dropping off two decibels at 40 and 8,000 cycles. The response is down 5 decibels at 25 cycles, and 4 decibels at 10,000 cycles.

The amplifier is designed for operation on 105–115 volt 60-cycle alternating current. It requires a total of about 35 watts of power.

The residual alternating-current hum is very low. The hum voltage is 0.35 volt across 5,000 ohms. This is a hum power of 0.024 milliwatt, 24 decibels below a zero level of 6 milliwatts. The output tube is the 245-type which will deliver about 1,600 milliwatts of output power without introducing greater than 5 per cent. harmonic

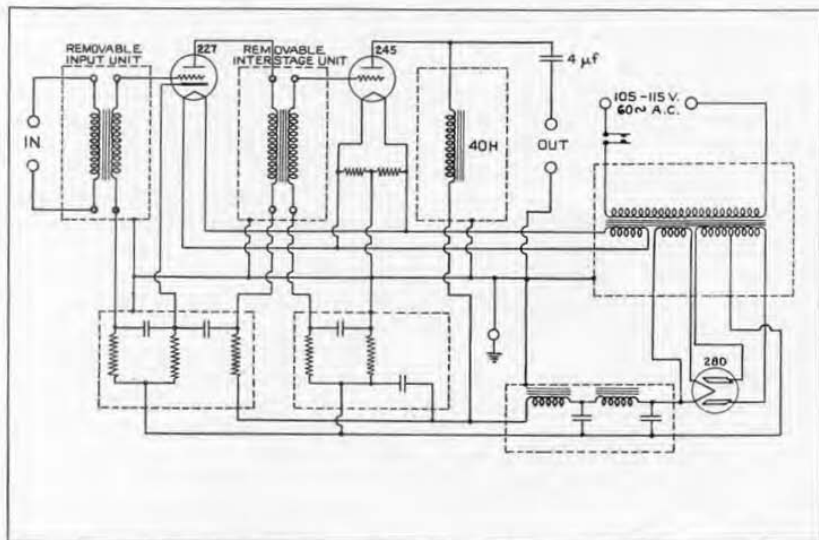


FIGURE 2. Wiring diagram for TYPE 645 Laboratory Amplifier

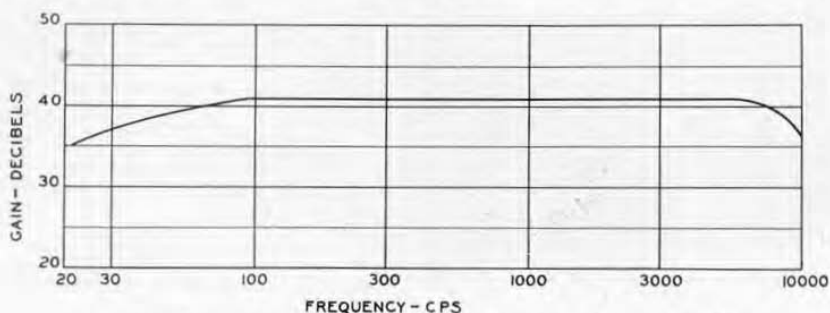


FIGURE 3. Frequency-response characteristic of TYPE 645 Laboratory Amplifier

distortion due to overloading. This corresponds to 89.5 volts across a 5,000-ohm load.

Any circuit containing iron will introduce a slight harmonic distortion to a pure sinusoidal voltage wave applied to it. With a direct-current bias the second harmonic is usually one of the worst generated from this cause. Its magnitude varies with the amount of power transferred through the iron circuit. The total second harmonic distortion present in the TYPE 645 Laboratory Amplifier, caused by the combination of the non-linearity of the iron, as well as that of the tubes in the circuit, has been measured. The amount can be expressed as a ratio between the amplitude of the pure sine wave and the second harmonic appearing at the output terminals of the amplifier, assuming that a pure sinusoidal wave is applied at the input. At 100 milliwatts output, the harmonic voltage is 35 decibels below the fundamental, and at 1,000 milliwatts output,

it is down 26 decibels. This small distortion is by no means entirely due to the iron, but the curvature of the tubes' characteristics, particularly at the higher output, is a factor.

An amplifier should never be used to increase a very small power to a value that can be read on ordinary instruments unless all of the constants of the amplifier are definitely known.

However, when *comparing* two or more low power sources the amplifier is invaluable because its constants enter into all measurements and cancel in the final result.

The General Radio TYPE 645 Laboratory Amplifier is suitable for all kinds of laboratory experimenting where a flexible and serviceable amplifier is needed.

The amplifier is sold without input or interstage transformers. Any good coupling unit may be used. We recommend the following, selected from our standard line.

Type	Unit	Voltage Ratio	Use
585-D	Transformer	1:2	plate-to-grid
585-H	"	1:3.5	plate-to-grid
585-G	"	1:3.6	line-to-grid
585-M	"	1:27	single button microphone-to-grid
585-M2	"	1:27	double button microphone-to-grid
573-A	Resistance Impedance Coupler	1:1	plate-to-grid

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TYPE 213 AUDIO OSCILLATOR

The old TYPE 213 Audio Oscillator, long a necessary element of bridge measurements, has been redesigned, and a 400-cycle model has been added. Its advantages are good waveform, simplicity of construction, and low cost.



Type	Frequency	Operated	Depth	Weight	Code Word	Price
*213-B	1000 cps	6 volts, d.c.	5 in.	5 lb.	ANGEL	\$34.00
*213-C	400 cps	6 volts, d.c.	6 $\frac{1}{8}$ in.	5 $\frac{3}{4}$ lb.	AMUSE	42.00

* Both TYPE 213-B and TYPE 213-C are built for other frequencies on special order. Code words and prices apply only to frequencies here listed.



TYPE 645 LABORATORY AMPLIFIER

Plug-in interstage transformers, high gain, good waveform, handy for all kinds of experimental work.

No transformers are supplied with the TYPE 645 Laboratory Amplifier, but the necessary mounting bases, ready for connection, are furnished. The price of \$78.00 does not include tubes.

Type	Code Word	Price
645	AMBLE	\$78.00

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