A microcomputer-based modulator for simulating insect songs and the response of crickets to an artificial calling song

D. JAMES CAMPBELL

University of Wollongong, Wollongong, New South Wales, Australia

and

WERNER LOHER

University of California, Berkeley, California

A machine language program for the 6502 KIM-1 microcomputer to produce a pulsed output for modulating a signal generator is described. The pattern of modulation is easily controlled to produce chirps, trills, and pauses as components of artificial insect songs. In the laboratory, increased locomotory activity of male and female field crickets (*Teleogryllus commodus*) is induced by an artificial calling song. In the field, crickets of both sexes are attracted to pitfall traps from which the song is broadcast.

The songs of crickets and some tettigoniids consist of trains of sine waves with a frequency reflecting the resonance properties of the sound-producing wings. In many other orthopterans, the sound is more complex and the tooth impact rate of the stridulatory organ is an important component of the song (Dorrscheidt & Rheinlaender, 1980). Natural and artificially generated cricket calling songs have been used frequently in both field and laboratory experiments (Cade, 1981; Campbell & Shipp, 1974; Hill, 1974; Loher, 1981; Pollack & Hoy, 1979; Popov & Shuvalov, 1977; Ulagaraj & Walker, 1973; Huber, Note 1). The principal aim of this paper is to describe a technique for the production of artificial insect songs by modulating a sine-wave generator adjusted to the resonant frequency of the *T. commodus* calling song using the KIM-1 microcomputer.¹

METHOD

Equipment and Operation

The equipment is compact and is fitted to a board that plugs into a 44-pin edge connector wired to the application port of the KIM-1. The microcomputer measures 21 x 27 cm, and the complete operating system is portable.

The sine-wave output, adjusted to 3500 Hz, of a Jameco signal generator (JE2206B) is used in conjunction with the modulator to produce the song, and the output is amplified using a Tandy 277-1008 amplifier wired to a Motorola 3.5-in. piezoelectric tweeter.

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Figure 1. Block diagram to illustrate the arrangement of components in the song generator.

The signal generator and amplifier are operated from the 12-V supply required for the cassette interface of the KIM-1. The piezoelectric tweeter operates effectively at 3500 Hz and has the advantage that it imposes only a small load on the amplifier, which can therefore have a low power rating. The audio output is voltage dependent, not current dependent. The program works by controlling the computer output, which is switched low or high at specified time intervals. The modulating signal level is shifted and its polarity is reversed with a 2N2222 transistor. It is then applied by an adjustable voltage divider to pin 1 of the XR2206CP chip of the signal generator. Thus, a series of 3500-Hz sound pulses is generated. The voltage divider is adjusted to give zero signal between pulses. A block diagram of the arrangement is given in Figure 1.

The Program

Since single-board microcomputers such as the KIM-1 come with full documentation, details of its operation are not repeated here.

The program for the modulator (available on request) is loaded into the computer starting at address 0200 and finishing at address 02DA. Note that all address locations are in hexadecimal notation.

Eight examples of songs are provided. The first (song 0) starts at address 0300, and the last (song 7) starts at address 0333. The addresses for all songs must be provided starting at address 02DB for song 0.

The modulator makes use of the computer's internal clock, which can measure an interval as small as 1,024 microsec in this program. The time required for program operation is 136 microsec; thus, the smallest time interval or unit interval for the modulator is 1,160 microsec. One unit interval low and one high gives

Figure 2. One phrase of the electronically generated calling song of the cricket *Teleogryllus commodus*, consisting of a chirp and a trill.

a periodicity of 2,320 microsec, or a frequency of 431 pulses/sec (PPS).

Reference to song 1, starting at address 0303, which is a simulation of the calling song of *T. commodus*, illustrates the programming of a song. Again, all numbers are hexadecimal. Song 1 is:

00 20 01 20 FE 06 00 10 01 10 FE 1E 00 A0 FF

The computer executes this as follows:

00 pulse off (level = low)
 20 for 20 (32) unit intervals (duration = 20)
 01 pulse on (level = high)
 20 for 20 (32) unit intervals (duration = 20)
 FE repeat this
 06 6 (6) times
 00 Pulse off (level = low)
 10 for 10 (16) unit intervals (duration = 10)
 01 pulse on (level = high)
 FE repeat this
 1E 1E (30) times
 00 pulse off (level = low)
 A0 A0 (160) times (duration = A0)
 FF start again from beginning

Where appropriate, the decimal equivalents of hexadecimal numbers are given in brackets. FE executes a pulse (low, high) a specified number of times, but this could be low, low or high, high. FF repeats the whole phrase.

Thus, song 1 consists of a chirp of 6 pulses with an interpulse interval of 0.074 sec (13.5 PPS), a trill of 30 pulses with an interpulse interval of 0.037 sec (27.0 PPS), and a pause with an interpulse interval of 0.241 sec (the pause duration = 0.186 sec). The interpulse interval in each case is measured from the beginning on one sound pulse to the next (Pollack & Hoy, 1979).

Song 0 (00 01 FF) produces no sound at all, song 7 (01 01 FF) produces a continuous 3500-Hz tone that is not pulsed, and, as a further example, song 4 (00 10 01 10 FF) produces a continuous trill of pulses with an interpulse interval of 0.037 sec (27.0 PPS). One phrase of song 1 is illustrated in Figure 2.

Running the Program and Operating Features

When the program plus the songs and their addresses are loaded into the microcomputer and checked, address 0200 is set and the GO key is pressed. The LED display darkens and the program waits in a loop until a key (0 to 7) is pressed. This indicates which song is required. The modulator output is from pin 9 of the application port (PB0) and can be heard by connecting one lead of the piezoelectric tweeter to this pin and the other to earth. It will sound like a series of clicks. If either pin 11 or pin 12 (PB2 or PB3) is connected to earth, the output stops and the display lights. A new song can then be obtained by pressing a key (0 to 7), and the song number shows on the right hand side of the display. Pins 11 and 12 are programmed to operate in a similar fashion to enable a control timer to be connected to one and a manually operated switch to the other. If this switch is not wired into the circuit, a new song is obtained by pressing the RS (RESET) key, the GO key, and then the song number key.

A summary of how the program works is provided in the flow diagram of Figure 3. Two aspects should be noted when the program is used. (1) Delay loop DE2 equalizes the low and high pathways of a pulse, provided FE follows a high. That is, since the FE pathway is executed when the level is high, the time required for this is compensated by the delay loop, which is executed when the level is low. Thus 00 10 01 10 FE 05 . . . is correct but 01 10 00 10 FE 05 . . . is not. In the latter case, each low will be 44 microsec over the duration specified, and each high will be 44 microsec under. The same applies to FF. In song 1, for example, the pause at the end of the phrase theoretically has a duration of $(1160 \times 160) + 44$ microsec, not 1160×160 microsec. (2) The value at location 0268 of the program (ND in the flow diagram) determines the number of clock cycles in a unit interval. This value is 01, but the unit interval can be doubled or tripled by replacing this value with 02 or 03, etc. With a value of 02 at this location, the interpulse intervals for song 1 are doubled.

Experimental Details

Laboratory. In order to test whether crickets respond to the artificial calling song (song 1), eight adult, newly emerged male and female crickets were each placed in individual Perspex testing boxes, where their locomotory activity was measured in the presence and absence of the song. The tweeter producing the song was placed at an average distance of 50 cm above the 16 test boxes.

Figure 3. Flow diagram of the computer program used to modulate a signal generator to produce the artificial cricket songs.

Figure 4. Temporal distribution of locomotory activity during Day 33 of the experiment, of seven male (channels 1 through 8) and seven female (channels 9 through 16) crickets in a light:dark cycle of 12:12 h at constant temperature ($\approx 26^{\circ}\text{C}$). No crickets were on channels 3 and 10. An increase in locomotory activity is observed during the period when the artificial song was switched on and also at lights off.

The output from the song generator was adjusted to 1 V peak to peak. This gave a sound intensity of 81 dB at 50 cm (A scale). A double infrared light beam traversed each box, and, when the beam was crossed by a cricket, an event was recorded. The output from each box was transmitted to a 20-channel Esterline Angus event recorder. Channels 1 through 8 were used for the male crickets, and channels 9 through 16 for the females.

Field. The artificial calling song (song 1) was also used in a field experiment to see whether it would attract crickets to pitfall traps. Each trap consisted of a cone 90 cm in diameter, with a 3-cm hole at the bottom leading into a collecting chamber into which the attracted crickets slipped. They were collected each morning. The tweeter was anchored 16 cm from the bottom of the cone and faced downward to protect it from rain. Two traps were used, and a tweeter was switched on each night, alternating between the traps.

The output from the song generator was adjusted to 8 V peak to peak, which gave a sound level of 100 dB at 50 cm.

RESULTS

Laboratory

Crickets were showing a pronounced locomotory response to the artificial song by Day 12 after the imaginal molt and the beginning of the experiment, and this persisted until the experiment ended on Day 60. The record of locomotory activity on Day 33 is shown in Figure 4 as an example. One male (channel 3) and one female (channel 10) had died by that time. The song was turned on 4 h after the lights had come on and continued for 2 h (see arrows in Figure 4). A marked increase in locomotory activity of both males (channels 1 through 8) and females (channels 9 through 16) is evident during this period. Since crickets are nocturnal, a further period of activity begins at lights off.

Field

The experiment was run for 36 days during the summer of 1982. A total of 39 males and 73 females were collected from the experimental traps when the

song was switched on, whereas 3 males and 3 females were collected from the controls. This indicates significant attraction of both males and females to the artificial song.

DISCUSSION

The results indicate that both male and female crickets are responsive to the calling song and can be attracted to it. This is consistent with previously published work in which tape recordings of the calling song have been used (Cade, 1981; Campbell & Shipp, 1979; Loher, 1981).

The technique described could be used in a variety of laboratory and field experiments involving many singing insect species. The method is an improvement over previously applied tape recorder techniques because song components can be controlled and modified if their role is to be investigated (Pollack & Hoy, 1979). In addition, it eliminates the need for mechanical tape drives, facilitating transmission of a song over extended periods of time. Song components are easy to specify within the program, and the program itself can be easily modified for other 6502-based microcomputers, such as the SYM-1.

AVAILABILITY

A listing of the program is available on request. If a taped record is required, send a cassette and a self-addressed envelope, plus \$5 to cover handling and airmail postage.

REFERENCE NOTE

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NOTE

1. The KIM-1 microcomputer is currently available from Falk-Baker Associates, 382 Franklin Avenue, Nutley, New Jersey 07110.

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