Phase Inversion Circuits

Part I—The transformer type of inverter, with some variations on standard circuits

By J. W. STRAEDE*

PHASE inverters are devices commonly used in amplifiers and large radios. Their purpose is to provide two equal but antiphase alternating voltages which are usually applied to the grids of push-pull output tubes. They are also used in electronic test equipment, including watt-meters, distortion meters and special types of oscilloscopes.

The signal voltage required by the following stage and the suitability of the system for use with negative feedback, are among the several factors that must be considered in the choice of a phase-inverter circuit. Power may also be required by the output tubes, as in class-AB2 operation, and, finally, the cost may override all other factors, no matter how desirable they might be.

Phase inverters are classified according to the way the signal voltages are fed from one stage to another. Classifications are: (1) Inductively coupled, (2) Resistance-capacitance coupled, and (3) Direct coupled.

The oldest form of inductively coupled phase inverter is the transformer with a center-tapped secondary, or with two secondary windings—one for each grid. Other inductive systems use a center-tapped choke coil, and a transformer with no center tap but with the secondary voltage divided by a pair of equal resistors. These three circuits are shown in Figs. 1, 2, and 3,

Transformer coupling

Biggest drawbacks to the use of transformers are their cost, liability to hum pickup, and imperfect frequency response. Hum can be reduced by mounting them away from power transformers and chokes and by rotating them until a position of minimum hum is found. High-frequency peaks can be reduced by shunting the secondary with resistors (about ½ megohm), while things can be improved generally by using negative feedback in the driver stage.

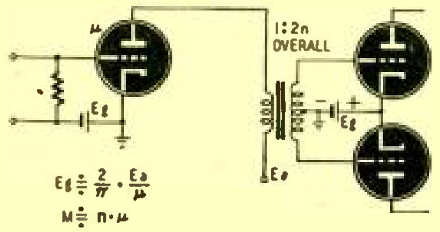


Fig. 1—Standard transformer-coupled circuit.

Advantages of transformer coupling are the large signal voltages obtainable, the low d.c. resistance in the grid circuits of the output tubes and its adaptability for class-AB2 operation. In this case, the transformer usually has a step-down ratio to match the minimum grid input resistance of the next stage to the plate resistance of the driver. (Grid input resistance varies from values too large to bother about when the grid is negative to values as low as a few hundred ohms when the grid is very positive.)

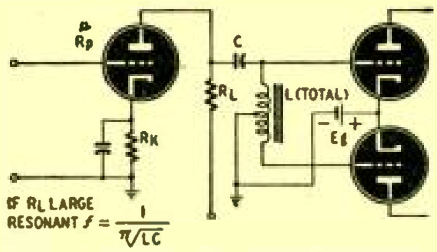


Fig. 2—Inversion with single tapped coil.

The gain M of the driver and the transformer is nearly equal to the product of the amplification factor and transformer ratio. The optimum grid bias Eg is $\frac{2}{\pi}$ times the plate voltage divided by the amplification factor.

The center-tapped choke is a comparatively inexpensive device, but is full of faults, such as unbalance at very high frequencies, low response at very low frequencies, and low voltage output. It is still useful for compact car radios and small mobile amplifiers where only a limited frequency range is required. A good quality center-tapped output transformer can be used with fair results if it has enough inductance.

The low output voltage is due to the voltage drop across RL (Fig. 2), together with the drop in effective load impedance also caused by RL. If RL is decreased to avoid the first defect, the second defect becomes more pronounced. At medium to high frequencies, the gain M approaches

$$\mu\left(\frac{RL}{RL + Rp}\right)$$

where μ is the amplification factor of the tube, RL is the load resistance, and Rp is the plate resistance. The bass resonant frequency is given by

$$f = \frac{1}{\pi\sqrt{LC}}.$$

The gain then is

$$\frac{\pi f L \mu}{2\,Rp},$$

where L is the inductance of the choke in henries, and C is the capacitance of the condenser in farads.

Transformer with resistors

A transformer with resistors (Fig. 3) is often used as a makeshift, but is quite capable of good gain and frequency response if the output tubes require no driving power and if high grid-circuit resistance is permissible. The two resistors must be as nearly equal as possible and must be large to prevent high-frequency loss in the transformer and to present a reasonably large load impedance to the driver tube. This impedance is given by $\frac{2\,Rg}{n^2}$, where n is the step-up ratio of the transformer. The gain to each grid is then $\frac{n\mu\,Rg}{2\,Rg + n^2Rp}$.

If the driver is a low-impedance tube such as a 6C5 and the grid resistors are each 0.5 megohm, the gain is very nearly equal to nμ at mid-frequencies. At low frequencies the gain is 3 db down when the reactance of the transformer primary is equal to the plate resistance of the driver.

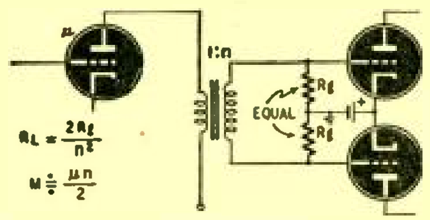
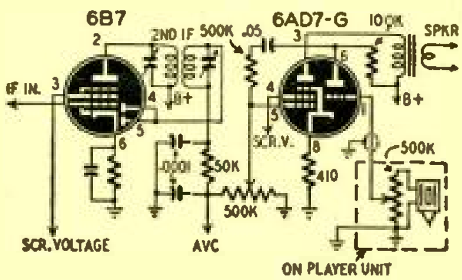


Fig. 3—How an untapped condenser is used.

A second article by Mr. Straede, in an early issue, will cover resistance-capacitance types of phase inverters.

PHONO PREAMPLIFIER

I have a small superheterodyne using a 6A8, 6B7, 6K6, and rectifier. I tried unsuccessfully to add a phono attachment by connecting it to the grid of the 6K6. The output of the pickup was too low for use without a preamplifier. I removed the 6K6 and wired in a 6AD7



as shown. The triode section is used as a preamplifier for the pickup without altering the performance of the set.

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Phase Inversion Circuits

Part II — The R-C coupled phase inverter

By JOHN W. STRAEDE*

ONE of the earliest types of resistance - capacitance - coupled phase inverters is the *paraphase*. The signal from an amplifier tube is taken from a tap on either its plate resistor or the grid resistor of the output tube it feeds (usually the latter), and applied to a phase-inverter tube. This tube reverses the polarity of the signal.

Because the phase-inverter tube also amplifies, only a portion of the first tube's signal is applied to it, and its output goes to the grid of the other output tube. The modern version of the paraphase circuit is shown in Fig. 1.

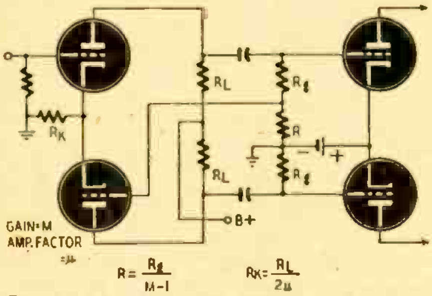

Fig. 1—A modern paraphase phase inverter.

The voltage-divider constants Rg and R are critical, and resistors with closer than 10% tolerance are required. Aging of the phase-inverter tube reduces its output and results in unbalance.

Automatic near-balance is obtained in the floating paraphase circuit (Fig. 2).

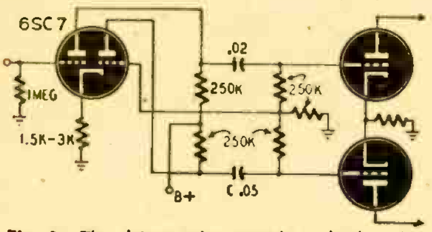

Fig. 2—The driver tube must have high gain.

The signal for the inverter section depends upon the lack of circuit balance. The greater the gain of this tube, the nearer is true balance approached; therefore, a high-gain tube such as a 6SC7 is commonly used.

A still closer approach to true balance can be obtained by making the plate and grid resistors in the inverter section just a trifle larger than those in the voltage amplifier.

Unbalance at low frequencies is due to extra phase shift caused by the lower coupling condenser C. This condenser should be much larger than the top one.

If a large amount of negative feedback is to be used over the phase-inverter stage, the straight paraphase circuit is preferable, since accurate balancing is important.

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In the split-load inverter (Fig. 3), output voltage from a tube is divided by placing half the load impedance be-

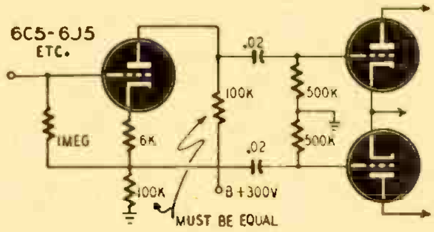


Fig. 3—Stage gain is low with this circuit.

tween cathode and ground. The voltage at the cathode is then out of phase with the voltage at the plate. Half the load in the cathode circuit also results in half the load being in the grid-to-cathode circuit and gives a negative feedback factor of one-half. Stage gain is therefore very low; in practice it is usually about 0.9 (from grid of phase inverter to grid of one output tube).

This circuit, popular in Australia, is sometimes known as the *kangaroo* phase inverter.

Accuracy of balance depends solely upon the equality of the load resistors and the following grid resistors. Because of degeneration, the cathode resistor does not require bypassing (unless a low-gain tube is used), and the coupling condenser to the grid of the phase inverter can be smaller than usual.

Cathode-Drive Inverters

If push-pull tubes share a common unbypassed cathode bias resistor, an interesting phenomenon occurs if the signal is removed from one tube. Instead of the output dropping considerably, there is only a slight lessening of volume and the output continues to come from both tubes, though there is a distinct lack of balance. The undriven tube is actually being driven by the other one through

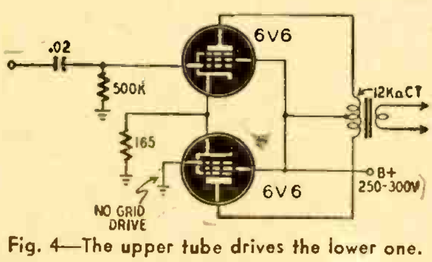


Fig. 4—The upper tube drives the lower one.

the common cathode impedance. One example of this is the Barnes "mystery" circuit of Fig. 4.

The greater this common cathode impedance in comparison to the load impedance, and the greater the stage gain, the more nearly perfect is the balance. If two push-pull voltage amplifier stages are used with no signal on one tube of the first stage, very good balance is obtained at the output of the second stage. This amplifier (Fig. 5) is sometimes known as the "long-tailed" amplifier.

If very good balance is desired, the size of the common cathode resistor is increased and tapped to give the correct grid bias, as in Fig. 6.

Accuracy of balance depends on the similarity of the tubes and the equality of the plate load resistors.

Fig. 7 shows a 2-stage direct-coupled amplifier with cathode-drive phase inversion. It responds to d.c. voltages as well as to a.c. Balance is not as good as in resistance-coupled amplifiers, but the unbalance is limited to a difference in

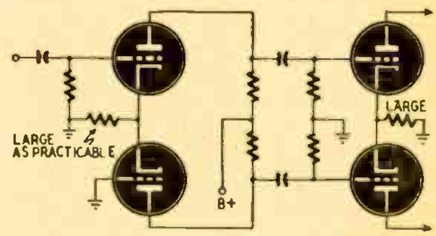


Fig. 5—The long-tailed push-pull amplifier.

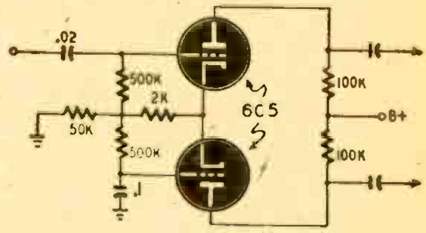


Fig. 6—Similar driver tubes improve balance.

amplitude. There is no unbalance due to phase shift at different frequencies.

Unusual phase inverters

Besides the more commonly used circuits, there are some unique variations of the split-load and paraphase circuits.

Fig. 8 is a simplified split-load inverter in which the inverter tube is directly coupled to the preceding tube. Gain is higher than might be expected, since part of the *load* for the first tube is actually amplified by the inverter. There is noticeable reduction in the number of

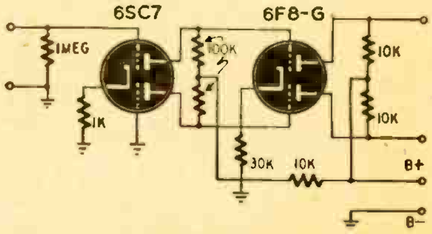


Fig. 7—A two-tube direct-coupled amplifier.

parts, and the output voltages are sufficient to drive 6V6's.

To obtain gain from the actual phase-inverter stage, the preceding tube must be a pentode and the load is amplified by a split-load inverter. The extra gain is due to load amplification and practi-

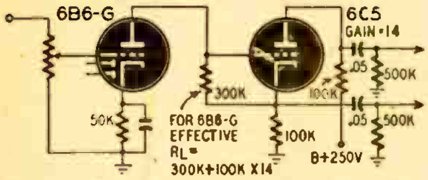


Fig. 8—Split-load direct-coupled inverter.

cally disappears if the preceding tube is a triode.

A version of this circuit is shown in Fig. 9. Over-all gain from the 6J7 input

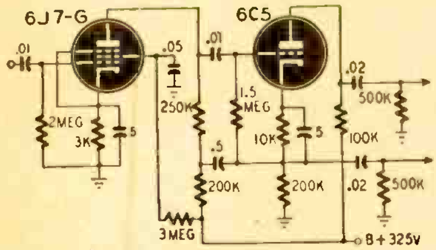


Fig. 9—This inverter provides high gain.

to one output tube grid is about 700, and each output is about 40 volts peak.

To economize in the use of tubes, attempts have been made to use one of the output tubes as a paraphase-type phase inverter. Part of the output voltage is applied to the grid of the other output tube. The output load impedance

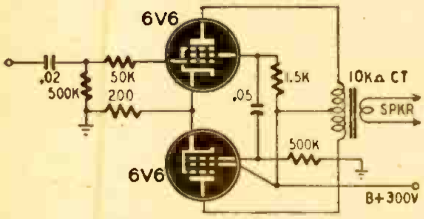


Fig. 10—One 6V6 is a paraphase inverter.

varies with frequency, so perfect balance is obtained over only a narrow band.

When pentode or beam tubes are used, the signal is usually obtained from the screen grid across a 1,000- or 2,000-ohm load resistor. The results are disappointing—in practice the circuit does not seem to function better than a pair of tubes in parallel or the Barnes mystery circuit of Fig. 4. One of the better circuits is shown in Fig. 10.

Note that the control grid of one 6V6 is coupled to the screen grid of the other through a .05-μf condenser. When a signal is applied to the upper tube, its screen current varies and develops a voltage across the 1,500-ohm resistor. This voltage has the correct magnitude and polarity to excite the lower tube.

References

RADIO-CRAFT, April 1946 (Amplifiers with Paraphase and with Split-load Inversion).
RADIO-CRAFT, November, 1944 (Amplifier with Paraphase Inverter).
RADIOTRON TUBE MANUAL RC 15 (Pages 222 and 223).
RADIOTRON DESIGNER'S HANDBOOK.

MAGNETIC RECORDERS

The impetus given during the war to magnetic recording has resulted in a number of consumer models using both tape and wire. The table below lists the important data on most currently available models. It was originally published in the *Saturday Review of Literature* as part of an article by James E. Jump.

All statements in the table are factual, except for the fidelity ratings, which are the author's personal opinions.

COMPARATIVE TABULATION OF AVAILABLE MAGNETIC RECORDERS

Manufacturer	List Price*	Cost Per Hour**	Fidelity	Appearance	Recording Time	Portability	Indexing Feature	Rewind Time	Modulation Indicator
WIRE:									
Brush									
Model BK-303	$795.00	$8.25	excellent	suitcase	30, 60, 120 180 min.	yes 50 lbs.	yes	2, 4, 8, 12 min.	eye
National Polytronics	$79.50	$4.50	fair	table model	10 min.	yes 20 lbs.	no	5 min.	ear
Pierce	$424.00 (3)	$9.00	good	professional	66 min.	yes 40 lbs.	yes	15 min.	eye
Powell	$225.00 (3)	$7.50	good	suitcase	60 min.	yes 26 lbs.	yes	7½ min.	lamp
Webster	$149.50	$5.00	fair	suitcase	15, 30, 60 min.	yes 28 lbs.	no	2, 4, 8 min.	lamp
Air King									
Model A-750	$129.50	$4.95	fair	suitcase	to 60 min.	yes 33 lbs.	no	10 min.	lamp
Model 4700	$239.50	$4.95	fair	walnut-finish console	to 60 min.	no	no	10 min.	lamp
Precision-Audio Products (Wire Master)	$295.50 (7)	$5.00	excellent	suitcase	15, 30, 60 min.	yes 45 lbs.	no (8)	2, 4, 9 min.	2 lamps
TAPE:									
Amplifier Corp. of America									
Model 800-A	$239 net	$5.00	good	table model (4)	30 min.	yes (4) 40 lbs.	optional (4)	½ min.	eye
Model 800-B	$263 net	$5.00	good	table model (4)	30 min.	yes (4) 40 lbs.	optional (4)	½ min.	eye
Model 800-E	$312 net	$2.50	fair	table model (4)	60 min.	yes (4) 40 lbs.	optional (4)	½ min.	eye
Model 800-F	$322 net	$10.00	excellent	table model (4)	15 min.	yes (4) 40 lbs.	optional (4)	½ min.	eye
Model 800-G	$401 net (5)	$10.00 (5)	excellent	table model (4)	15, 30, 60 min. (6)	yes (4) 40 lbs.	optional (4)	½ min.	eye
Brush									
Model BK-401	$229.50	$5.00	excellent	table model	30 min.	yes 40 lbs. (1)	yes	1 min.	eye
Model BK-403	$375.00	$2.50	excellent	suitcase	30, or 60 min. (2)	yes 50 lbs.	yes	¾ min.	eye

*Includes microphone, amplifier, speaker and recording mechanism unless otherwise noted.

**Cost per hour of wire or tape at nominal speed, whether 60-minute reels available or not.

(1) Carrying case with handle supplied for $16.50 extra.

(2) At 4½ inches per second. At 7½ inches per second for maximum fidelity the running time is proportionately less.

(3) Recorder and playback mechanism only—no microphone, speaker or playback amplifier provided. Faster rewind device available at $40 extra.

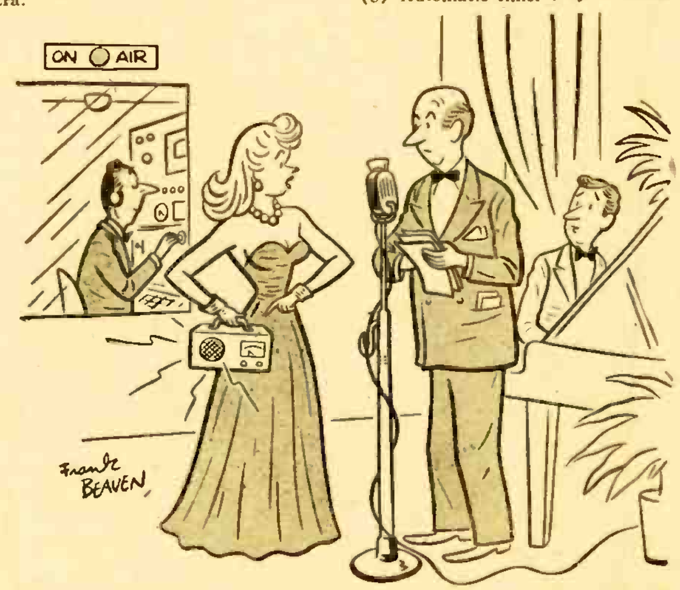
(4) Similar portable models available for $42.00 extra. Other optional features include indexing device at $11.90 extra and automatic program timer at $28.80.

(5) Includes 3 capstans ($25.00 each) but may be purchased with only 1 or 2 capstans. Tape cost $2.50, $5.00, $10.00, depending upon fidelity desired.

(6) Based on 3 capstans.

(7) Microphone not included — suitable ones recommended on request. (Price range from $24.00 to $62.00.)

(8) Automatic timer may be used.



Idea by Merrylen Townsend, New York City

"I bought it so I could listen to myself when I sing over the air."