

Keying

6-1 Keying Principles and Characteristics

Requirements — The keying of a transmitter can be considered satisfactory if the method employed reduces the power output to zero when the key is open, or “up,” and permits full power to reach the antenna when the key is closed, or “down.” Furthermore, the keying system should accomplish this without producing keying transients or “clicks,” which cause interference with other amateur stations and with local broadcast reception, and the keying process should not affect the frequency of the emitted wave.

Back-wave — From various causes, some energy may get through to the antenna during keying spaces. The effect then is as though the dots and dashes were only louder portions of a continuous carrier; in some cases, in fact, the *back-wave*, or signal heard during the keying spaces, may seem to be almost as loud as the keyed signal. Under these conditions the keying is hard to read. A pronounced back-wave often results when the amplifier stage feeding the antenna is keyed; it may be present because of incomplete neutralization (§ 4-7) of the final stage, allowing some energy to get to the antenna through the grid-plate capacity of the tube, or because of magnetic coupling between antenna coupling coils and one of the low-power stages.

A back-wave also may be radiated if the keying system does not reduce the input to the keyed stage to zero during keying spaces. This trouble will not occur in keying systems which cut off the plate voltage when the key is open, but may be present in grid-blocking systems (§ 6-3) if the blocking voltage is not great enough and in power-supply primary keying systems (§ 6-3) if only the final-stage power-supply primary is keyed.

Keying waveform and sidebands — A keyed c.w. signal can be considered equivalent to a modulated signal (§ 5-1), except that, instead of being modulated by sinusoidal waves and their harmonics, it is modulated by a rectangular wave, as in Fig. 601-A. If it were modulated by a sinusoidal wave of single frequency, as in Fig. 601-B, the only sidebands would be those equal to the carrier frequency plus and minus the modulation frequency (§ 5-2). A keying speed of 50 words per minute, sending sinusoidal dots, would give sidebands only 20 cycles either side of the carrier. However, when harmonics are present in the modulation the sidebands will extend out on both sides of

the signal as far as the frequency of the highest harmonic. The rectangular wave form contains an infinite number of harmonics of the keying frequency, so a carrier modulated by truly rectangular dots would have sidebands covering the entire spectrum. Actually, the high-order harmonics are eliminated because of the selectivity of the tuned circuits (§ 2-10) in the transmitter, but there still is enough energy in the lower harmonics to extend the sidebands considerably. Considered from another viewpoint, whenever a pulse of current has a steep front (or back) high frequencies are certain to be present. If the pulse can be slowed down, or caused to *lag*, through a suitable filter circuit, the highest-order harmonics are filtered out.

Key clicks — Because the high-order harmonics exist only during the brief interval when the keying character is started or ended (when the amplitude of the keying wave is building up or dying down), their effects outside the normal communication channel are observed as pulses of very short duration. These pulses are called *key clicks*.

Tests have shown that practically all operators prefer to copy a signal which is “solid” on the “make” end of each dot or dash; i.e., one that does not build up too slowly but just slowly enough to have a slight click when the key is closed. The same tests indicate that the most pleasing and least difficult signal to copy, particularly at high speeds, is one that has a fairly soft “break” characteristic; i.e., one that has practically no click as the key is opened. A signal with heavy clicks on both make and break is difficult to copy at high speeds (and also causes considerable interference), but if it is too “soft” the dots and dashes will tend to run together. It is relatively simple to adjust the keying of a transmitter so that for all normal hand speeds (15 to 40 w.p.m.) the readability will be satisfactory

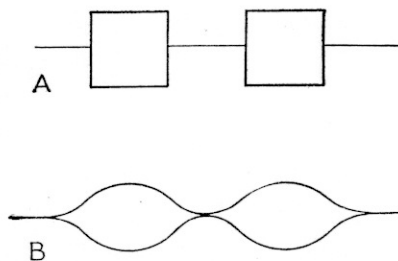


Fig. 601 — Extremes of possible keying waveshapes. A, rectangular characters; B, sine-wave characters.

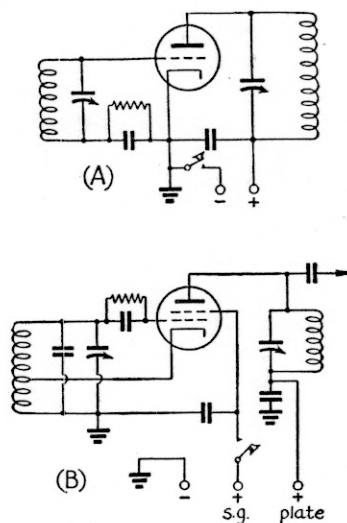


Fig. 602 — A, plate keying; B, screen-grid keying. Oscillator circuits are shown in both cases, but the same keying methods can be used with amplifier circuits.

while the keying still will not cause interference to reception of other signals near the frequency of the transmitter.

Break-in keying — Since, in code transmission, there are definite intervals between dots and dashes and between words, when no power is being radiated by the transmitter it is possible, with suitable keying methods, to allow the receiver to operate continuously and thus be capable of receiving incoming signals during the keying intervals. This practice facilitates communication, because the receiving operator can signal the transmitting operator, by holding down the key of his transmitter, whenever he has failed to copy part of the message, and thus obtain a repetition of the missing part without loss of time. This is called *break-in* operation.

Frequency stability — Keying should have no effect upon the output frequency of a properly designed and adjusted transmitter. However, in many instances keying will cause a "chirp," or small frequency change, at the instant of closing or opening the key, which makes the signal difficult to read. Multi-stage transmitters keyed in a stage subsequent to the oscillator usually are free from this condition, unless the keying causes line-voltage changes which in turn affect the frequency of the oscillator. When the oscillator is keyed for break-in operation, special care must be taken to insure that the signal does not have keying chirps.

Selecting the stage to key — It is advantageous from an operating standpoint to design the c.w. transmitter for break-in operation. In ordinary cases this dictates that the oscillator be keyed, since a continuously running oscillator will create interference in the receiver and thus prevent break-in operation

on or near the transmitter frequency. On the other hand, it is easier to avoid a chirpy signal by keying a buffer or amplifier stage. In either case, the tubes following the keyed stage must be provided with sufficient fixed bias to limit the plate currents to safe values when the key is up and the tubes are not being excited (§ 8-9). Complete cut-off reduces the possibility of a back-wave if a stage other than the oscillator is keyed, but the keying waveform is not as well preserved and some clicks can be introduced even though the keyed stage itself produces no clicks. It is a good general rule to bias the tubes so that they draw a key-up plate current equal to about 5 per cent of the normal key-down value.

Keyed power — The power broken by the key is an important consideration, both from the standpoint of safety for the operator and that of arcing at the key contacts. Keying the oscillator or a low-power stage is favorable in both respects. The use of a keying relay is highly recommended when a high-power circuit is keyed.

6-2 Keying Circuits

Plate-circuit keying — Any stage of the transmitter can be keyed by opening and closing the plate power circuit. Two methods are shown in Fig. 602. In A the key is in series with the negative lead from the plate power supply to the keyed stage. It could also be

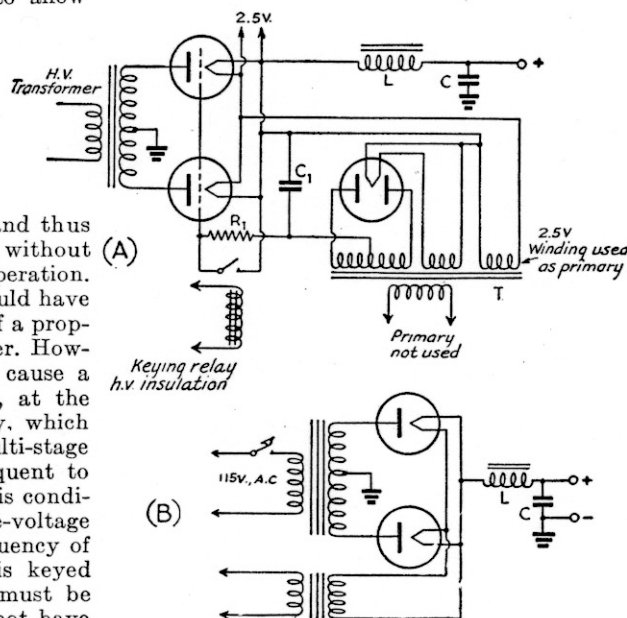


Fig. 603 — Power-supply keying. Grid-control rectifiers are used in A. Transformer T is a small multiple-secondary unit of the type used in receiver power supplies, and is used in conjunction with the full-wave rectifier tube to develop bias voltage for the grids of the high-voltage rectifiers. R₁ limits the load on the bias supply when the keying relay is closed; 50,000 ohms is a suitable value. C₁ may be 0.1 μ fd. or larger. L and C constitute the smoothing filter for the high-voltage supply in both circuits. B shows direct keying of the transformer primary.

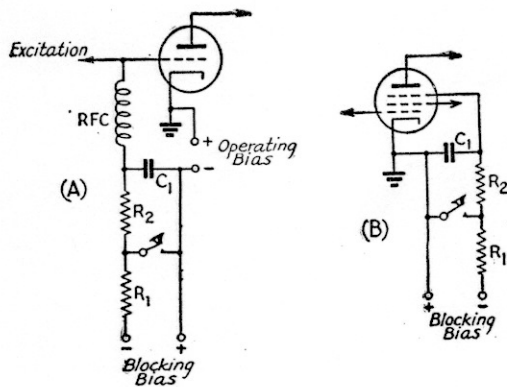


Fig. 604 — Blocked-grid keying. R_1 , the current-limiting resistor, should have a value of about 50,000 ohms. C_1 may have a capacity of 0.1 to 1 $\mu\text{fd.}$, depending upon the keying characteristic desired. R_2 also depends on the performance characteristic desired, values being of the order of 5000 to 10,000 ohms in most cases.

placed in the positive lead, although this is to be avoided whenever possible because the key is necessarily at the plate voltage above ground, and there is danger of shock unless a keying relay is used.

Fig. 602-B shows the key in the screen-supply lead of an electron-coupled oscillator. This can be considered to be a variation of plate keying.

Both the plate and screen-grid keying circuits, A and B of Fig. 602, respond well to the use of key-click filters, and are particularly suitable for use with crystal and self-controlled oscillators which are operated at low plate voltage and power input.

Power-supply keying — A variation of plate keying, in which the keying is introduced in the power-supply system itself, rather than in the connections between the power supply and transmitter, is illustrated by the diagrams in Fig. 603.

Fig. 603-A shows the use of grid-controlled rectifier tubes (§ 3-5) in the power supply. Keying is accomplished by applying suitable bias to the grids to cut off plate current flow when the key is open, and by removing the bias when the key is closed. Since in practice this circuit is used only with high-powered high-voltage supplies, a well-insulated keying relay is a necessity.

Direct keying of the primary of the plate power transformer for the keyed stage or stages is shown in Fig. 603-B. This and the method at A inherently have a keying lag because of the time constant (§ 2-6) of the smoothing filter. If enough filter is provided to reduce ripple to a low percentage (§ 8-4) the lag (§ 6-1) is too great to permit crisp keying at speeds above about 25 words per minute, although this type of keying is very effective in eliminating key clicks. A single-section plate-supply filter (§ 8-6) is about the most elaborate type that can be used if a reasonably good keying characteristic is to be achieved.

Blocked-grid keying — Keying may be accomplished by applying sufficient negative bias voltage to a control or suppressor grid to cut off plate current flow when the key is open, and by removing this blocking bias when the key is closed. The blocking bias voltage must be sufficient to overcome the r.f. grid voltage, in the case where the bias is applied to the control grid, and hence must be considerably higher than the nominal cut-off value for the tube at the operating d.c. plate voltage. The fundamental circuits are shown in Fig. 604.

In both circuits the key is connected in series with a resistor, R_1 , which limits the current drain on the blocking-bias source when the key is closed. R_2C_1 is a resistance-capacity filter (§ 2-11) for controlling the lag on make and break of the key circuit. The lag increases as the time constant (§ 2-6) of this circuit is made larger. Since grid current flows through R_2 when the key is closed in Fig. 604-A, additional operating bias is developed, hence somewhat less bias is needed from the regular bias supply. The operating and blocking biases can be obtained from the same supply, if desired, by utilizing suitable taps on a voltage divider (§ 8-10). For circuits in which no fixed bias is used R_2 can be the regular grid leak (§ 3-6) for the stage.

With blocked-grid keying a relatively small direct current is broken as compared to other systems. Thus any sparking at the key is reduced. The keying characteristic (lag) readily can be controlled by a suitable choice of values for C_1 and R_2 .

Cathode keying — Opening the d.c. circuits of both plate and grid simultaneously is called cathode keying. It is usually called center-tap keying with a directly heated filament-type tube, since in this case the key is placed in the filament-transformer center-tap lead. Typical circuits for this type of keying are shown in Fig. 605.

Cathode keying results in less sparking at the key contacts, for the same plate power, as compared with keying in the plate-supply lead. When used with an oscillator it does not respond as readily to key-click filtering (§ 6-3) as does plate keying, but there is little difference in this respect between the two systems when an amplifier is keyed.

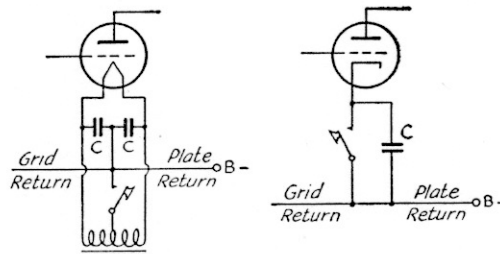


Fig. 605 — Center-tap and cathode keying. The condensers, C , are r.f. by-pass condensers. Their capacity is not critical, values of 0.001 to 0.01 $\mu\text{fd.}$ ordinarily being used.

6-3 Key-Click Reduction

R.f. filters — A spark at the key contacts, even though minute, will cause a damped oscillation to be set up in the keying circuit which may modulate the transmitter output or may simply be radiated by the wiring in the

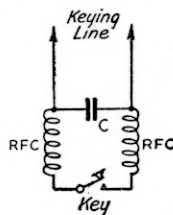


Fig. 606 — R.f. filter used for eliminating the effects of sparking at key contacts. Suitable values for best results with individual transmitters must be determined by experiment. Values for RFC range from 2.5 to 80 millihenries and for C from 0.001 to 0.1 μfd .

keying circuit. Interference from the latter source is usually confined to the immediate vicinity of the transmitter, and is similar in nature and effects to the click which is frequently heard in a receiver when an electric light is turned on or off. It can be minimized by isolating the key from the wiring by means of a low-pass filter (§ 2-11), which usually consists of an r.f. choke in each key lead, placed as close as possible to the key, and by-passed on the keying-line side by a condenser, as shown in Fig. 606. Suitable values must be determined by experiment. Choke values may range from 2.5 to 80 millihenrys, and condenser capacities from 0.001 to 0.1 μfd .

This type of r.f. filter is required in nearly every keying installation, in addition to the lag circuits which are discussed in the next paragraph.

Lag circuits — A filter used to give a desired shape to the keying character, to eliminate unnecessary sidebands and consequent interference, is called a *lag circuit*. In one form, suitable for the circuits of Figs. 602 and 605, it consists of a condenser across the key terminals and an inductance in series with one of the leads. This is shown in Fig. 607. The optimum values of capacity and inductance must be found by experiment, but are not especially critical. If a high-voltage low-current circuit is being keyed a small condenser and large inductance will be necessary, while if a low-voltage high-current circuit is keyed the capacity required will be high and the inductance

To Keyed Circuit

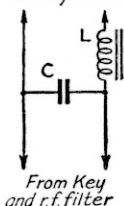


Fig. 607 — Lag circuit used for shaping the keying character to eliminate unnecessary sidebands. Actual values for any given circuit must be determined by experiment, and may range from 1 to 30 henries for L and from 0.05 to 0.5 μfd . for C , depending on the plate current.

small. For example, a 300-volt 6-ma. circuit will require about 30 henrys and 0.05 μfd ., while a 300-volt 50-ma. circuit needs about 1 henry and 0.5 μfd . For any given circuit and fixed values of current and voltage, in-

creasing the inductance will reduce the clicks on "make" and increasing the capacity will reduce the clicks on "break."

Blocked-grid keying is adjusted by changing the values of resistors and condensers in the circuit. In Fig. 604, the click on "make" is reduced by increasing the capacity of C_1 , and the click on break is reduced by increasing C_1 and/or R_2 . The values required for individual installations will vary with the amount of blocking voltage and the grid current. The constants given in Fig. 604 will serve as a first approximation.

Tube keying — A tube keyer is a convenient adjunct to the transmitter, because it allows the keying characteristic to be adjusted easily without necessitating condenser and inductance values which may not be readily available. It uses the plate resistance of a tube (or tubes in parallel) to replace the key in a plate or cathode circuit, the keyer tube (or tubes) being keyed by the blocked-grid method (§ 6-2). A typical circuit is shown in Fig. 608. Type 45 tubes are suitable because of their low plate resistance and consequent small voltage drop between plate and cathode. When a tube keyer is used to replace the key in a plate or cathode circuit, the power output of the stage will be somewhat reduced because of the voltage drop across the keyer tube, but this can be compensated for by a slight increase in the supply voltage. The use of a tube keyer makes the key itself entirely safe to handle, since the high resistance in series with the key and blocking voltage prevents possible danger of shock through contact with high-voltage circuits.

6-4 Checking Transmitter Keying

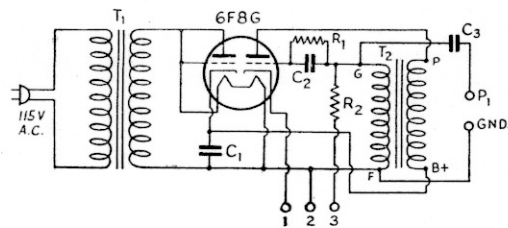
Clicks — Transmitter keying can be checked by listening to the signal on a superheterodyne receiver. The antenna should be disconnected, so that the receiver does not overload, and, if necessary, the r.f. gain may be reduced as well. Listening with the beat oscillator and a.v.c. off, the keying should be adjusted so that a slight click is heard as the key is closed but practically none can be heard when the key is released. When the keying constants have been adjusted to meet this condition, the clicks will be about optimum for all normal amateur work. If the clicks are too pronounced, they will cause interference with other amateur transmissions, and possibly to nearby broadcast receivers.

Chirps — Keying chirps (instability) may be checked by tuning in the signal or one of its harmonics on the highest-frequency range of the receiver and listening with the b.f.o. on and the a.v.c. off. The gain should be sufficient to give moderate signal strength, but it should be low enough to preclude the possibility of overloading. Adjust the tuning to give a low-frequency beat note and key the transmitter. Any chirp introduced by the keying adjustment will be readily apparent.

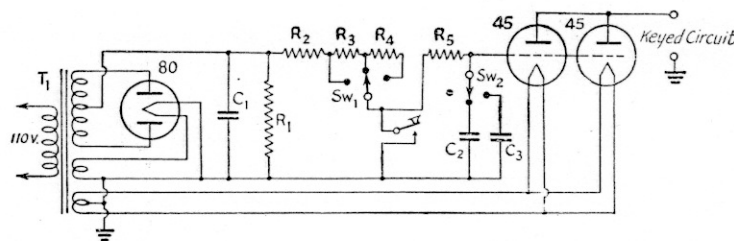
Oscillator keying—The keying of an amplifier is relatively straightforward and requires no special treatment, but a

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Self-controlled oscillators can be made to meet the same requirements by using a high C/L ratio in the tank circuit, low plate and screen currents, and judicious feed-back adjustment (§ 3-7). A self-controlled oscillator intended to be keyed should be designed for good keying rather than maximum output.



C₁—25- μ fd. 25-volt electrolytic.
C₂—250- μ fd. mica.
C₃—Approximately 0.01 μ fd. (see text).
R₁—0.15 megohm, $\frac{1}{2}$ -watt.
R₂—Approximately 0.1 megohm, 1-watt (see text).
T₁—6.3-volt 1-ampere filament transformer.
T₂—Small audio transformer, interstage type,



C₁ — 2 μ f. 600-volt paper.
 C₂ — 0.003- μ f. mica.
 C₃ — 0.005- μ f. mica.
 R₁ — 0.25 megohm, 2-watt.
 R₂ — 50,000 ohms, 10-watt.
 R₃, R₄ — 5 megohms, $\frac{1}{2}$ -watt.
 R₅ — 0.5 megohm, $\frac{1}{2}$ -watt.
 Sw₁, Sw₂ — 1-circuit 3-position rotary switch.
 T₁ — Power transformer, 325 volts each side of center-tap, with 5-volt and 2.5-volt filament windings.

tendency toward parasitic oscillations, either of which can adversely affect the keying characteristic, usually will evidence itself.

If the transmitter oscillator is keyed for break-in, the keying terminals of the oscillator may be connected in parallel with those of the transmitter. With cathode keying, terminals 1 and 2 will be connected across the key, with terminal 2 going to the ground side of the key. With blocked-grid keying, terminals 2 and 3 go to the key and a resistance of 0.1 megohm or so is inserted in series with terminal 3.