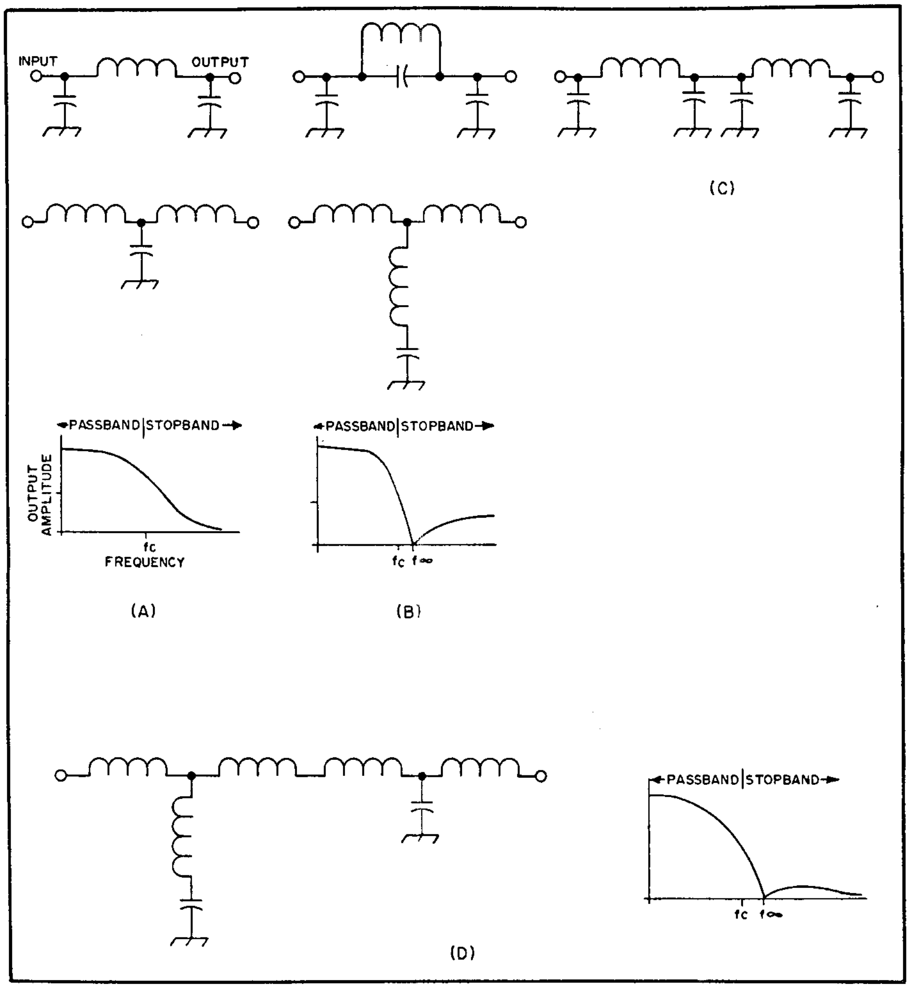

Fig. 22 — Constant-*k* (A) and *m*-derived (B) filters and their frequency responses. While these are all low-pass filters, they may be transformed into high-pass filters by replacing each coil with a capacitor whose reactance is the same at the cutoff frequency and by replacing each capacitor with a coil with the same reactance at the cutoff frequency.

the best characteristics of each type — that is, good attenuation both near and far away from the cutoff frequency (Fig. 22D).

It is important that these filters be terminated in the proper value of output resistance. Knowing this resistance, the cutoff frequency and, in the case of *m*-derived filters, the frequency of infinite attenuation (trap frequency), you can determine the exact component values from the formulas in chapter 6 of the 1977 ARRL *Handbook* (chapter 2 in earlier editions).

A power-supply *ripple filter* is a type of low-pass filter. In this instance, the cutoff frequency is set as low as is practicable to give as much attenuation to the 60- or 120-Hz ripple voltage as possible. In the case of the simple, single-capacitor filter of Fig. 23A, this is done by making the capacitor large enough that its reactance at the ripple frequency is much lower than the load resistance. (To compute load resistance, divide output voltage by load current.) Series choke inductors are often added to further reduce ripple (Fig. 23B and C). Specific design information can be found in chapter 5 of the ARRL *Handbook.*

The Thyristor

The *thyristor*, also known as the silicon-controlled rectifier (SCR), is a diode whose forward conduction from cathode to anode is controlled by a third terminal, the gate. Specifically, the diode will not conduct until the voltage exceeds the forward-breakdown voltage, a value that is determined by the gate current. Once the rectifier begins to conduct, the gate no longer has any control, and the device behaves as a low-forward-resistance diode. This condition persists until the voltage drops to zero again at which time the forward-breakdown voltage barrier is re-established, and the gate regains control.

Fig. 24A shows a typical motor-speed control/light-dimmer circuit using a thyristor. During each positive half cycle, the SCR will not conduct until the .1-μF capacitor has charged up to the conduction voltage of the neon bulb. When the bulb fires, sufficient gate current flows to trigger the thyristor, and it conducts for the remainder of the half cycle. The percentage of the half cycle that the SCR conducts is determined by the *R-C* time constant and can be varied by adjusting the 100-k resistor. Since this circuit will only conduct in one direction, two thyristors are often used (Fig. 24B) to allow up to nearly full 360-degree conduction time. The same thing can be done using a *triac*, a type of bi-directional thyristor. Electrically, a triac is equivalent to two SCRs connected back-to-back (anode-to-cathode) with their gates tied together. A practical triac circuit is described in chapter 18 of the ARRL *Handbook.*

Power Supplies

So-called *electronic voltage regulation* is a technique of providing a very steady power-supply voltage by means of a *pass transistor* or *series control tube* in series with the unregulated voltage source. The conduction of the control device is controlled in such a way that a nearly constant voltage appears at the output no matter how much load current is drawn. The simplest implementation of this idea uses only three components in addition to the rectifier and filter (Fig. 25A). This circuit may be viewed as an emitter follower — the output voltage at the transistor emitter closely follows the voltage at its base. Since the voltage across the zener diode is nearly constant, then so will be the output voltage. Resistor R1 provides operating current for the Zener diode and bias current for the transistor.

The circuit of Fig. 25B has an adjustable output voltage. Under normal conditions, the voltage at the wiper-arm terminal of R2 is equal to the Zener-diode voltage plus the transistor base-

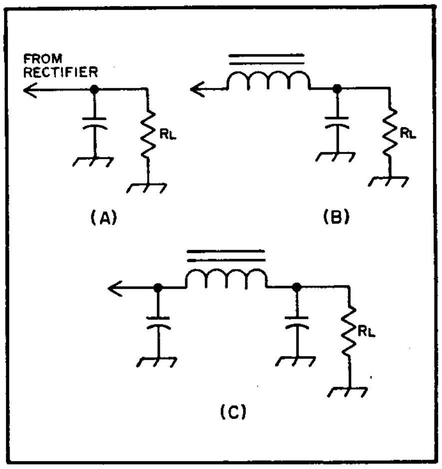

Fig. 23 — Power-supply ripple filters. The capacitor-input filters of A and C usually have an output voltage somewhat higher than the transformer rms output voltage, depending on transformer and rectifier series resistance and load current. The choke input filter at B will produce an output voltage that is very near .9 times the rms voltage for all load currents above a certain minimum value.

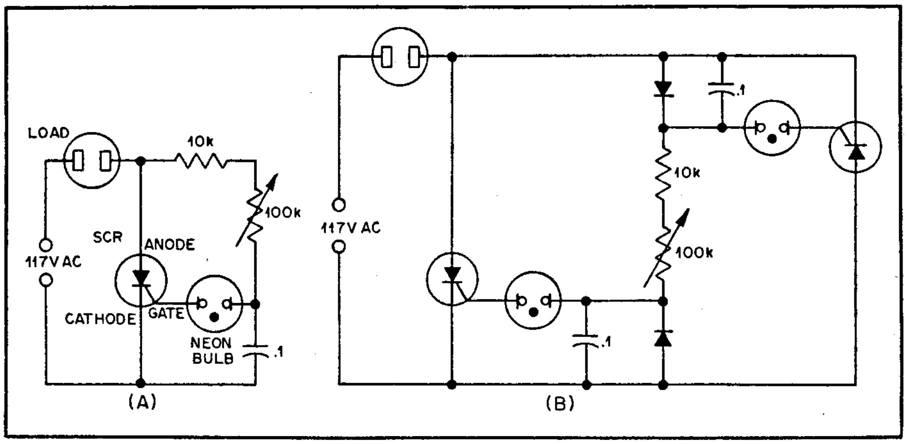

Fig. 24 — A pair of thyristor (SCR) light-dimmer/motor-speed control circuits. The circuit at A conducts only on half cycles while the circuit at B has up to nearly 360-degree conduction.

emitter forward voltage drop, hereafter referred to as the reference voltage. If the output voltage starts to increase, Q2 base current will increase, and Q2 will draw more current. This will cause a greater voltage drop across R1 so the Q1 base voltage will decrease and thus force the output voltage down again. Similarly, if the output voltage tries to decrease, Q2 will conduct less, Q1 base voltage will increase, and the output voltage will be brought back up. Now, the adjustment of R2 sets the percentage of the output voltage that appears across the Zener diode and Q2 base-emitter junction, but as we have just shown, the regulator circuit automatically adjusts the output potential so that the voltage on the wiper arm of R2 just equals the reference voltage. Thus the setting of R2 determines the output voltage. Note that the lowest voltage attainable with this circuit is the reference voltage. The highest voltage is the reference voltage times the ratio (R2 + R3)/R3.

One disadvantage that both of these circuits have is that if you accidentally short the output, the regulator will pass a very large current in an attempt to keep up the output voltage. This, of course, will cause the pass transistor to self-distruct. In Fig. 26A, Q3 acts as a *current limiter*. As the load current rises, the voltage drop across R4 increases until it reaches the base-emitter forward conduction voltage of Q3. When that happens, Q3 conducts and feeds a relatively large current (limited only by R5) into the base of Q2. This causes Q2 to conduct, the voltage drop across R1 increases, and the output voltage goes down. Output current is thus limited to a value determined by R4 and the base-emitter conduction voltage of Q3.

Fig. 26B shows a two-terminal current limiter usable in any power-supply circuit. R1 normally provides enough bias current so that Q1 is biased on and current flows freely through the limiter. When the current is high enough that the voltage drop across R2 equals the base-emitter conduction voltage of Q2, it conducts. This removes bias from Q1 so that it stops conducting, and the limiter cuts off power to the load. While this device may be placed either on the load side or the supply side of the regulator, it is usually placed on the power-supply side since the resistance of R2 in series with the regulator output can degrade its performance.

Voltage regulation is covered in chapter 5 of the ARRL *Handbook.*

Amateur Television

A block diagram of a complete ATV station is shown in Fig. 27. The fm modulator is used only if the standard 4.5-MHz fm audio subcarrier is being used. Since the TV video is amplitude modulated, the audio may simultaneously frequency modulate the video carrier if this method of transmitting the voice signal is desired. The audio can also be sent on another frequency band using a separate transmitter and re ceiver.

Coaxial cable is used for transmission line in most amateur installations, while balanced "twin lead" is used on most TV sets. For this reason, it is necessary to connect a 4 to 1 balun between the TV receiver and the uhf converter to match the TV set's 300-ohm balanced input to the converter 75-ohm unbalanced output. If the converter is a type designed for hom TV set use and has 300-ohm input and output, the balun should be connected between the preamplifier and the converter. The preamp is needed since most uhf TV converters have inadequate sensitivity for serious amateur work.

See the ARRL *Specialized Communications Techniques* handbook for more information.

High-Frequency Transmitting Circuits

There is a fundamental misunderstanding among many amateurs as to what is meant by the term "linear" when applied to radio-frequency amplifiers. At audio frequencies, any ampli-

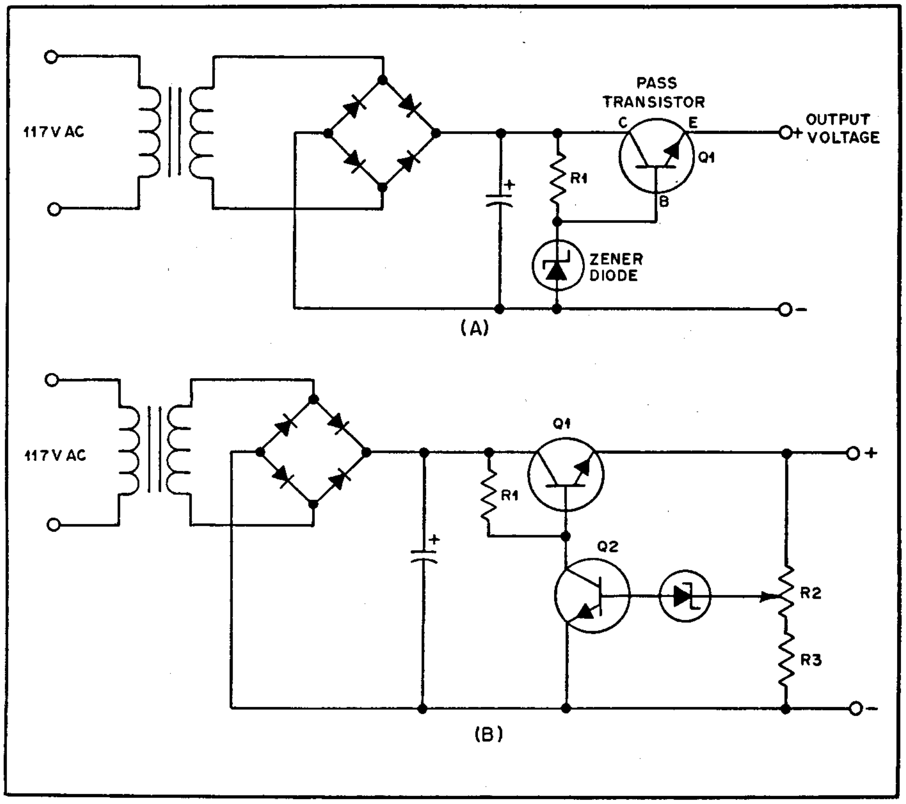

Fig. 25 — Electronic voltage-regulator circuits. The circuit at A is suitable for fixed output voltages. At B the output voltage may be adjusted by varying the setting of potentiometer R2.

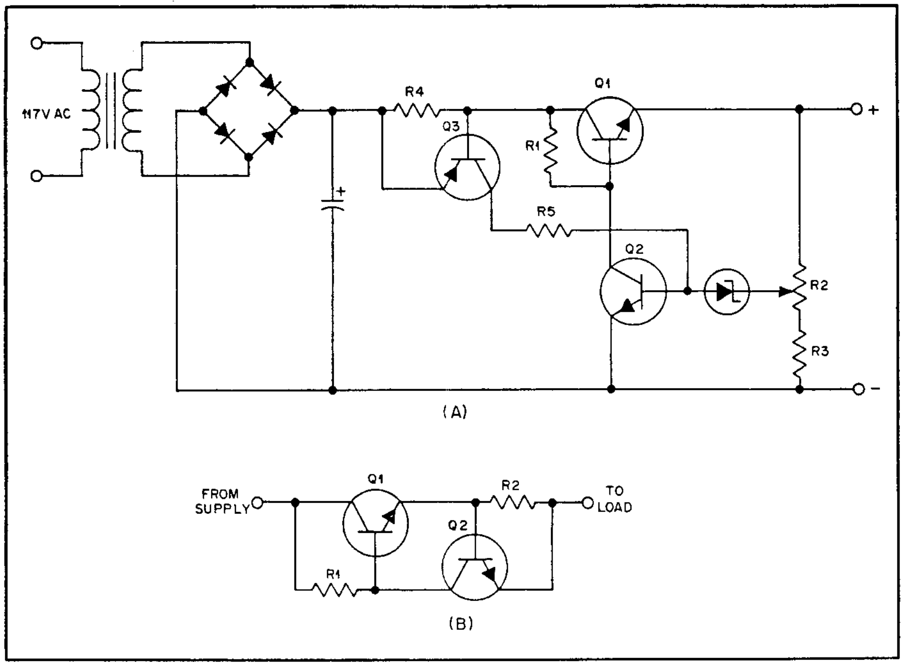

Fig. 26 – At A, a current-limiting transistor Q3 has been added to the circuit of Fig. 25B. The two-terminal current limiter at B may be added to any power-supply circuit.

fier that distorts the waveform is nonlinear. At radio frequencies. any amplifier that distorts the *rf envelope* is considered to be nonlinear. Since a tuned circuit or filter is invariably used between the rf amplifier and the antenna, the rf waveform is always restored to a fairly pure sine wave, so if the shape of the rf envelope is retained, the output signal will be a nearly perfect representation of the input.

When an audio amplifier is amplifying a sine wave, it must be conducting throughout the entire 360 degrees of each cycle in order to be linear. Such an amplifier is said to be operating in *Class A*. Class A power amplifiers are rarely used at radio frequencies because of their low efficiency in converting dc supply power to rf output power. The theoretical maximum efficiency is 50 percent and in practical amplifiers, 20 to 30 percent is a more realistic figure.

In order to be considered linear, an rf power amplifier must amplify all signals by an equal factor, no matter how small or large the input signal amplitude. With large input signals, the amplifier must begin to conduct as soon as the input rf voltage begins a positive half cycle, and it must continue to conduct so long as the instantaneous input voltage remains positive (negative for pnp transistors). In other words, it must amplify over at least half a cycle, or 180 degrees. If the operating angle is exactly 180 degrees, the amplifier is said to be operating *Class B*. A *Class AB* amplifier operates for more than 180 degrees but less than 360 degrees of each cycle. Both Class AB and B operation is satisfactory for rf linear amplifiers. Theoretical efficiency of a true Class B amplifier is about 68-1/2 percent and of a Class AB amplifier, between 50 and 68-1/2 percent. A well designed Class AB amplifier typically would have about 60-percent efficiency.

A *Class C* amplifier has an operating angle of less than 180 degrees. Such amplifiers distort the modulation envelope of a voice signal and are thus usable only for continuous-wave applications. In fact, if fixed grid bias is used, a Class C stage will even distort the wave shaping of a keyed cw signal, a condition that can cause key clicks. This does not occur if a continuous signal is available at the input and the amplifier itself is keyed. There is no specific theoretical limit to the efficiency of a Class C amplifier, but in practice a figure between 65 to 85 percent is typical.

For Class B operation the amplifying device should be biased at *cutoff*; that is, bias should be adjusted to the point where the device just starts to draw current from the power supply. Since even a slight positive voltage on the control element (grid, base or gate) will cause the device to draw current, it will, therefore, have a 180-degree conduction angle, the essential requirement for Class B operation. A Class A amplifier must draw current all the time, so enough positive bias is provided so that even on negative peaks of the input signal the device will still be drawing a small amount of current. Class AB amplifiers are biased such that they draw a steady current under no-signal conditions but are still cut off during the negative peaks of the input signal. Class C devices are biased beyond cutoff. That is, a small positive input voltage will not be sufficient to cause them to conduct; current will be drawn only on the positive peaks of relatively large input signals. Tube-type Class B and C amplifiers are nearly always adjusted so that grid current is drawn during positive signal peaks. A Class AB amplifier may or may not draw grid current, depending on the design. Frequently, the subscripts 2 and 1 are used to designate whether grid current is drawn or not respectively. Thus a Class AB_2 amplifier is a Class AB amplifier in which grid current is drawn during positive peaks of the input signal.

For proper operation, an rf amplifier must be terminated in the correct value of load resistance. As a rule of thumb, a Class A power amplifier should be terminated in a resistive impedance equal to the ratio of plate voltage to current. Load resistance for a Class AB amplifier should be about 2/3 this value, and a Class B or C amplifier should be terminated in a resistance about half this ratio.

Specific circuits and techniques to

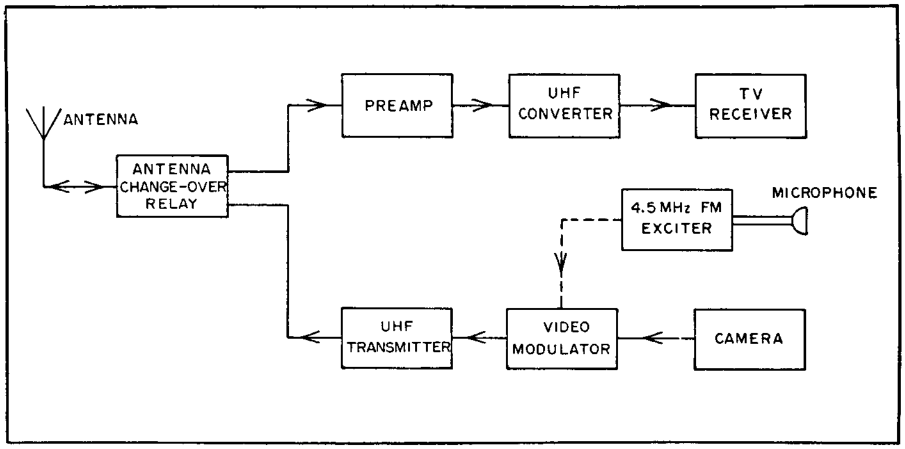

Fig. 27 – Block diagram of an amateur television station. Most common video modulators use grid modulation of the transmitter final-amplifier tube. Because grid modulation requires little driving power from the video modulator, it is usually a simple one-or two-transistor device built into the transmitter cabinet.