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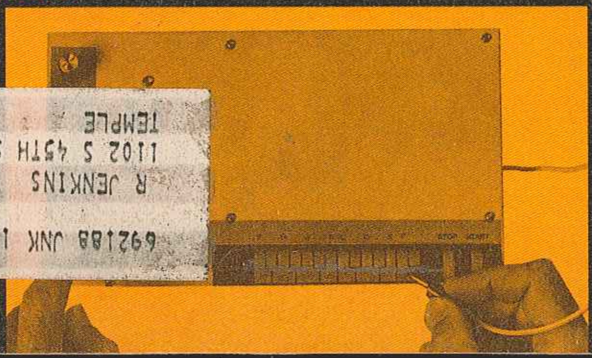
Program Any Tunes with the RA...



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PLUS: 1975 ANNUAL CUMULATIVE ARTICLE INDEX

Table II. Sample Specification Sheet

Specification	Monophonic	Stereophonic
Usable Sensitivity	10 dBf (1.8 μV)	20 dBf (5.5 μV)
50 dB Quieting Sensitivity	13 dBf	33 dBf
S/N at 65 dBf	70 dB	65 dB
Muting Threshold / (Stereo Threshold)	20-30 dBf (variable)	30 dBf
Frequency Response, 30-15 kHz	± 1dB	+0, −2 dB
Distortion at 50 dB Quieting		
100 Hz	1.05%	1.0%
1,000 Hz	0.8%	0.9%
6,000 Hz	1.0%	2.0%
Distortion at 65 dBf		
100 Hz	0.4%	0.6%
1,000 Hz	0.3%	0.5%
6,000 Hz	0.5%	1.3%
Intermodulation Distortion	0.5%	1.0%
Capture Ratio	1.3 dB	—
Adjacent Channel Selectivity	22 dB	—
Alternate Channel Selectivity	80 dB	—
Spurious Response Ratio	95 dB	—
Image Response Rejection Ratio	85 dB	—
IF Rejection	90 dB	—
AM Suppression Ratio	60 dB	—
Frequency Drift	±30 kHz	—
Stereo Separation		
100 Hz	—	35 dB
1,000 Hz	—	42 dB
10,000 Hz	—	30 dB
Subcarrier Product Rejection	—	60 dB
SCA Rejection Ratio	—	65 dB

indicated by the sudden drop in output (S+N+D) and decreased noise and distortion as the tuner automatically "switches back" into mono at the stereo switching threshold. And thanks to the linear scales, the curves are much easier to interpret. Other salient points are (2) "Usable Sensitivity in Stereo," (3) "50-dB Quieting Sensitivity in Stereo," (4) "Distortion at 50-dB Quieting in Stereo," (5) "Distortion at 65 dBf in Stereo," and (6) "S/N at 65 dBf in Stereo."

Stereo Separation. In the past, most manufacturers reported their products' stereo separation capacities at 400 or 1000 Hz only. The new Standard specifies that channel separation must be rated at three separate frequencies—100, 1000, and 10,000 Hz. Furthermore, if a

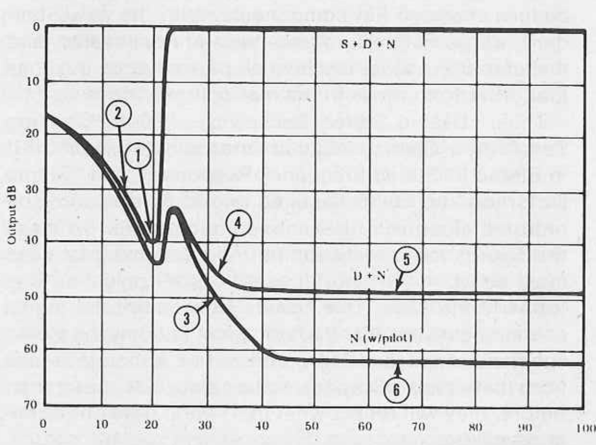


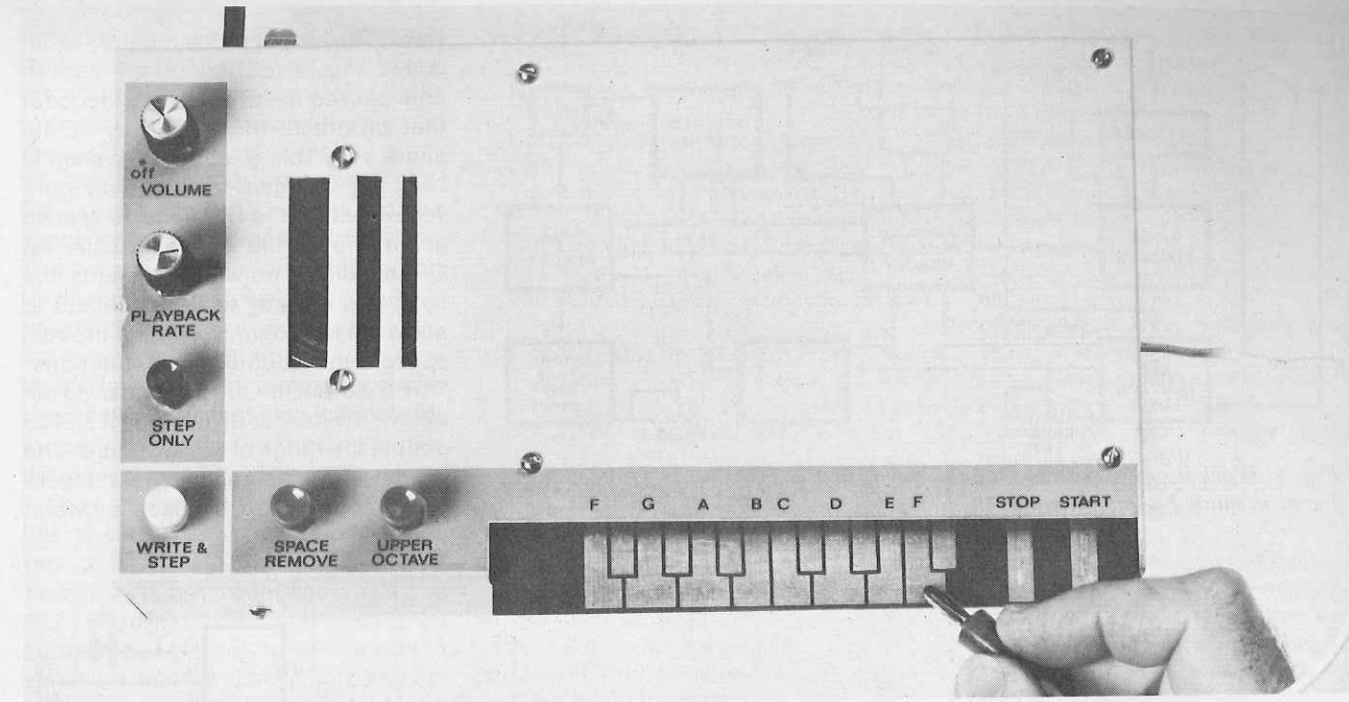
Fig. 4. Stereophonic sensitivity curves.

tuner or receiver is equipped with a "blend" circuit (to reduce noise on weak-signal stereo programs), reduced separation will be experienced at mid and high frequencies with the "blend" activated. To reflect this, the manufacturer is expected to disclose realizable separation at 1000 and 5000 Hz under "blend" conditions.

Other Stereo Specs. Multiplex circuits often generate high-frequency products that are not part of the desired audio information. Such products consist of 19- and 38-kHz carrier components which have not been totally filtered out. Although they are inaudible, they can adversely affect "off-the-air" recordings made on ac-biased tape machines. Accordingly, "Subcarrier Product Rejection" (expressed in dB referenced to 100% modulation) must now be reported.

Additionally, the unit's ability to reject SCA subcarriers (67-kHz signals modulated by "background music") must be specified in dB referenced to 100% modulation. For this test, a 67-kHz SCA subcarrier modulates the main carrier 10%. In turn, the sub-carrier must be modulated by a 2500-Hz audio signal, causing a maximum subcarrier deviation of ±6 kHz—the "worst case" condition.

A Typical Spec Sheet. The specification sheet—a capsule summary of tuner performance—reflects all the changes induced by the new Standard. For a preview of what it will now look like, see Table II. This not only lists the required specifications that we've examined, but also offers a sample set of figures for a modern, good-quality component. Undoubtedly, you'll learn a lot more than before about the new tuner that's caught your eye and ear by considering its specifications based on the new FM broadcast receiver standard. ◈



CONSTRUCTION

THE PROGRAMMABLE MUSIC BOX PART 1

Compose your own tunes for playback at any time.

BY MITCHELL WAITE AND LARRY BROWN

THE PROGRAMMABLE music box presented here represents an important evolutionary step in music box design. Employing a *reusable* RAM (random-access memory) rather than a nonvolatile ROM (read-only memory) IC, a melody can be programmed, stored, and played back on command. The melody can be erased or a programming error corrected without spending an additional cent. And you can hear each note as it is programmed. Furthermore, it features a unique piano type of keyboard entry to simplify programming, play tunes much as one would do with a forefinger on a conventional piano, and double as a teaching tool for music scales. The memory system is static. As long as power is applied to the music box, a tune in the memory will remain there until it is erased or power is interrupted.

The music box can be started by any type of spst switch. Thus, it can be used as a musical doorbell, jewelry box, cigar case, etc. Although it is self-contained, if you wish louder volume for the tune being played, the output of the music box can be fed into an amplifier.

As presented here, the music box has a 40-word memory system. Next month, we will describe how to add another 256 words to the system for playing long tunes, and describe how to program the Music Box.

About the Circuit. The block diagram shown in Fig. 1 illustrates how the system operates. The input is via a monophonic 26-note keyboard. Depending on the shortest note in the tune, you can store up to 40 notes in a hex 40-bit shift register. A WRITE/STEP switch enters the selected note into the memory and then advances to the next memory position. The SPACE REMOVE switch controls the pause between individual notes and allows the user to control the duration of the note. A RATE control permits regulation of the playback speed. Supplementing these controls are the VOLUME control, OCTAVE switch, and a STEP ONLY switch. START and STOP pads on the printed circuit board to the right of the "piano" keys control the operation.

In operation, a positive voltage applied to the keyboard (via a simple probe) forms the input to a diode encoder that produces a four-bit parallel binary word each time a key is activated. The words are deposited in the shift register (reusable memory) by activating the WRITE/STEP switch. This also steps the memory forward by one

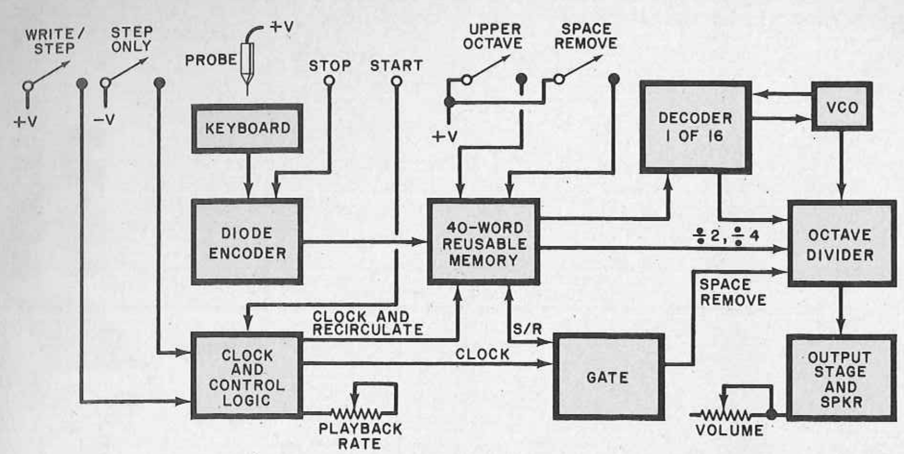


Fig. 1. Block diagram shows how the music box works. Input is made by touching a probe to the keyboard.

word. The output of the memory is decoded into a four-bit binary pattern and passed to a one-of-16 decoder that programs the frequency of the audio vco. This part of the system is basically a digital-to-frequency converter that has 14 frequencies spaced according to the musical scale. An OR'ing diode network connects the keyboard directly to the decoders to allow the keyboard to operate the vco, space remove, and octave functions.

The output of the vco goes to an octave divider for division by 2 or 4 to double the range of the keyboard. The divider and gate-enable circuits work together to insert a space between notes, which controls the timing and each note's relative length. The memory also contains a register that holds the space information and the state of the bit in this register tells the clock whether or not to insert a space after the note is played. Leaving out the space makes the notes run together. The output of the octave divider goes to an audio amplifier that drives a speaker.

An astable oscillator, which contains a variable RATE control, provides the clock pulses that step the memory through each word and play the programmed melody.

The complete schematic diagram of the music box is shown in Fig. 2. The vco consists of *IC7* (a 741 op amp). Two binary-to-octal decoders, *IC2* and *IC3*, produce the 14 frequencies spaced according to the western equally tempered scale (ETS). The actual frequencies are determined by *R13* through *R27* in the feedback loop of the vco. Four-bit parallel words from memory *IC1* or the keyboard are decoded and a register junction is enabled. The vco then oscillates at a frequency determined by the total resistance in the chain. The key of the vco is

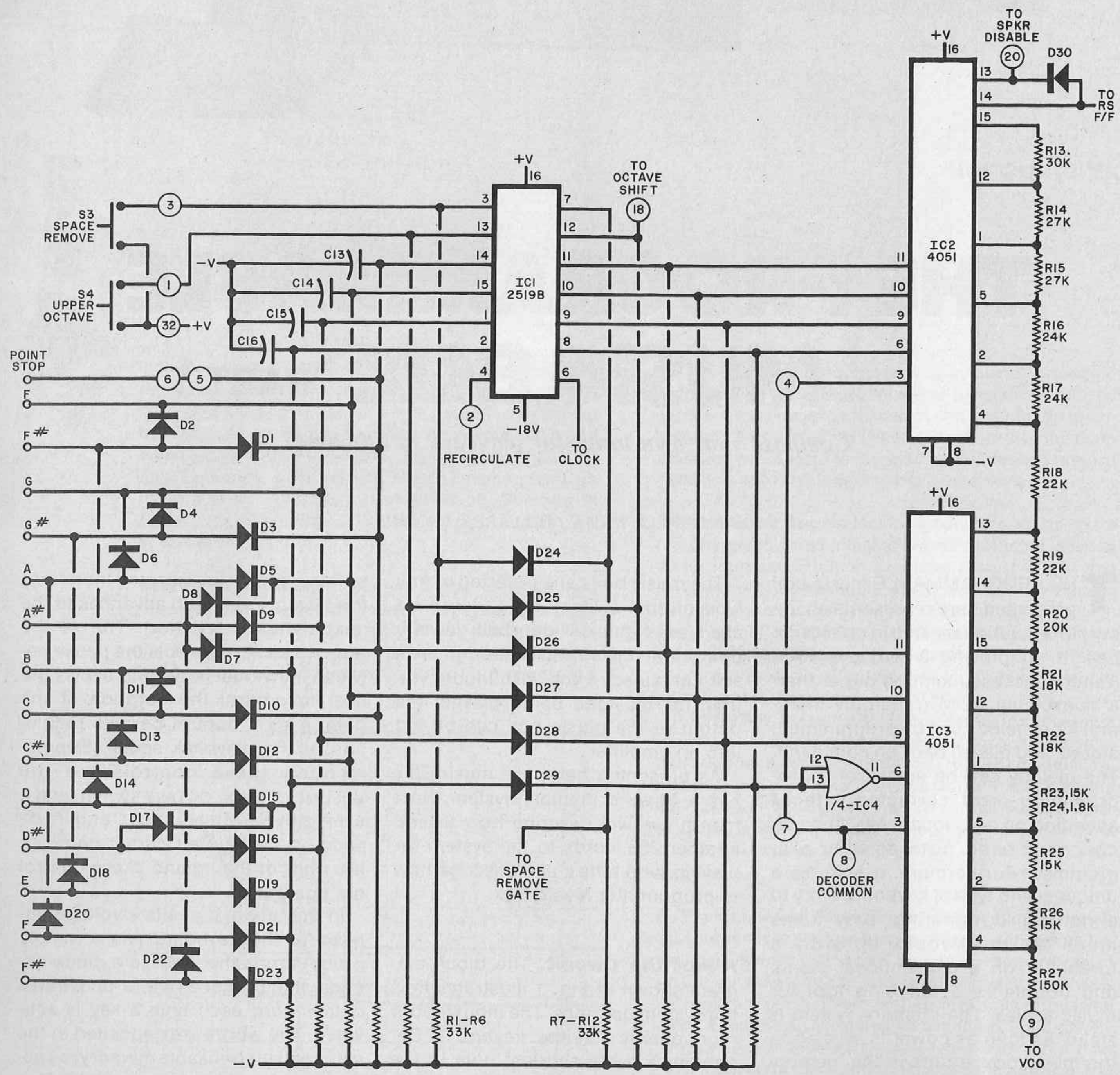
PARTS LIST

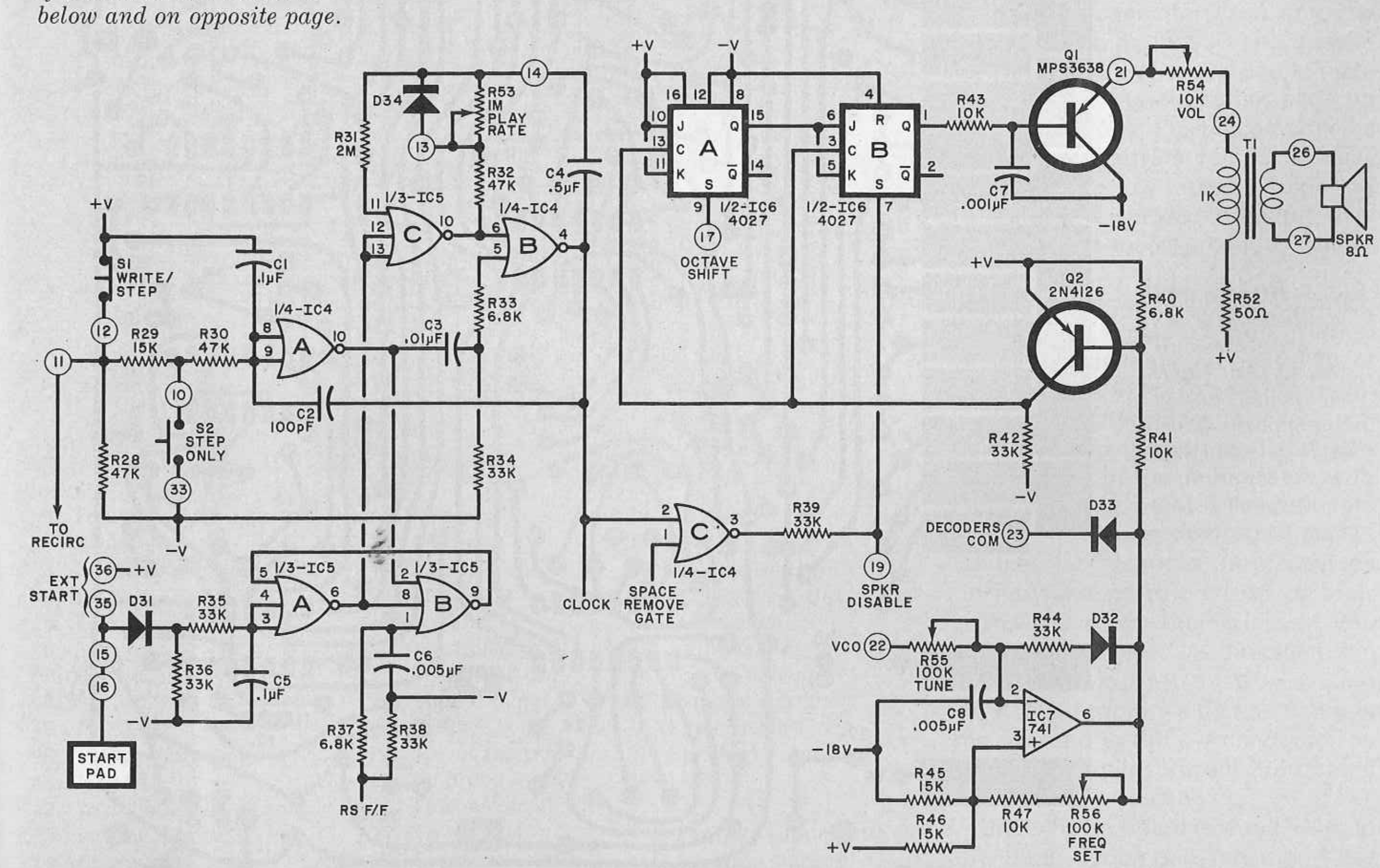
C1,C5,C11,C12—0.1-μF, 50-volt Mylar capacitor
C2—100-pF, 50-volt disc capacitor
C3—0.01-μF, 50-volt Mylar capacitor
C4—0.5-μF, 50-volt Mylar capacitor
C6,C8—0.005-μF, 50-volt Mylar capacitor
C7—0.001-μF, 50-volt Mylar capacitor
C9—50-μF, 25-volt electrolytic capacitor
C10—470-μF, 25-volt electrolytic capacitor
C13 through C16—200-pF, 50-volt disc capacitor
D1 through D34—1N4148 (or similar) diode
IC1—2519B 40-bit shift register (Signetics)
IC2,IC3—34051CP one-of-eight decoder (Fairchild)
IC4—34001CP quad 2-input NOR gate (do not substitute) (Fairchild)
IC5—34025CP triple 3-input NOR gate (do not substitute) (Fairchild)
IC6—34027CP dual JK flip-flop (Fairchild)
IC7—741 operational amplifier
Q1—MPS3638 transistor
Q2—2N4126 transistor

Following resistors are ¼-watt, 5% tolerance:
R1 through R12,R34,R35,R36,R38,R39, R42,R44—33,000 ohms
R13—30,000 ohms
R14,R15—27,000 ohms
R16,R17—24,000 ohms
R18,R19—22,000 ohms
R20—20,000 ohms
R21,R22—18,000 ohms
R23,R25,R26,R29,R45,R46—15,000 ohms
R24,R49—1800 ohms
R27—150,000 ohms
R28,R30,R32—47,000 ohms
R31—2 megohms
R33,R37,R40—6800 ohms
R41,R43,R47,R48,R51—10,000 ohms
R50—330 ohms
R52—47 ohms
R53—1 megohm
R54—10,000-ohm audio-taper potentiometer with spst switch
R55,R56—100,000-ohm horizontal printed-circuit trimmer potentiometer
S1—Spst momentary-action, normally closed switch
S2 through S4—Spst momentary-action normally open switch
SPKR—8-ohm, 2" diameter speaker
T1—1000:8-ohm, 150-mW matching transformer
Misc.—Probe with banana-type tip; control knobs (2); battery holder (optional); chassis (LMB No. LMB-5952 or similar); spacers; dry-transfer lettering kit; mounting hardware; hookup wire; solder; etc.

Note: The following items are available from Cal Kit, P.O. Box 877, Sebastopol, CA 95472: Drilled and plated printed circuit board No. MC1-3 at $8; complete kit, including pc board, ready-to-use enclosure, all components (less battery) No. MC1-1 at $70; same as MC1-1 kit but for ac operation, No. MC1-2 at $86; MOS IC's (IC1 through IC6) No. MC1-9 at $18; sockets for all IC's, No. MC1-10, at $5. California residents, please add 6% sales tax.

Fig. 2. Complete schematic of the music box is shown below and on opposite page.





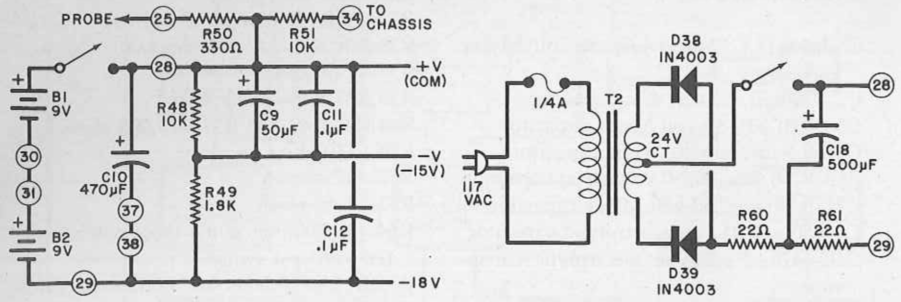


Fig. 3. Battery or line-operated power supply can be used. Components following C10 (left) must be added to other circuit also.

set by *R56*, while the tune (expanded or compressed) is set by *R55*.

Two of the words stored in the memory are decoded as instructions. One instruction, no note, is used to store the condition for no note played, or a pause. Each time it is decoded, the speaker is silenced for one clock cycle. This is accomplished by making the *set* input of *IC6B* low for one clock cycle.

The other instruction, stop, is used to disable the speaker and stop the clock. When this instruction is decoded, the astable multivibrator that clocks the tune out of memory is stopped. This allows a one-shot operation for doorbell or other switches.

Starting and stopping the clock is controlled by *IC5A* and *IC5B* connected as an RS flip-flop. One input to this flip-flop goes to the keyboard pad labelled START, while the other input goes to the decoder output labelled STOP. The output of the flip-flop enables the input of the astable clock. When +V is applied to the START pad, via the probe, the flip-flop goes to a state that frees the clock to permit it to run. When a stop instruction is decoded, the flip-flop disables the clock. The clock remains disabled until the START pad is again activated. The start input is debounced by *R35, R36,* and *C5*, while *R37, R38,* and *C6* debounce the stop input.

The astable multivibrator, comprised of *IC4B* and *IC5C*, uses *R53* for varying its operating frequency. The output of the multivibrator goes to the clock input of *IC1*. When the clock is disabled, *IC1* can be single stepped a word at a time by the *IC4A* gate. STEP ONLY switch *S2* is debounced by *R30* and *C1*, and *IC4A* produces a pulse that is differentiated by *R33, R34,* and *C3*. The output of *IC4B* cleans up the pulse and drives the memory clock. Capacitor *C2* provides positive feedback to speed up the rise time of the clock pulse.

WRITE/STEP switch *S1* is connected so that the recirculate input of *IC1* is enabled and step action occurs. The memory will then store whatever note is being played when *S1* is depressed, clocking the memory forward by one word.

The output of the vco (*IC7*) goes to *Q2* to improve the rise time. Then the signal goes to the clock inputs of the two *IC6* flip-flops, which are arranged to divide the vco signal by 2 or 4. If the set input is high, the vco signal is divided by 2, which gives the effect of doubling the frequency when compared to division by 4. The set input is connected to a register in *IC1* so that the octave can be programmed along with the note.

A second function of the flip-flops is to control the duration of the note. The clock pulse is passed to gate *IC4C*, while the other input of this gate goes to the space-remove register in *IC1* and to space-remove switch *S3* via *D24*. The gate input is connected to the set input of *IC6B*. Hence, if the gate is enabled, the clock pulse will set the flip-flop once per clock cycle and insert a narrow (20% of on time) pulse or space after each note. Disabling the gate with *S3* removes the space and permits the notes to run together. Consequently, a note can be made an integral number of times longer than another note, which allows precise duplication of music notation.

The output from *IC6B* goes to *Q1*, a transistor driver that provides power gain for matching transformer *T1* to the speaker.

Diodes *D1* through *D33* convert the keyboard operations to four-bit parallel words for storage in memory. Diodes *D24* through *D29* are used to OR the keyboard and function switches with the memory input, allowing you to play the music box without using the storage function. Resistors *R1* through *R12* serve the pulldown function for *IC1*, and *R50* is in series with the probe to limit probe current.

With the music box, you have a choice of either ac or battery operation. Both power supply circuits are shown in Fig. 3.

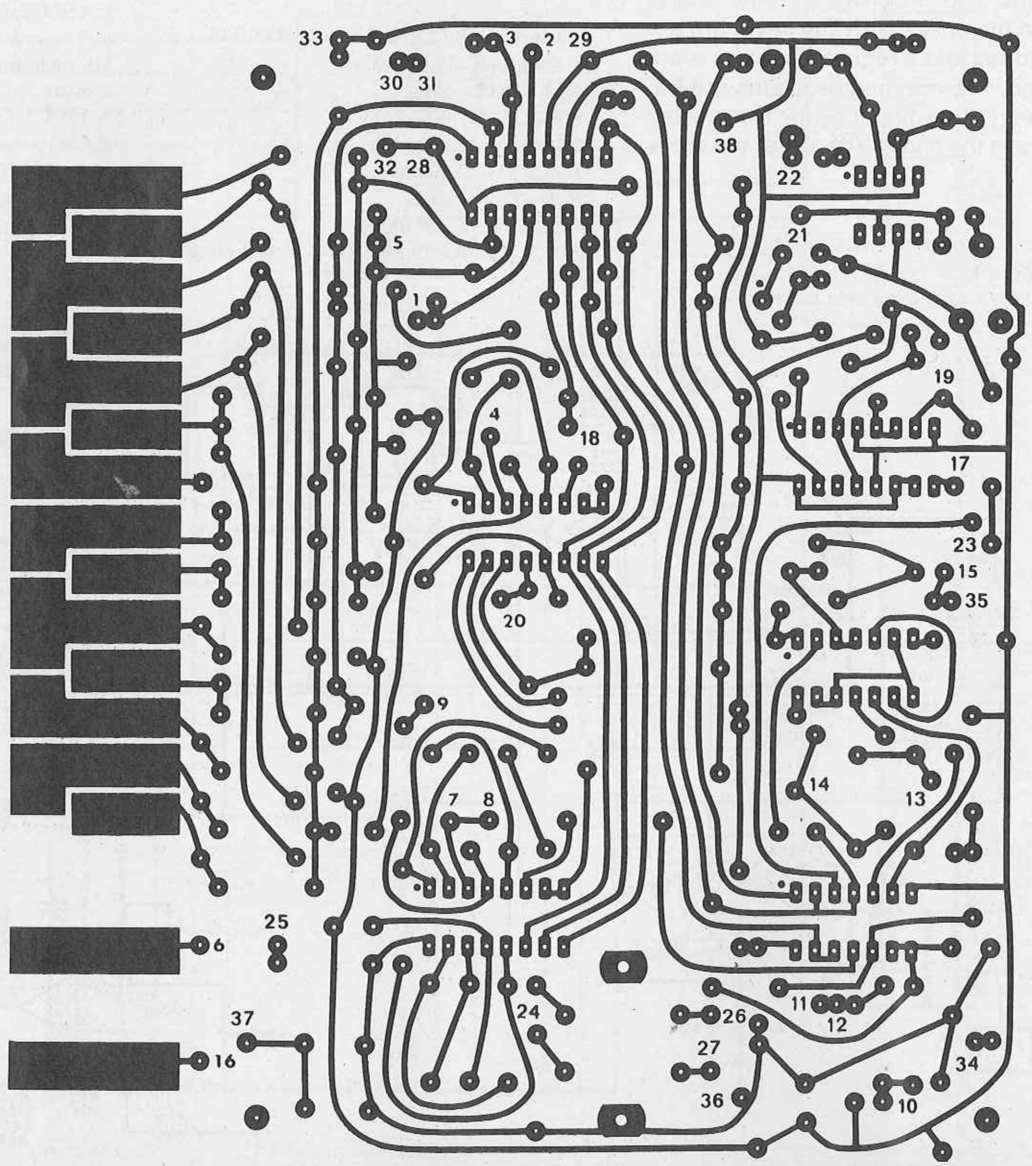
Construction. We recommend that you use a printed circuit board for the music box for two reasons. First, the circuit's extensive use of IC's demands an easy-to-control wiring medium. Secondly, the keyboard is an integral part of the pc foil pattern. Therefore, if you plan to make your own pc board, use the actual-size etching and drilling guide shown in Fig. 4.

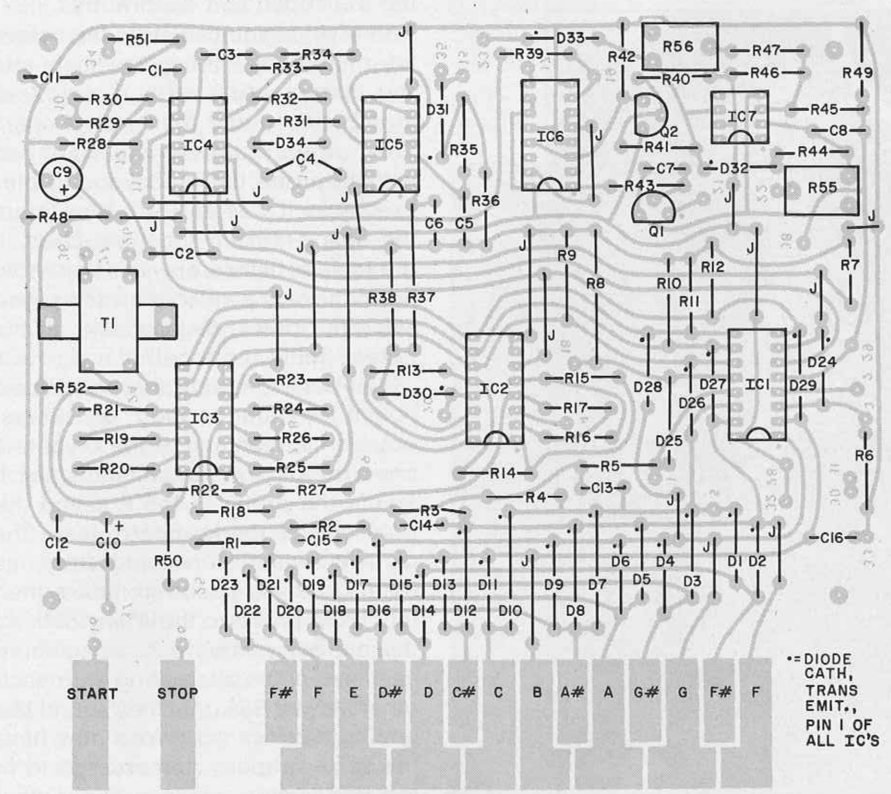
When installing components on the board, make certain that diodes and electrolytic capacitors are properly polarized and that the IC and transistor pin configurations properly mate with the appropriate solder pads on the board. (See Fig. 4 components placement diagram for parts locations.) Use a low-wattage soldering iron and fine solder, and apply only enough heat to assure good solder connections.

For the IC's, we recommend the use of sockets or Molex Soldercons, which will eliminate the possibility of heat damage to these sensitive components. Furthermore, sockets will permit you to install the CMOS IC's without fear of damaging them with static electricity during the soldering operation. Always install the CMOS devices last. Handle these devices only by the narrow edges of their cases—never by their pins. (If you elect to solder the IC's directly to the pc board, wrap a bare wire around your soldering iron's tip and connect the free end to the +V conductor on the pc board to prevent high static charges from building up.)

Once the pc board is wired, refer to the table accompanying Fig. 4 for

Fig. 4. Etching and drilling guide for printed circuit board is at right; component layout on opposite page. Table below layout gives connections to numbered points on the pc board.





1. To upper octave switch
2. Recirculate
3. To space remove switch
4. To 7
5. To 6
6. Stop pad
7. Pin 3 IC3
8. Pin 3 IC3
9. To 22
10. To step only switch
11. To 2
12. To write & step switch
13. To play rate pot
14. To play rate pot
15. To 16
16. Start pad
17. To 18
18. Pin 12 IC1
19. To 20
20. Pin 13 IC2
21. To volume pot
22. Tune trimmer
23. To 8
24. To volume pot
25. To probe
26. To speaker
27. To speaker
28. To on/off switch
29. −18V in
30. Negative Battery A*
31. Positive Battery B*
32. +V to all but step only switch
33. −15V to step only switch
34. To chassis lug
35. External start in**
36. External start in**
37. To 38
38. −18V

*For battery supply only
**For remote starting

making interconnections between the circuit board assembly and off-the-board components. When wiring the power supply, note that all of the components shown after *C10* in Fig. 3 are common to both types of supply. If you elect to use the ac supply, connect it to the board assembly across *C10* via pads 28 and 29 on the board.

The chassis in which you house the music box should have an open bottom and a slot cut in one side (see photo) so that the keyboard can protrude for easy accessibility. Mount the board in the box with the aid of spacers and machine hardware. The speaker, switches, controls, and power supply mount directly on the chassis box, the last with terminal strips and point-to-point wiring.

Each switch, control, and keyboard pad must be identified. They can easily be labelled according to function with a dry-transfer lettering kit. Finally, the flexible stranded probe wire exits to the chassis through a grommet-lined hole and is terminated in a banana-type plug.

Checkout and Tuning. Turn on the music box and try playing it by touching the probe tip to the contacts on the keyboard. As you move the probe up the scale, each note should increase in frequency. Try using the OCTAVE switch; depressing it should cause the pitch of the notes to double in frequency.

Clear the memory by turning off the power for about 10 seconds. Then, to check the storage function, load each note of the scale into a memory location by holding the probe tip against the desired keyboard note pad and pressing the WRITE/STEP switch once for each note. Touch the probe to the START pad. The notes you just stored should play back continuously, at a rate determined by the PLAYBACK RATE control.

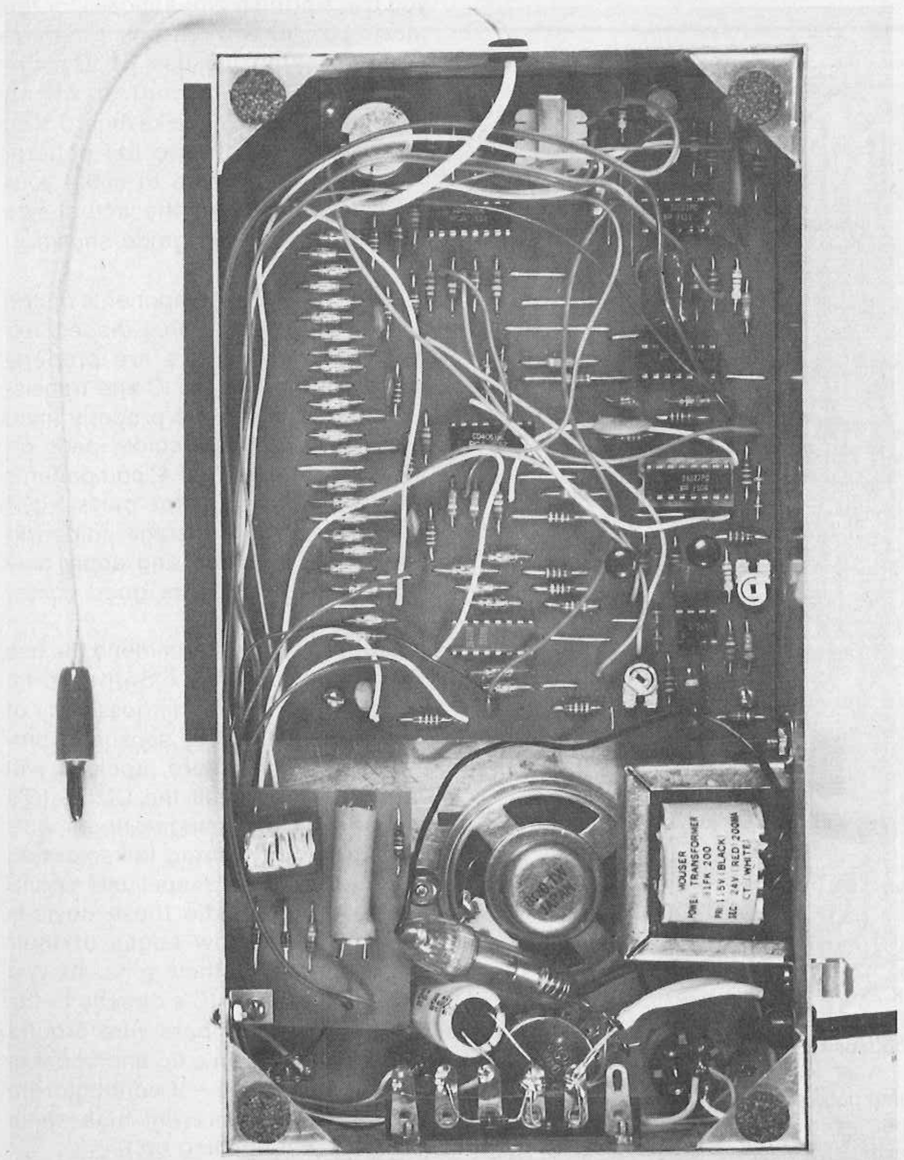
Check the STEP ONLY function by pushing the button. The tune should cease playing, and repeated pressing of the switch should step the tune one note at a time. Next, check the SPACE REMOVE function by holding down the switch while a melody is playing. The notes should all run together. To test the stop function, stop the melody by pressing the STEP ONLY switch at a clear spot in the tune. Hold the probe on the STOP pad on the keyboard and press the WRITE/STEP switch. This should deposit in memory the code for stopping a tune after it has played through once. Touch the probe tip to the START pad and confirm this.

Verify that you can store the octave information by loading the scale into the memory first with the OCTAVE switch closed and then with it open. Then, when you touch the START pad with the probe, the melody should play exactly as it was entered. Now, store the space-remove function. Load in the scale as before, only this time, hold down the SPACE REMOVE switch as you store the notes. In playback, all the notes should run together.

You can now tune the music box. Touch the probe to the F key (lowest note) on the left end of the keyboard, press the OCTAVE switch, and store it. Touch the probe to the F key at the right end of the keyboard, leave the OCTAVE switch alone, and store the note. Do these about six times, then touch the probe to the START pad. As the melody comes out, you should hear two notes alternating with each other. Adjust *R55* until they sound like one continuous note. You now have the scale properly compressed to fit the ETS. Later, you can experiment with changing it and then easily get back into tune by following this procedure.

A simple way to adjust the frequency of the keyboard is to use an oscilloscope to adjust FREQUENCY trimmer *R56* so that the higher F (right key), with the OCTAVE switch pressed, has a period of about 715 μs, corresponding to 1396 Hz, or F in the sixth octave.

With everything operating properly, you can try your hand at storing some melodies. ◈



Internal view of the music box. Power supply here is line-operated (components at bottom right).

BY RICHARD PHARES

The Mysterious "Negistor"

A negative-resistance element, disguised as a transistor, with many useful applications.

IT IS known that some transistors, when connected into a circuit in reverse, have a negative resistance similar to that of the tunnel diode. That is, the current through and the voltage across the transistor both increase until the voltage reaches a certain point. Then the transistor breaks down and any further increase in current results in a decrease in voltage. To simplify our discussion, we will call such devices "negistors." In circuit diagrams, we represent it as a conventional transistor with the letter "N" added.

Chances are you can't buy a negistor as such at your local electronics store. (They probably wouldn't know what you were talking about anyway.) However, if you have a few npn silicon transistors, you probably already have a supply on hand without knowing it. (But don't expect to find a negistor among the germanium or the pnp silicon units.)

There are a number of types of npn transistors among which negistors can be found: Motorola's MPS-5172, the 2N2218, 2N2222, 2N697, for example. Transistors which may be useless for anything else may be excellent negistors. We have used negistors to build both crystal-controlled and tunable sine-wave oscillators, variable-width pulse generators, oscilloscope sweeps, and many other circuits. Other suggested applications include timing circuits for SCR power control, latching circuits for power-supply regulator protection, timers, etc.

What Makes It Work. The behavior of the negistor is caused by avalanche multiplication as a result of impact ionization produced by mobile charge carriers. This characteristic is also used to enhance switching speed in some logic circuits.

The negative-resistance characteristic shown in Fig. 1 results when a 2N2218 is connected as shown. In this case the breakdown voltage is about 7.7V. Using this characteristic, the negistor can be used to perform some of the functions of a tunnel diode or a UJT—often with simpler additional circuitry.

When used in tunnel diode applications, the output of a negistor is much greater than that of the diode. As a UJT, the reverse transistor dissipates power only during breakdown and therefore its use is limited only by the peak current.

Applications. A useful circuit employing the negistor is the sawtooth and pulse generator shown in Fig. 2. Output frequency is determined primarily by *R1*, *R2* and *C1*. The current through the negistor is limited by *R2*, which also sets the maximum fre-

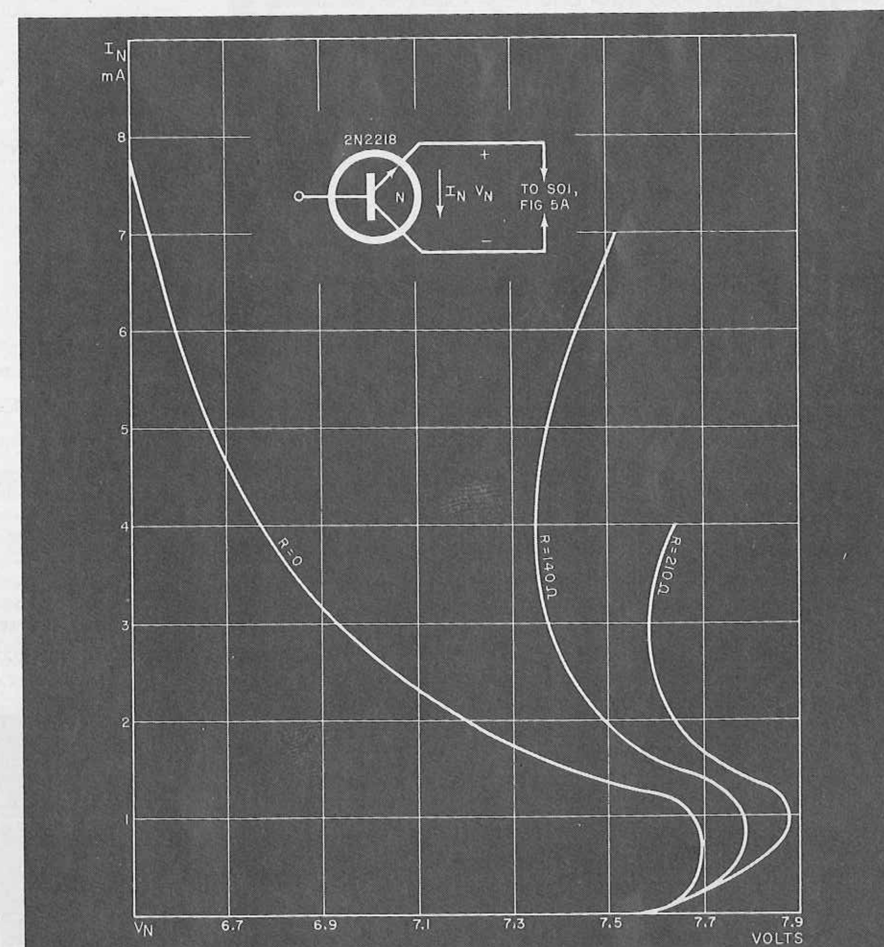


Fig. 1. I-V characteristics of a typical negistor. Many npn transistors exhibit negative-resistance behavior.