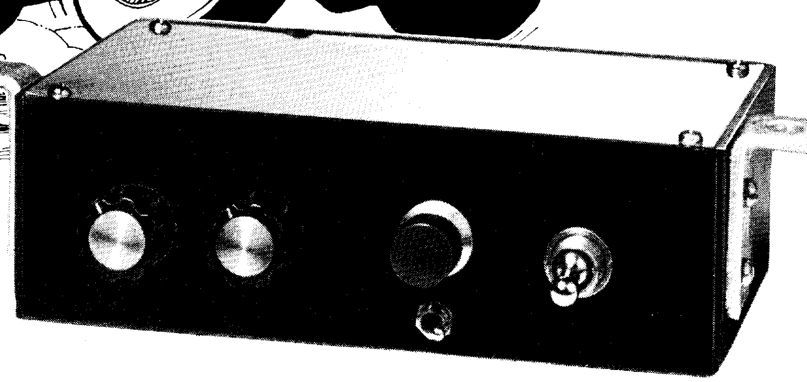
BY RONALD W. REESE



BUILD "Charge!"

A digital electronic bugle-call generator with an audio amplifier for mobile or home use.

IF YOU have ever seen a Western movie, you're no doubt familiar with the bugle call played as the U.S. Cavalry charges over the hill to the rescue. This project generates that bugle call electronically. Because digital circuitry establishes the musical intervals between the notes, it will never drift out of tune. "Charge!," as the project is called, can be built from readily available, inexpensive TTL logic, 555 timer IC's, and silicon transistors.

Two versions of the circuit are presented. One, incorporating a high-power output stage, requires a 12-volt dc supply and is well suited for use as a vehicle horn or a cheerleading device at parades and school sporting events. The low-power version, operated from the ac line, can be used as an annunciator, doorbell, alarm, or simply as an attention-getting conversation piece. Two controls allow the user to vary both the tempo and pitch of the bugle call.

About the Circuit. Free running timer *IC1* and its associated components (Fig. 1) form a tone oscillator whose operating frequency is governed by the setting of *R2.* The oscillator output, a square wave with a duty cycle close to 50%, is frequency divided by factors of 10, 12, and 15 by *IC2, IC3,* and *IC4,* respectively. In this way the three tones that form the bugle call melody are generated. Digital frequency division ensures that the intervals between the three notes remain constant. However, the pitch of the bugle call can be varied by adjusting *R2.*

Square waves from *IC1* are applied to the three frequency dividers simultaneously. The 7490 functions as a symmetrical ÷ 10 counter in the following manner. Input signals are routed to the internal ÷5 counter (pin 1). The output of this counter is connected to the input (pin 14) of the IC's ÷2 counter. Output signals appearing at pin 12 have a frequency one-tenth that of the input and a duty cycle of 50%. A ÷12 counter (*IC3*) is formed in a similar manner by interconnecting the ÷6 and ÷2 counters contained in a 7492 IC.

A different approach must be taken to realize a ÷15 function because 15 is not divisible by two and some other integer. In this project, a 74193 presettable up/down counter is used as the ÷15 stage. This counter IC has four data inputs (pins 15, 1, 10 and 9) and four corresponding outputs (pins 3, 2, 6 and 7). The counter outputs can be preset to

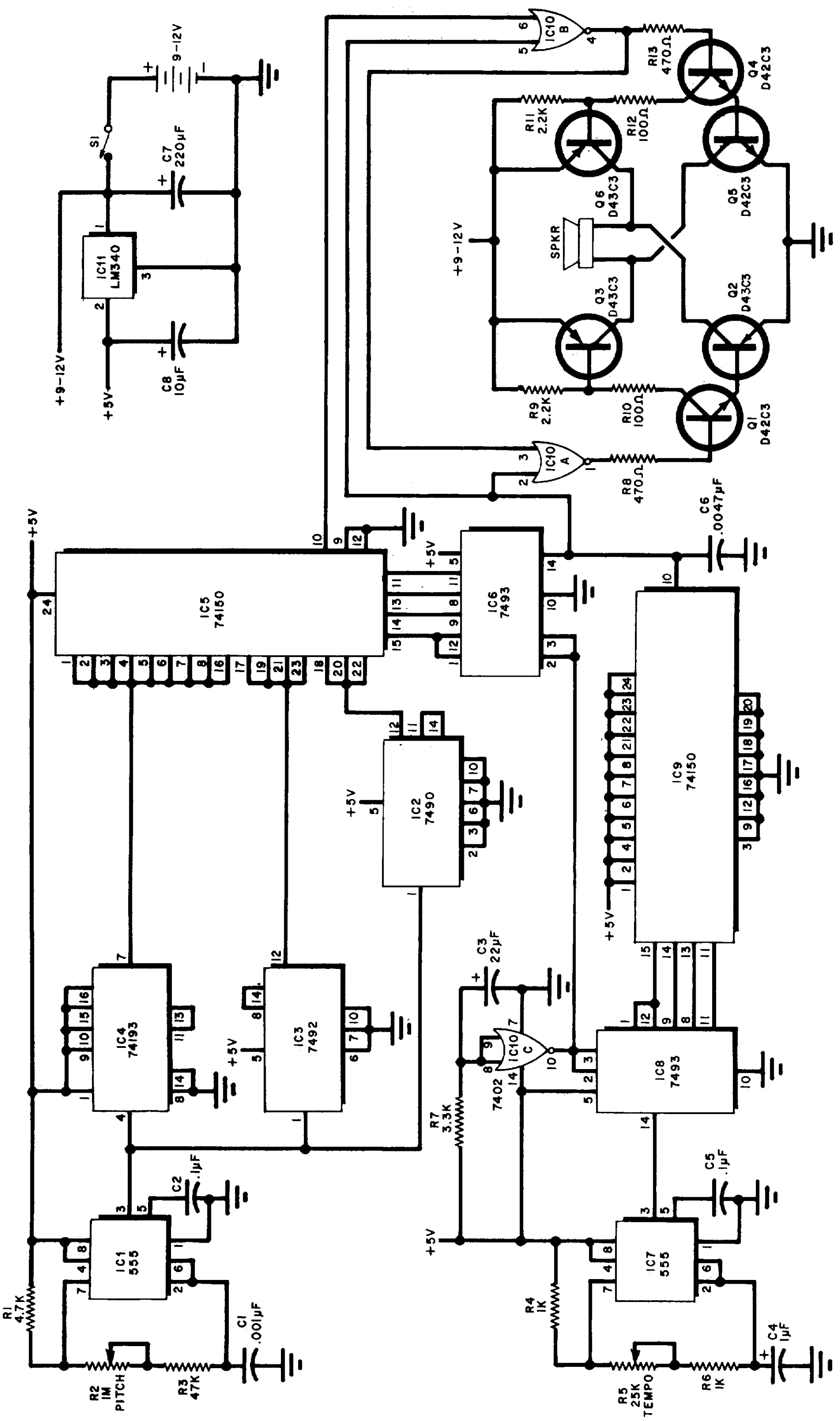


Fig. 1. Schematic diagram of "Charge!" Tempo and musical notes of the bugle call are generated digitally.

PARTS LIST

C1—0.001-μF disc ceramic capacitor
C2, C5—0.1-μF disc ceramic capacitor
C3—22-μF, 16-V electrolytic capacitor
C4—1-μF, 16-V electrolytic capacitor
C6—0.0047-μF disc ceramic capacitor
C7—220-μF, 16-V electrolytic capacitor
C8—10-μF, 16-V electrolytic capacitor
IC1, IC7—NE555 timer
IC2—SN7490 decade counter
IC3—SN7492 ÷12 counter
IC4—SN74193 synchronous 4-bit binary up/down counter IC with preset inputs
IC5, IC9—SN74150 16-line to 1-line data selector/multiplexer
IC6, IC8—SN7493 4-bit binary counter
IC10—SN7402 quadruple 2-input NOR gate
IC11—LM340 5-volt regulator
Q1,Q2,Q4,Q5—Silicon npn power tab transistor (GE D42C3 or equivalent)
Q3, Q6—Silicon pnp power tab transistor (GE D43C3 or equivalent)
The following are ¼-W, 10% carbon resistors:
R1—4700 ohms
R3—47,000 ohms
R4,R6—1000 ohms
R7—3300 ohms
R8,R13—470 ohms
R9,R11—2200 ohms
R2—1-megohm linear taper potentiometer
R5—25,000-ohm linear taper potentiometer
R10,R12—100-ohm, 1-W, 10% carbon composition resistor
S1—Spst 3-ampere switch
SPKR—8-ohm, 15-W weatherproof horn speaker
Misc.—Printed circuit or perforated board, IC sockets, suitable enclosure, control knobs, heat sink (if necessary), heat sink paste, screw-type terminal strips, machine hardware, hookup wire, solder, etc.

form a four-bit binary number by applying four bits to the data inputs and grounding the load input (pin 11) momentarily. When this is done, the four bits applied to the inputs appear at the outputs.

After the load input returns to the logic one state, the IC can count down if pulses are applied to the count down input (pin 4) while the count up input (pin 5) is at logic one, or count up if pulses are applied to the count up input while the count down input is at logic one. In this application, the 74193 is used as a down counter. It is loaded with the binary number 1111 (15_{10}), and is then allowed to count down as pulses are received from *IC1*. When the counter output reaches 0000 (0_{10}) and the count down input falls to logic zero, a logic zero appears at pin 13, the borrow output of the IC.

The logic zero at the borrow output indicates that 15 pulses from *IC1* have been counted by *IC3* and that the IC must be preset again to 15 for the next counting cycle. By connecting all data inputs to the +5-volt supply and the borrow output to the load input, the counter will automatically preset itself to 15 after it has counted down to zero. Square waves appearing at the Q output of the counter's D flip-flop (pin 7) are used as the output signal from this stage. The output of this flip-flop will be at logic one for seven pulses from *IC1* and at logic zero for eight pulses. This results in a duty cycle of about 47%, which is reasonably close to 50%.

A sequential tone selector is formed by *IC5*, a 16-line to 1-line data selector/multiplexer and *IC6*, a 7493 four-bit binary counter. Pulses from the beat generator, which will be discussed later, are counted by *IC6* over the range 0000_2 to 1111_2. The binary number generated by *IC6* is applied to the data select inputs of *IC5*. As *IC6* counts upward, *IC5* sequentially selects signals from frequency dividers *IC2*, *IC3*, and *IC4*. The three tones produced by the counters appear at the data inputs of *IC5* in the order in which they appear in the bugle call. In this way tones are selected and gated in proper sequence for application to the power amplifier.

The tempo at which the call is played is governed by the beat generator. This circuit also establishes the timing relationships between the notes and rests, and supplies a clock signal to counter *IC6* in the tone selector circuit. The beat generator is formed by interconnecting *IC7*, a free-running 555 timer, *IC8*, a 7493 four-bit binary counter, and *IC9*, a 74150 16-line to 1-line data selector/multiplexer. The oscillating frequency of *IC7*, determined by the setting of potentiometer *R5*, sets the amount of time allotted to each beat.

A repetitive beat can be used due to the nature of the song. The notes in the bugle call are played in pairs. That is, one note is played, followed by a short rest, and then the next note is played, followed by a longer rest. All notes are of the same duration—five beats. The short rest separating the two notes forming a pair is one beat long. The longer rest separating pairs of notes is five beats long. Therefore, a total of 16 beats is required by one pair of notes and two rests (one short, one long).

Binary counter *IC8* will count 16 pulses and automatically overflow to zero, providing a convenient way to determine the passage of 16 beats. The four binary outputs of the counter (pins 12, 9, 8 and 11) are connected to the four data select inputs of multiplexer *IC9*. The data inputs of the multiplexer are connected to either +5 volts or ground. The first five inputs (zero through four, pins four through eight) are tied to the +5-volt line. An internal NOR gate is the multiplexer's output stage, so a logic zero appears at pin 10 (the multiplexer output) for the first five beats. This allows NOR gates *IC10A* and *IC10B* to pass an inverted version of the output signal at pin 10 of multiplexer integrated circuit *IC5*.

Input five (pin 3) of multiplexer *IC9* is connected to ground, so a logic one appears at the multiplexer's output on the sixth beat. This causes the outputs of *IC10A* and *IC10B* to remain at logic zero regardless of what is applied to the other input of each gate. No signals can pass to the power amplifier during this interval, resulting in a one-beat rest. Inputs six through ten, pins 2, 1, 23, 22, and 21, are connected to +5 volts. When *IC9* selects input six, its output goes low, causing two things to happen. Decade counter *IC6* counts up one pulse, allowing *IC5* to select the next note. Also, NOR gates *IC10A* and *IC10B* pass signals from the tone multiplexer to the power amplifier. The output of *IC9* remains low through the tenth beat.

The last five inputs, 11 through 15 at pins 16 through 20, are connected to ground. This causes the output of *IC9* to go high, disabling the power amplifier. By this time, two notes have been played and the beat generator counter, *IC8*, has overflowed to 0000 and the beat sequence will repeat itself. The sequence must be repeated eight times for

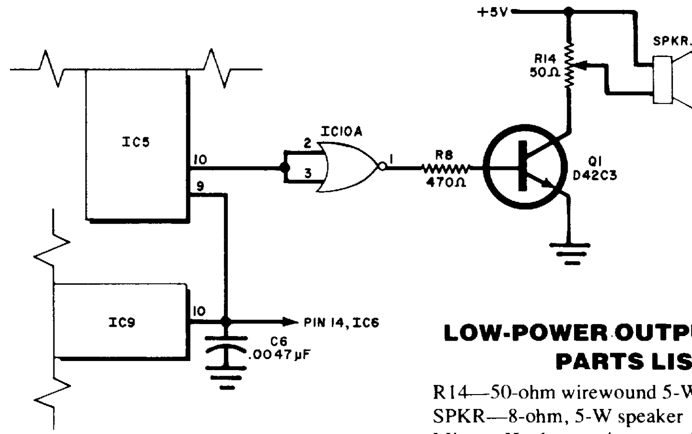
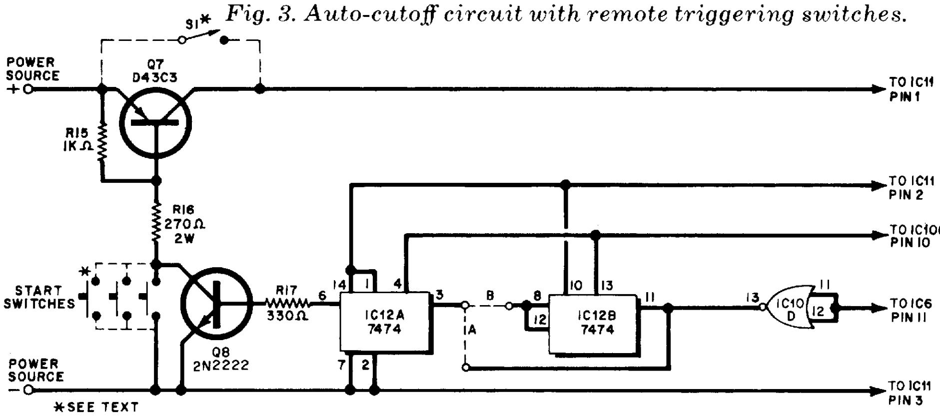


Fig. 2. Output stage for the low-power version.

LOW-POWER OUTPUT STAGE PARTS LIST

R14—50-ohm wirewound 5-W potentiometer
SPKR—8-ohm, 5-W speaker
Misc.—Hookup wire, small enclosure if speaker is mounted remotely, machine hardware, terminal strip, solder, etc.

Fig. 3. Auto-cutoff circuit with remote triggering switches.



AUTOMATIC CUTOFF PARTS LIST

IC12—SN7474 dual D-type edge-triggered flip-flop
Q7—Silicon pnp power tab transistor (GE D43C3 or equivalent)
Q8—2N2222 npn switching transistor
The following are 10% carbon composition resistors.
R15—1000 ohms, ½ W
R16—220 ohms, 2 W
R17—330 ohms, ½ W
S1—Spst 3-A switch (optional)
Misc.—Normally open momentary-contact pushbutton switches (optional), IC socket, heat sink, mica washer, heat sink paste, machine hardware, hookup wire, solder, etc.

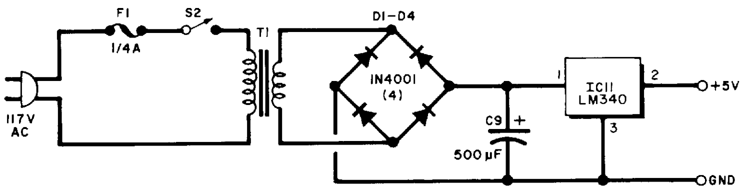


Fig. 4. Ac supply for low-power "Charge!"

LOW-POWER LINE-OPERATED SUPPLY PARTS LIST

C9—500-µF, 25-V electrolytic capacitor
D1 through D4—1N4001 silicon rectifier diode
F1—¼-ampere fuse
S2—Spst 1-ampere switch
T1—12.6-V, 1-A filament transformer

all the notes to be selected and played. When all notes have been played, both beat generator counter *IC8* and note selector counter *IC6* will overflow to 0000, and the bugle call will repeat until power is removed. An auto start circuit comprising *IC10C, R7* and *C3* ensures that *IC6* and *IC8* start counting at 0000 when power is applied.

Transistors *Q1* through *Q6* and resistors *R8* through *R13* form the power amplifier. The tone selected by *IC5* is applied to one input of *IC10B*. The output of this gate provides base drive for *Q4* and is also applied to one input of *IC10A*. Gate *IC10A* inverts and passes the signal to *Q1* when the output of *IC9* is low. When the square wave applied to *IC10B* goes low, the output of the gate goes high, turning on transistors *Q4, Q5,* and *Q6,* which energize the speaker. The logic one at *IC10B*'s output also produces a logic zero at the output of *IC10A*, cutting off transistors *Q1, Q2,* and *Q3*.

When the output of *IC10B* goes low, *Q4, Q5* and *Q6* are cut off, the output of *IC10A* goes high, and *Q1, Q2,* and *Q3* turn on. Current again flows through the speaker, but in the opposite direction. The transistors are, of course, turning on and off at the audio frequency of the selected tone. This arrangement is considerably more complex than the more commonly used switching circuits, but provides much more output power.

The amplifier draws current directly from the power source. The TTL integrated circuits, however, require +5 volts, which is provided by *IC11*.

Circuit Options. Your particular application might not require the high output power and/or continuous play capability of the circuit shown in Fig. 1. Therefore, a low-power output stage (Fig. 2) and an automatic cutoff circuit (Fig. 3) are possible options.

The manual cutoff, high-power circuit will start playing the bugle call each time power switch *S1* is closed. It will continue to play the call until *S1* is opened. This version of Charge! is suitable for use in a vehicle or as a cheerleading device. However, if the unit is intended for indoor use, the low-power output stage should be employed. (A line-powered supply for the low-power version is shown in Fig. 4.)

If Charge! is to be operated so that it plays the tune once after a momentary switch (such as a doorbell switch or magnetic door switch) closes, the automatic cutoff circuit should be included. Either circuit option can be employed separately, or both used together. The power supply shown in Fig. 4 can accommodate the auto cutoff as well as the low-power output stage.

The auto cutoff circuit controls power to regulator *IC11*. A momentary switch closure latches the circuit on until the bugle call has been played in its entirety. If the "A" wiring is used, flip-flop *IC12A* will then toggle and turn off *Q8*. This, in turn, cuts off pass transistor *Q7*. If the "B" wiring is used, *IC12A* will not toggle until the bugle call has been played twice. Of course, you can install an SPDT switch to select either the "A" or "B" connection. Similarly, you can connect power switch *S1* across *Q7* to provide a choice of either continuous or automatic cutoff operation.

Transistors *Q2* through *Q6* and resistors *R9* through *R13* are omitted in the low-power output stage. Gate *IC10A* inverts the tone square waves at the output of multiplexer *IC9* and applies them to the base of *Q1*. When the output of *IC10A* is high, *Q1* conducts and current flows through the speaker. Potentiometer *R14* functions as an output level control. When the output of *IC10A* is low, the transistor is cut off and the speaker coil passes no current. Referring to the previous description of the high-power output stage, it can be seen that the average current through the speaker is doubled by that circuit as compared to the low-power stage. This results in a four-fold increase in output power.

If you decide to employ the low-power stage, be sure to connect the output of multiplexer *IC9* to the strobe input of multiplexer *IC5*. When the strobe input is high, the multiplexer output remains high no matter what logic levels appear at the data and data select inputs. A logic zero at the strobe input of *IC5* allows the chip to pass signals (in inverted form) from the selected input to the output. All other connections remain the same whether the high- or low-power output circuit is used.

Construction. Printed circuit, point-to-point, or Wire Wrap assembly techniques can be used. Parts placement is not critical. Wire Wrap sockets should be used with the IC's if this method of duplicating the circuit is chosen. Wire no smaller than No. 24 should be used for all power supply and output stage connections. All ground connections should be made to one common point.

If Charge! is housed in a metallic utility box, *IC11* should be mounted on the enclosure with thermal coupling through heat sink paste. The utility box will then be connected to the circuit common or ground. If desired, a small heat sink approximately 1" x 1" (2.5 x 2.5 cm) with ½" (1.3-cm) fins can be used with *IC11*. A heat sink is a necessity if the project is housed in a nonmetallic enclosure.

Power switch *S1*, PITCH control *R2*, and TEMPO potentiometer *R5* can be mounted at convenient spots on the enclosure. The power switch must be able to handle at least 3 amperes dc at 12 volts. If the automatic cutoff circuit is used, the momentary contact switches should be rated for 50 mA, and, if preferred, *S1* can be eliminated.

For automotive applications, tap +12 volts at a convenient point and route it to the project's power input. (Screw-type terminal strips mounted on the project enclosure simplify connections.) If the circuit is housed in a metallic enclosure, bolting it to the vehicle chassis will furnish a ground return. When connecting a speaker to the audio output, note that both sides of the speaker coil are floating. It's important, therefore, not to let one side of the speaker become inadvertently grounded. Mount the speaker, which should be a horn-type transducer for outdoor use, in or on the vehicle at a suitable location. The box housing the circuitry should be installed so that the power switch, TEMPO and PITCH controls can be easily reached. ◇

Out of Tune

In "Build 'Charge!'" (January 1978), transistor Q2 should have been shown in Fig. 1 as an npn D42C3. The Parts List was correct.

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