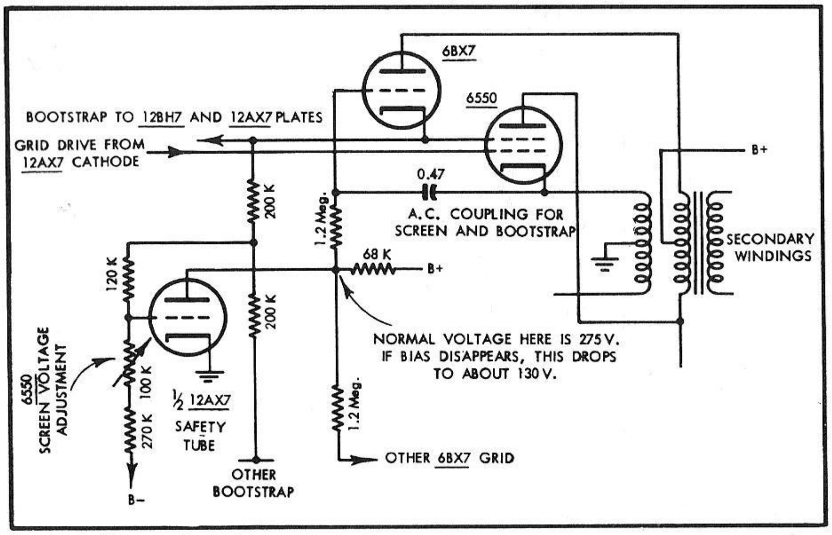

Fig. 9. Addition of another cathode follower (6BX7) to feed the screen of the output tube (as well as the bootstrap) enables unity coupling to be applied to tubes using pentode operation with different quiescent plate and screen voltages.

the driver stage at the low-frequency end to an impossible degree.

The only positive way to eliminate this effect is to have the output tube direct coupled to the tube that immediately drives it. This is possible by using a cathode-follower stage interposed between the bootstrap drive stage and the output tube grid. The driver stage can then be resistance/capacitance coupled to the grid of the cathode follower stage and everything works quite happily.

The cathode-follower stage is bootstrapped as well, which enables a low-current high-mu tube, such as a 12AX7, to be used to good advantage (*Fig.* 8). Although the actual resistance, from cathode to the negative return point necessary to provide the correct operating condition for the tube, is of value 220k, the effective a.c. resistance at this point is in the region of 600 to 1000 ohms—the effective cathode resistance of this tube operating as a cathode follower.

Direct bias for the output tube is controlled by the grid bias of the cathode-follower stage. To achieve this the negative voltage provided for the cathode return of the cathode follower is potted down by two resistors so that the negative point for the grid circuit is just right for the output tubes.

Just one more refinement to be necessary. Before the tube starts to conduct, during warm-up, the cathode of the 12AX7 and the grids of the output tubes are at the maximum negative potential of this return point, because there is no current flowing through the cathode resistor of the 12AX7. This means the cathode/heater potential of the 12AX7 can be excessive. To avoid this possibility a further resistor of 220 ohm is connected between cathode of the cathode follower and cathode of the output tube, thus forming a voltage divider to limit voltage during warm-up. In operation this will only have small audio voltage across it, and consequently represents negligible audio loading.

One more circuit has been developed for use with the unity-coupled output stage to enable it to be applied to tubes that can give considerably more output by operating the plates at much higher potential than the screens. To achieve this, a further cathode follower tube is inserted in the screen feed to the output tubes. The grid for this cathode follower derives its audio voltage from the cathode of the tube it feeds, while the d.c. potential is supplied through a separate control tube, half of a 12AX7, which combines a safety function, making the screen voltage drop almost to zero in the event the grid-bias voltage should disappear for any reason. This action is illustrated in the partial schematic of *Fig.* 9.

The feedback arrangement of the unity-coupled amplifiers is pretty much in conformity with general feedback practice, utilizing a resistor with phase-correcting capacitor from the secondary of the output transformer back to the pre-phase-splitter cathode.

The Output Transformer

In some of the more modern unity-coupled amplifiers, the output transformer has been elaborated somewhat from the simple bifilar arrangment originally used for providing just loudspeaker impedance tappings. For some applications a 70-volt or 600-ohm tapping is required. One method of achieving this was take tappings from the primary side, utilizing the section connected to ground in the cathode circuit. A 70-volt output could be achieved by using the ground point and a suitable tapping, while the 600-ohm output requires two tappings, or in some instances a connection to the tube cathodes. (*Fig.* 10).

A disadvantage of this method for some systems is that the 600-ohm or the 70.7-volt circuit, as the case may be, is permanently attached to the amplifier ground, because it uses the actual cathode winding. To overcome this disadvantage, so that ground isolation can be achieved when necessary, either for hum reduction in the system or to conform with system regulations, the output transformer is stepped up from *bi*filar windings to "*tri*filar" windings. In this way a section of the transformer, wound at the same time as the primary, is used for the high-voltage outputs, 70 volts and 600 ohms, while a separate winding, wound bifilar with the secondary, is used for the feedback. This enables the secondary also to be isolated. In some instances parts of the secondary are also wound trifilar to enable other combinations of impedance to be achieved, not so readily possible with just a single winding.

There is one more important feature improvement in the unity-coupled circuit from the original arrangment. This is a device to improve the transient-handling capacity of the amplifier. Because the amplifier uses resistance smoothing, the impact of a transient alters the supply voltages. These voltage changes can put an asymmetrical transient through the system, because they get referred to the single-ended part of the amplifier.

To overcome this effect, a "long-tailed" splitter is used in which the grid return for the second half of the inverter is not coupled directly to ground, but through a time-constant circuit that produces an

Fig. 10. Different ways of picking off 600-ohm or 70-volt outputs, according to power and impedance of the output circuit. In some professional types, these tappings are separated by trifilar winding.