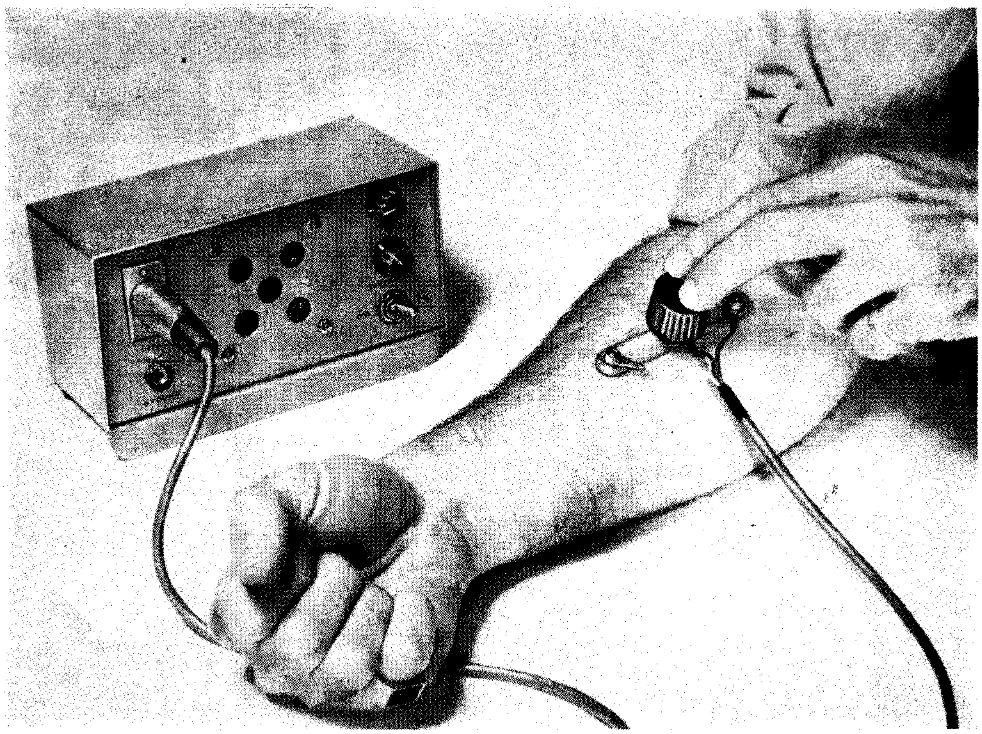

Build the Muscle Whistler

LISTEN TO YOUR BICEPS DO THEIR THING

BY HARRY GARLAND AND ROGER MELEN

There are 656 muscles in the human body and all of them generate a small voltage potential when they are activated. This voltage, called myoelectricity or EMG, is present on the surface of the skin surrounding the muscle. The detection of this signal is important in both clinical medicine and medical research.

Reaction time, for example, can be measured by noting the time lag between a stimulus and the onset of EMG activity. Audible EMG monitoring has been used experimentally in training athletes—it has been hypothesized that athletes can learn complicated, coordinated muscle skills faster by listening to their muscles during training.

The Muscle Whistler, described here, can monitor many of the muscles in the body, producing a whistling tone each time a muscle is activated. Try it, for instance, with the electrodes on the biceps muscle (upper arm) and lift a heavy object. Signals can also be picked up with the electrodes on the triceps (back of upper arm) when you try to push something. The flexor muscles (on the front of the lower arm) are active when you clench your fist, and the gastrocnemius muscle (in the calf of the lower leg) is active when you stand on your toes. You may be surprised to hear muscle activity even when you think a muscle is relaxed. This is called "muscle tone" and is characteristic of all muscles.

Whether you listen to the Muscle Whistler to monitor the force generated by your muscles, measure your reaction time, or improve your golf swing, this project will provide an entertaining introduction to an important area of medical electronics.

Construction. The circuit of the Muscle

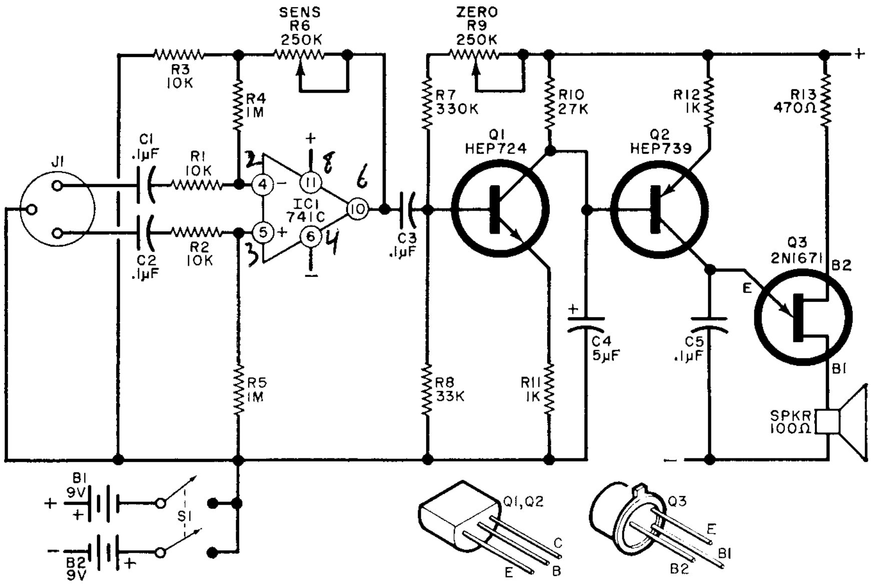

Fig. 1. Essentially, the skin voltage signals applied to the op amp high-gain differential amplifier control the frequency of the UJT.

PARTS LIST

Q1 - 2N4401
Q2 - 2N4403

B1,B2—9-volt battery
C1-C3,C5—0.1-μF disc capacitor
C4—5-μF, 15-volt electrolytic capacitor
IC1—Operational amplifier (Fairchild μA741C)
J1—Three-pin microphone connector
Q1—Transistor (Motorola HEP724)
Q2—Transistor (Motorola HEP739)
Q3—2N1671 transistor
R1-R3—10,000-ohm resistor
R4,R5—1-megohm resistor
R6,R9—250,000-ohm potentiometer
R7—330,000-ohm resistor
R8—33,000-ohm resistor
R10—27,000-ohm resistor
R11,R12—1000-ohm resistor
R13—470-ohm resistor
S1—Dpst slide or toggle switch
SPKR—100-ohm speaker
Misc.—Battery connectors, battery mounting clips, knobs (3), IC socket (optional), three-lead cable, plastic strip for electrodes, solder lugs (3), electrode hardware, perf board, component clips, etc.

Whistler is shown in Fig. 1. The prototype was built on a piece of perf board, though any other method may be used. The components are mounted on small clips, except that a 14-pin dual in-line socket may be used for the IC if desired. The input connector (*J1*), the speaker, the zero and sensitivity potentiometers (*R9* and *R6*, respectively), and the on-off switch (*S1*) are mounted on the front panel of the selected chassis.

A conventional three-lead microphone jack with an associated three-lead microphone connector and a few feet of three-lead cable are used to connect the muscle electrodes to the circuit.

The electrodes are fashioned from two screws mounted 3 or 4 inches apart on a narrow piece of plastic as shown in Fig. 2. A third screw midway between the other two forms the ground electrode. Solder lugs under the nuts are used to connect the three color-coded leads from the circuit. The center screw is longer than the other two so that a knob, or some other type of handle, can be attached.

Operation. With power applied to the circuit, adjust *R9* so that there is no output from the speaker when there is no input signal. The output varies from a whistle down to a series of slow clicks. Adjust *R9* until the clicks just stop. With the sensitivity control (*R6*) turned up

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MUSCLE WHISTLER

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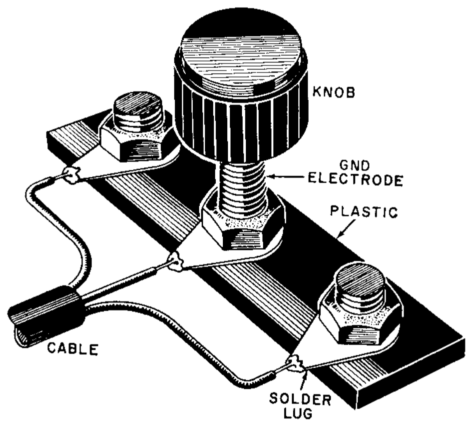

Fig. 2. Electrodes are mounted on a small length of plastic as shown here. An insulated knob on the ground screw acts as the handle.

slightly, touching one of the end electrodes on the muscle probe should cause the circuit to squeal due to imbalance in the operational amplifier circuit. (It is actually pickup from the field created by the 60-Hz power line.) However, when both electrodes are touching the skin, virtually all of this ambient noise is rejected by the differential amplifier.

Good electrical contact must be made between the electrodes and the skin. Use a commercial electrode paste or make your own by mixing salt, water, and flour in a good pasty consistency. The paste is rubbed into the area of skin where the electrodes are to be applied.

Before the electrodes are placed against the skin, set *R6* partially up and be sure *R9* is adjusted to give no output. Place the electrodes against the skin. There will be a change in the tone of the output. Adjust *R9* just below the oscillation point and adjust *R6* until the output changes frequency as the muscle is activated. Each time the muscle is flexed, the whistle changes frequency—the tenser the muscle, the higher the frequency.

Theory of Circuit Design. Operational amplifier *IC1* is a very high gain differential amplifier whose gain (sensitivity) is controlled by feedback potentiometer *R6*. The differential input to the op amp is picked up by the electrodes applied to the skin.

Unijunction transistor *Q3* is wired in the classical UJT oscillator configuration with *C5* determining the frequency and the emitter-collector resistance of *Q2* (with limiting resistor *R12*) acting as the charging resistor. The interelement resistance of *Q2* is a function of the applied base current and the voltage to move this current is stored in capacitor *C4*, which is charged up by amplifier *Q1*. The size of the steady-state charge on *C4* is determined by the setting of *R9*.

When a muscle voltage is amplified by *IC1* and fed to *Q1*, the collector voltage on *Q1* varies, thus changing the charge on *C4*. This, in turn, varies the UJT oscillator frequency. The speaker forms the load for *Q3*, and the audible tone consists of a series of spikes, each occurring as the UJT fires. ◈