Stompboxology™

Volume 8, Number 1

Ring Modulators

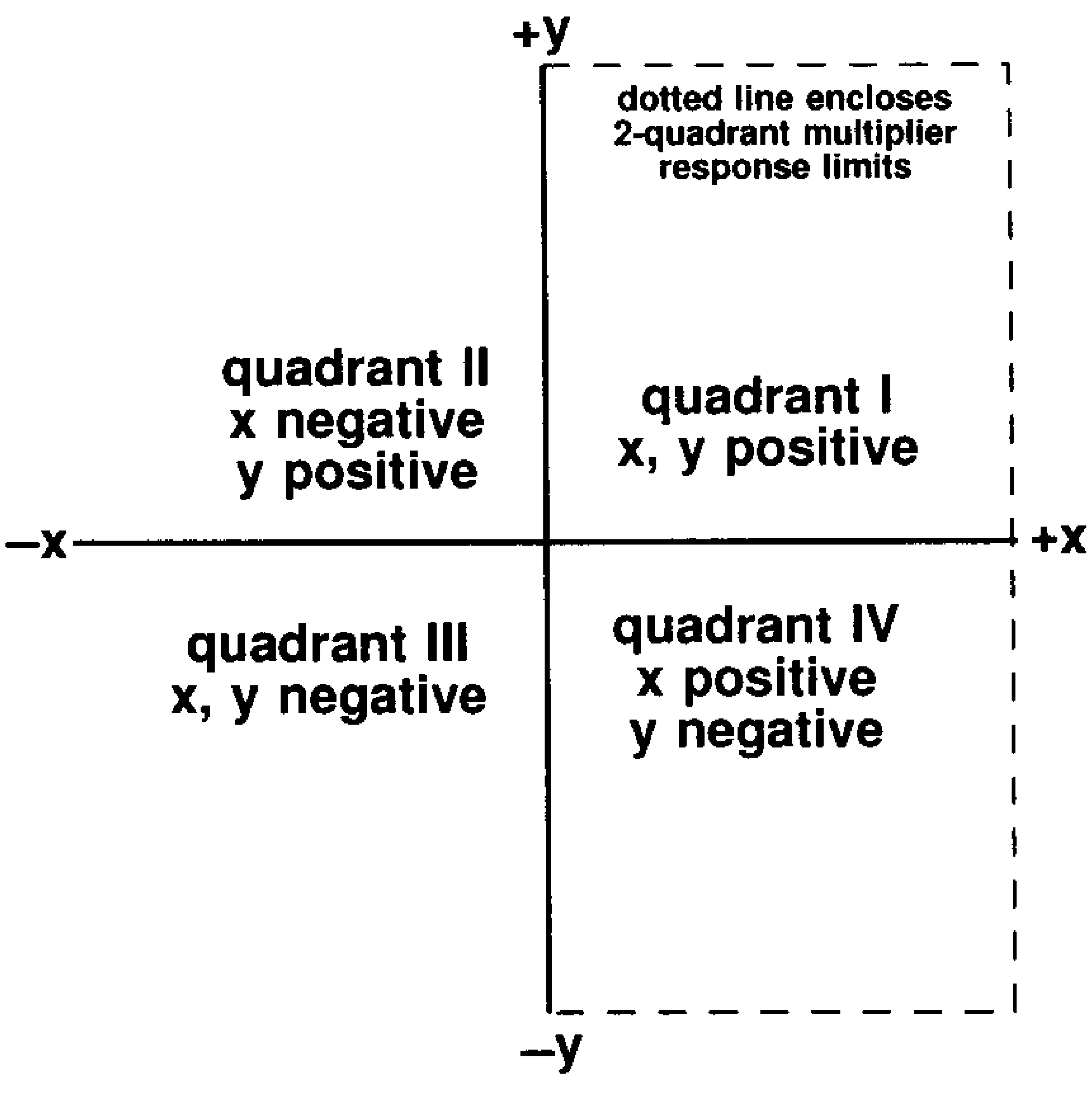
Ring modulation sounds discordant and so gets spare use. Yet means exist to soften the dissonance and diversify the effect. This issue explains ring modulation and presents plans for four Ring Modu-Matics.

What is Ring Modulation?

Ring modulation is synonymous with *balanced modulation, doubly balanced mixing*, and *four-quadrant multiplication*; and also with *mixing*, in the Ham-radio sense of the word. All these terms connote the combination of two tones so as to yield their sum and difference. For example, 1237 Hz mixed with 554 Hz gives (1237 + 554) = 1791 Hz, and (1237 – 554) = 683 Hz. *Balanced* implies that neither input tone appears at the output. But for a tone multiplied against itself, and occasional harmonic coincidence, ring modulated tones bear no musical relation to each other or to their parent tones. Sum and difference terms created by an audio amplifier are called *intermodulation distortion*, distinct from harmonic distortion, whose terms contain even or odd multiples of the input. Ring modulated tones sound discordant, but also novel and unexpected, often perverting the relation between input pitch and output pitch.

Balanced mixing has countless uses outside music. The process is universal in radio receivers. A typical FM portable contains an oscillator tunable from about 98 Mhz to 119 MHz. The receiver mixes the antenna feed with the internally generated signal: 98.8 MHz mixed with a station frequency of 88.1 MHz gives (98.8 – 88.1) = 10.7 MHz, and (98.8 + 88.1) = 186.9 MHz. Filters select 10.7 MHz, from which audio may be recovered directly, or which may undergo a second downconversion.

Fig. 1. Diagram illustrates the origin of multiplier nomenclature. *Quadrant* refers to one of four possible combinations of input voltage polarities. A 4QM returns the correct output from any pair of inputs; e.g., –3V times –2V outputs +6V. A 2QM responds to positive and negative deviations of y, but only to x-deviations at and above 0. A 1QM is limited to positive values for both inputs.



In this issue:

Ring modulation formed the basis for sound effects well back into the tube era and heard frequently in films an TV series. *The Outer Limits* (1963–5) made particularly free use of the process. Balanced mixing can also be heard in certain voice scramblers, and in single- and double-sideband radio transmissions.

Achieving Ring Modulation

Many and varied circuits yield the sum and difference of two inputs. They include:

- RF mixer ICs (LM1496, NE602, etc.)
- analog multiplier ICs (LM1495, AD534, etc.)
- multiplier-configured OTAs
- synchronous detectors
- diode-transformer mixers

RF mixer ICs are exemplified by the LM1496, long a staple of Ham-radio gear. Typical applications use balanced transformer inputs & outputs. Configured for audio, the chip tolerates a relatively low signal level before harmonic distortion rises. Unlike other 4QMs, the 1496 delivers an output whose amplitude can exceed the input by a factor of four (Fig. 3).

Analog multiplier ICs include the antiquated LM1495, which demands a host of support parts, including several trims. Though instructive to study, the 1495 is less practical than chips laser-trimmed during manufacture, such as the AD534, which needs no trimming in many applications (Fig. 2–3). This chip and its successors offer low distortion, large headroom, and lower noise than earlier multipliers. The 534 is also capable of excellent carrier feedthrough trim, but prefers to run off ±15V. This chip is an expensive option, currently about $47 for the Burr-Brown version. The MPY634, currently ~$17 through Digi-Key, has the same pinout and key specs as the 534.

Operational transconductance amps (OTAs; e.g., LM3080, LM13600) are easily configured as balanced multipliers that make one of the most practical stompbox choices, being cheap, widely available, and adaptable to nine volts (Fig. 2–4). They're capable of >40 dB of carrier feedthrough suppression, while tolerating a large input signal.

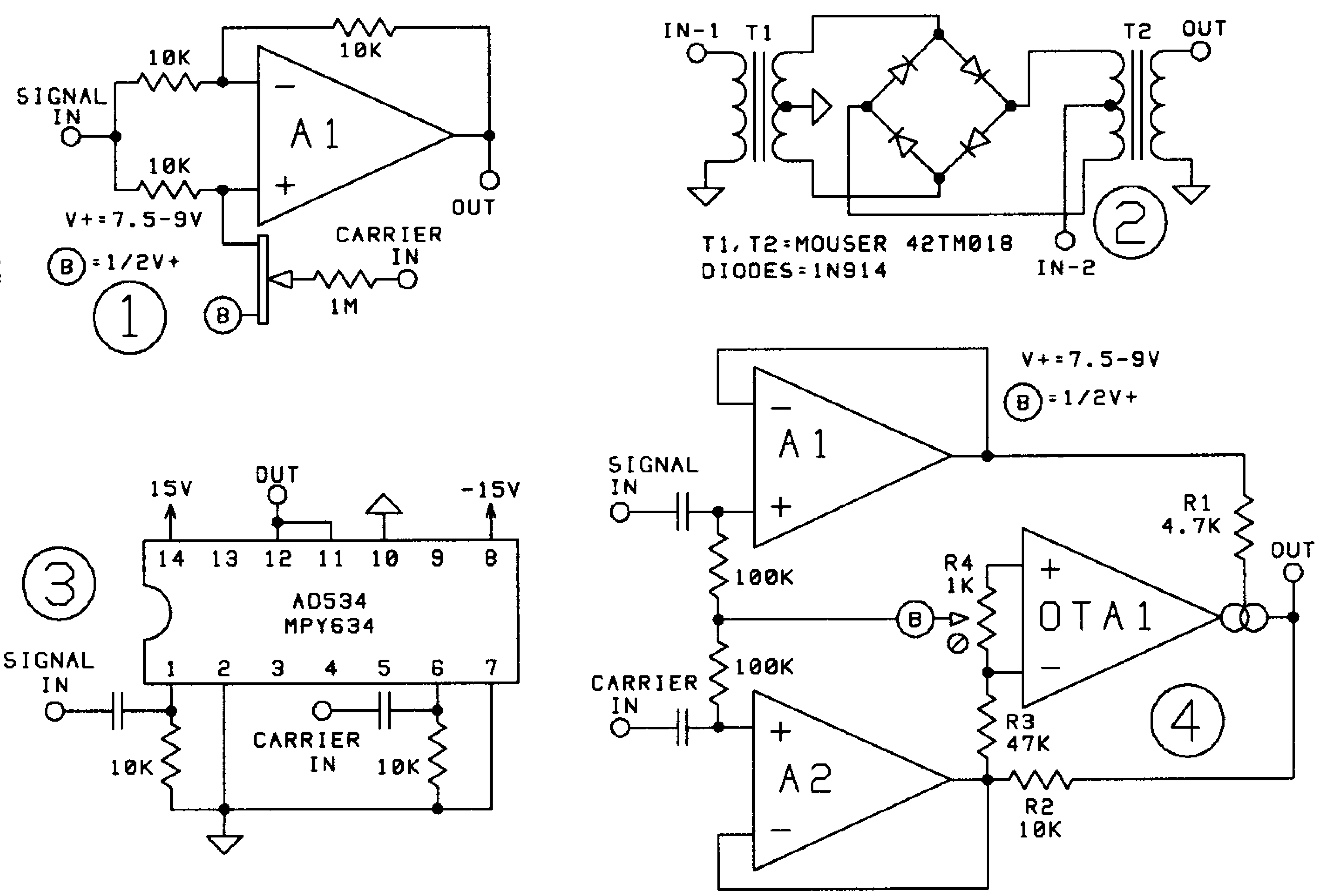


Fig. 2. Different approaches to balanced multiplication. 1—Crude synchronous detector generates sum and difference terms if Q1 is toggled by squarewave carrier. Output sounds harsh due to high quotient of squarewave harmonics. 2—Diode-transformer mixer of a type found in RF circuits. When auditioned, the variation shown gave more harmonic distortion than sum/difference output. 3—About the simplest configuration of an AD534 or MPY634 used as balanced modulator for audio signals. The y-inputs (pins 6 & 7) are preferred for the carrier, as their feed-through, at audio frequencies, is much less than x-inputs' (pins 1 & 2). As shown, transfer function is: [(x × y) ÷ 10]. 4—OTA (3080, or half a 13600) configured as balanced multiplier and optimized for 9V operation. 1K pot nulls carrier feedthrough; null shifts if supply voltage changes.

A *synchronous detector* (Fig. 2–1) is a circuit that alternately multiplies a signal by 1 and –1. If a constant tone toggles the multiplication sign and the axe feed acts as the signal, the output contains sum and difference terms, rich in squarewave harmonics because the carrier is a squarewave. The circuit is easily built from an op amp and a FET (or a CMOS switch), but the sound is so harsh that some players regard it less a musical effect than a sound effect.

Other approaches have theoretical worth that often fails to pan out musically. The diode-transformer mixer shown in Fig. 2–2 gave a sound rich in harmonic distortion, with relatively few intermodulation products.

More about Four-Quadrant Multiplication

The two multiplier inputs are designated x and y. Multipliers are categorized according to the polarities of x and y for which they generate an output of correct polarity. A circuit that returns correct polarity only for positive values of x and y is called a one-quadrant multiplier (1QM; *quadrant* denotes a combination of input polarities, illustrated in Fig. 1). A circuit that responds to positive and negative values of y, but only positive values of x, is called a *two-quadrant multiplier* (2QM). Common voltage controlled amplifiers are 2QMs. A circuit responsive to all polarity combinations of x and y is called a *four-quadrant multiplier* (4QM), which generates the sum/difference terms that characterize ring modulation.

Because the product would quickly exceed the available headroom, practical multipliers divide the output by a constant, usually 10. Thus, six volts multiplied against minus seven volts generates an output of [(6 × –7) ÷ 10] = –4.2V.

Analog multipliers perform many other functions, such as squaring, cubing, or raising values to higher powers; taking square, cube, or other roots; root-mean-square detection, division, and the derivation of trigonometric functions.

Designing Ring Modulator Stompboxes

A musically practical ring modulator consists of:

- modulator
- carrier generator
- carrier suppression means

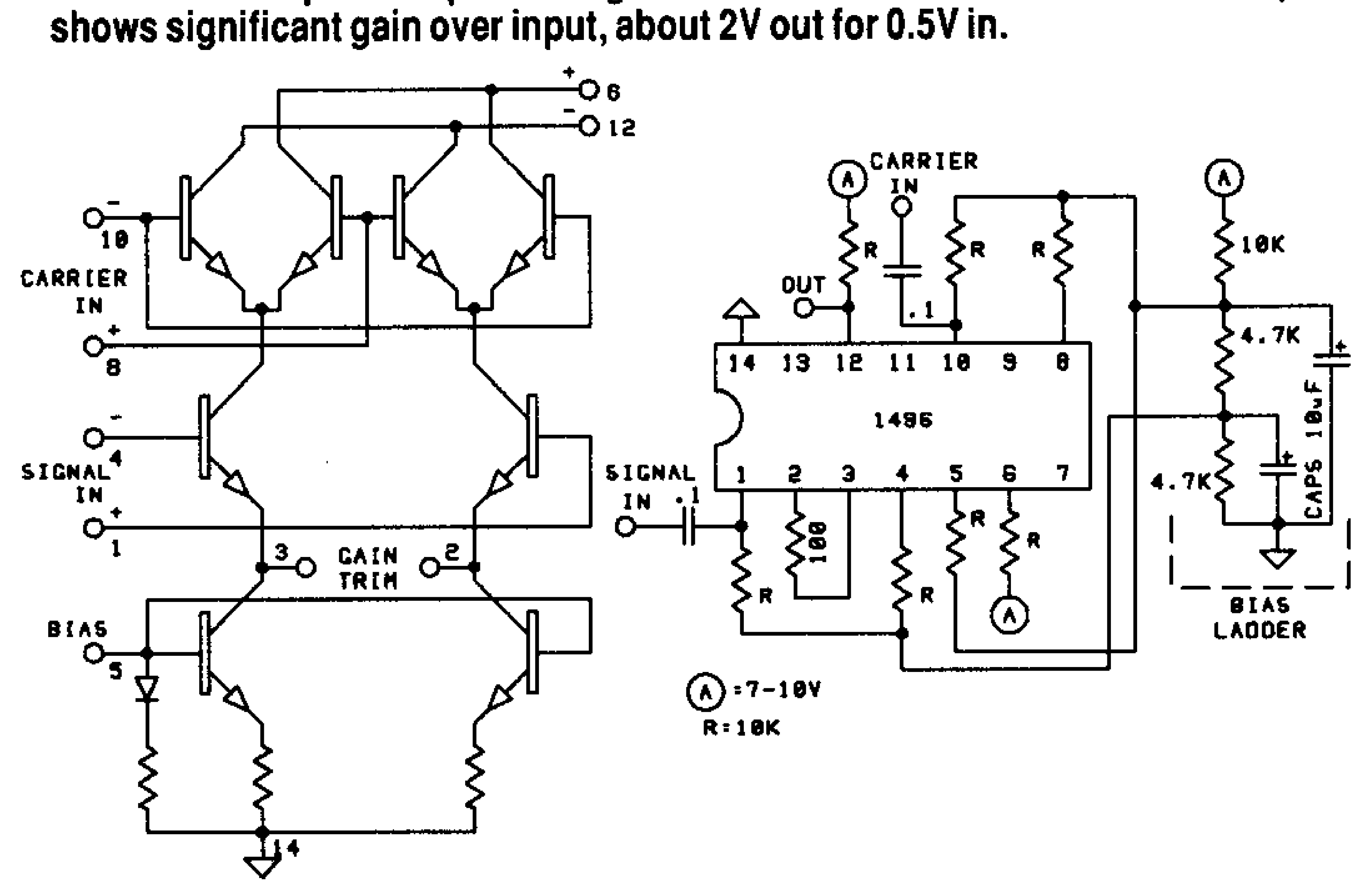
While any of the circuits listed above can serve as modulator, some sound more musical than others. The AD534 and similar chips rank first, but their preference for ±15V takes them out of contention in the average stompbox. OTAs' low cost, wide availability, simple circuitry, and low-voltage operation make them clear stompbox winners. The LM1496 is also a good choice if its harmonic distortion is acceptable. A synchronous detector is simple, runs at stompbox voltage, and is easily configured from common parts, but places behind other contenders out of harsh sound.

Just about any oscillator can serve as carrier generator. But here, too, some approaches sound better than others. Pure-sine oscillators deliver the most musical sound, but tend to be finicky, especially when running at nine volts. Many are not practical to place under voltage control. Derived-sine oscillators are easily tuned and adapted to voltage control, but generate incidental squarewaves and triangle waves whose harmonics are difficult to exclude from the signal path.

Whatever the choice of modulator and carrier generator, the box lives or dies by carrier suppression while the instrument is silent. This poses the chief tactical problem in designing musical ring modulators. Non-sine carriers are harder to suppress due to their enormous harmonic energy. Most modulators allow some form of carrier feedthrough trim, but this is rarely good enough to silence the box at rest. A quiet box demands additional carrier suppression, such as:

- gated oscillator
- gated modulator (input or output)

Fig. 3. Internal schematic of LM1496 shows configuration typical of balanced modulators. This circuit is suitable for experimenting with the 1496 as a ring modulator. Chip is unique among 4QMs discussed here in that the output shows significant gain over input, about 2V out for 0.5V in.



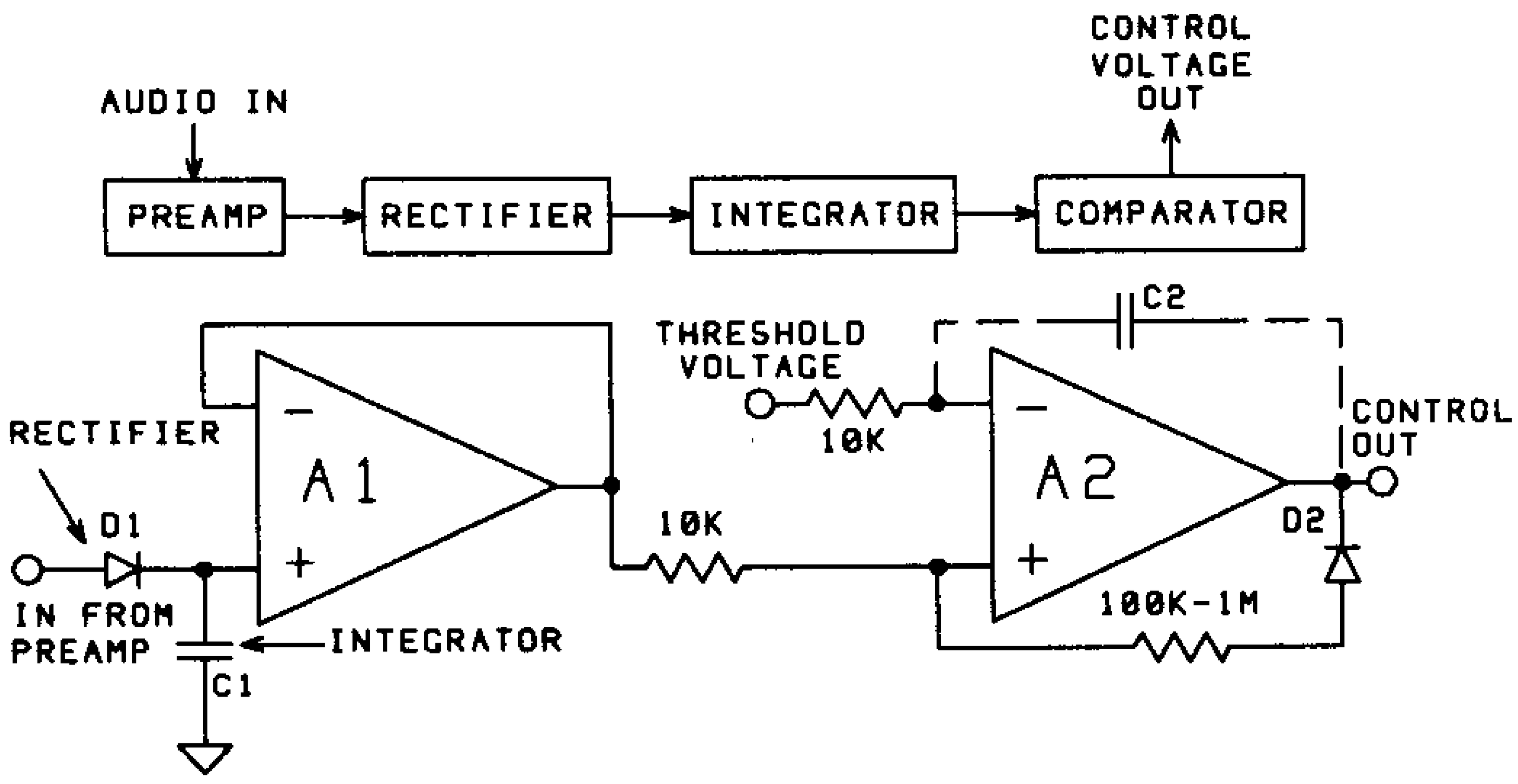


Fig. 4. Functions of gate block diagram are reduced to minimum in actual circuit: D1 is the rectifier, C1 is the integrator; raw voltage is buffered by A1; feeds comparator A2; D2 and resistor add unidirectional hysteresis if desired; optional C2 slows comparator transitions to prevent clicks in signal path (not needed in all applications).

- quasi-companding
- true companding
- treble emphasis/de-emphasis

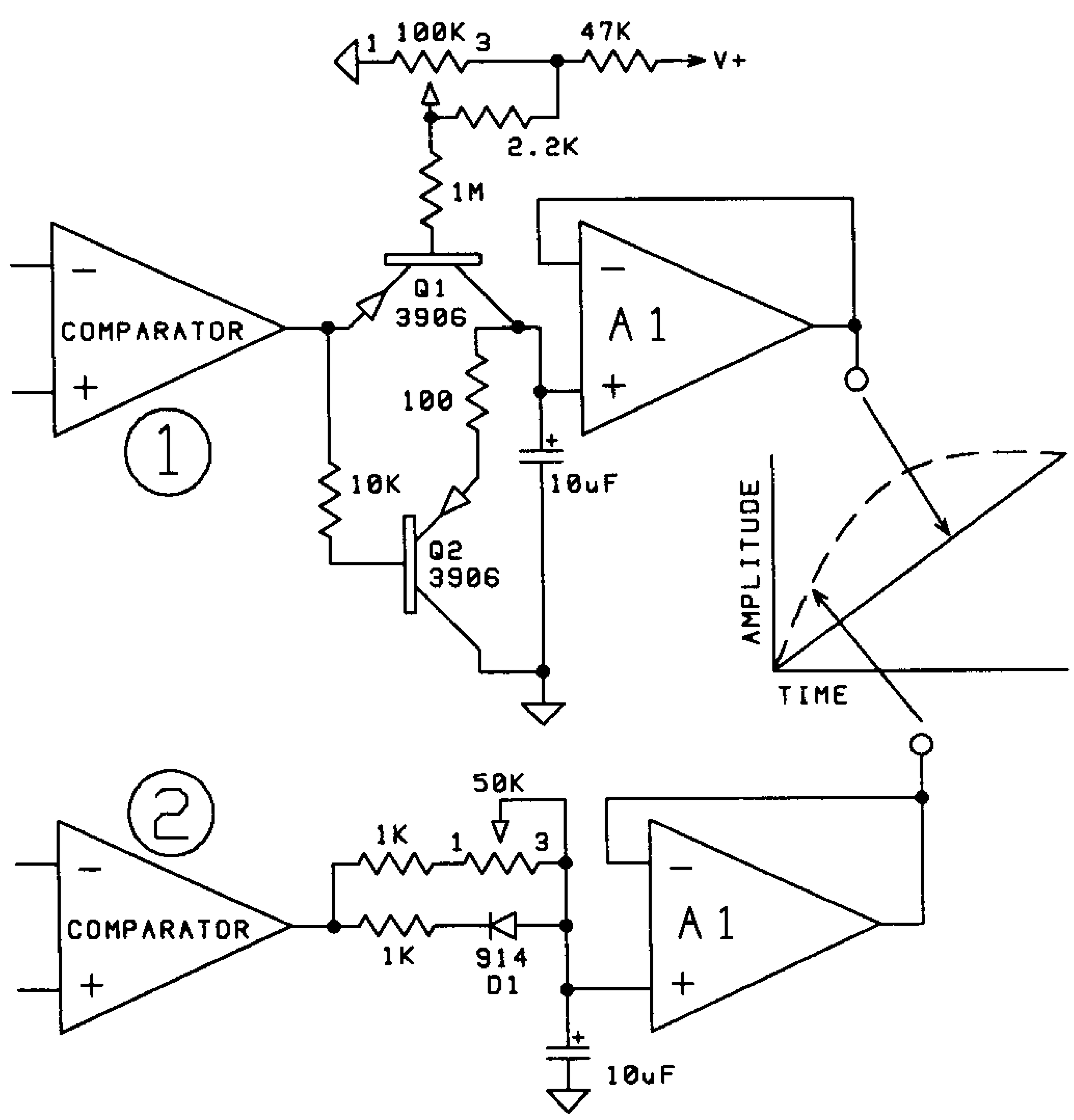
Derived-sine oscillators lend themselves to gating of oscillation itself. Gating a pure-sine oscillator may result in an audible lag in restarting oscillation, so the preferred approach gates the output of the oscillator without halting oscillation.

Variations on a Theme

Single-tone ringmod makes a sound that gets old quick. Means to diversify the effect include:

- rhythmically varying carrier frequency, intensity, or both
- dynamically varying carrier frequency, intensity, or both
- dynamically varying the wet/dry mix
- rhythmically varying the wet/dry mix
- unbalancing the modulator to let input terms bleed through

Fig. 5. 1—Ramp generator used in Attack-O-Matic. When comparator output flips high, it applies a constant voltage to emitter of Q1, which allows current to pass at a constant rate determined by the setting of the 100K pot. As a result, the 10µF cap charges at a constant rate, creating a linear rise in voltage. This is a true ramp. 2—Similar circuit used in Ring Modu-Matic II. When comparator output flips high, a constant voltage is applied to 50K pot in series with 1K. The 10µF cap charges nonlinearly; the curve is typical of a cap charging through a resistor. This is not truly a ramp, but may be called such in electronic slang.



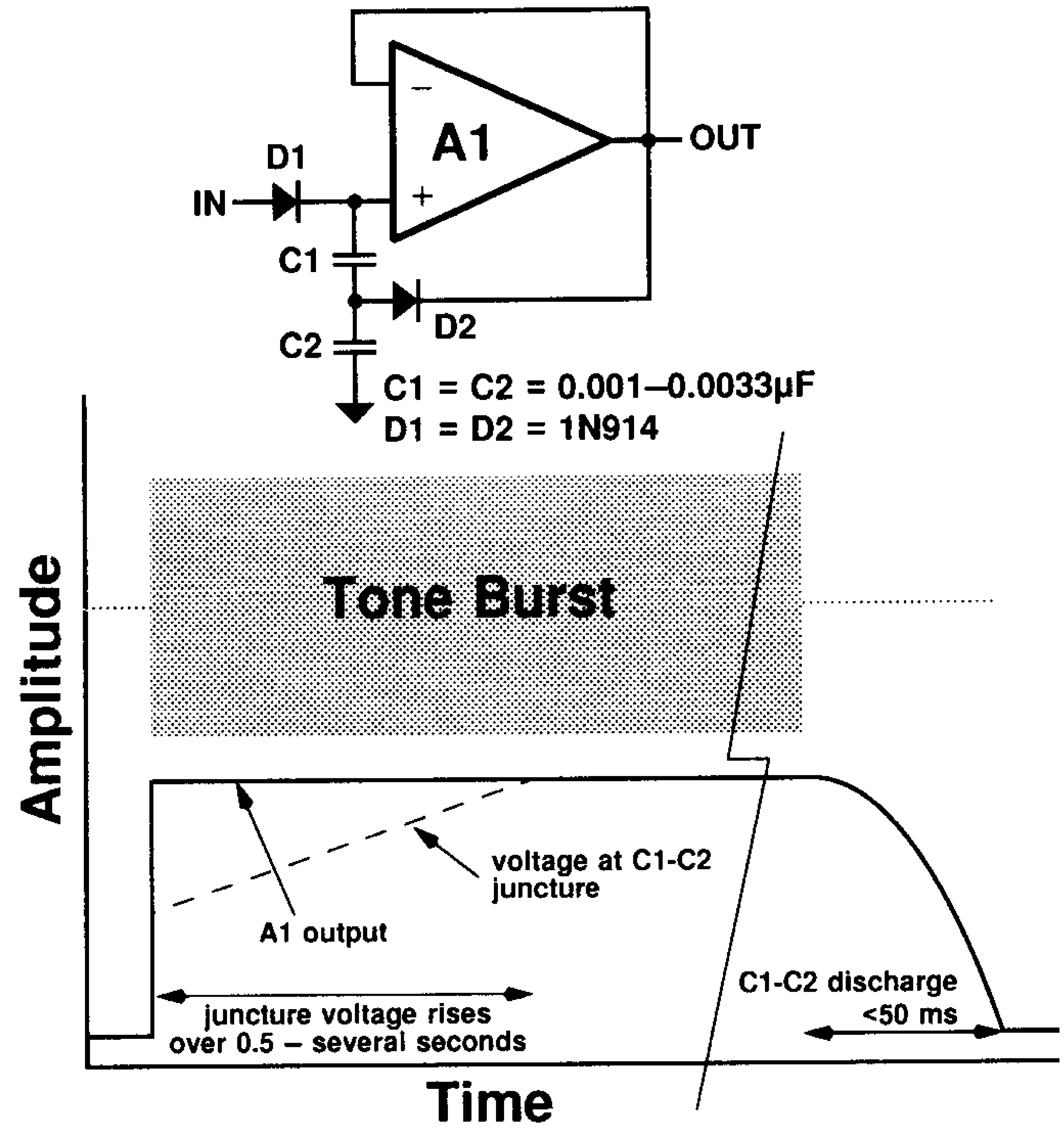


Fig. 6. Auto-variable decay circuit. Upon receipt of tone burst input, voltage at D1-C1 reaches full amplitude almost instantly; divider action causes voltage at C1-C2 juncture to settle initially at half of maximum. Juncture voltage then rises, taking time to reach maximum that depends on amplitude of input and values of C1 & C2. If tone burst ceases before juncture voltage has reached maximum, decay exhibits two phases. First phase occurs slowly, by leakage, down to the C1-C2 juncture voltage. Second decay phase occurs below that voltage, when decay path D2 opens up; decay then becomes very fast, <50 ms. If juncture voltage has risen to equal that at D1-C1, then D2 acts as the main decay path; entire decay takes less than 50 ms. Circuit gives low ripple relative to decay time, and makes it convenient to derive other control voltages, e.g., the voltage at the C1-C2 juncture, buffered by an FET-input op amp; and the difference between the juncture voltage and the output of A1.

to the output

- using the raw ringmod output as the control voltage of a VCA

Ring Modu-Matics II and III incorporate some of these options.

Beginner's View

Q. In Ring Modu-Matic, why run the modulator off a regulated 5V?

A. To prevent feedthrough trim from shifting as the battery ages. The same principle applies to the 12V supply in RMM3, where sine amplitude trim would otherwise shift.

Q. RMM3 runs the AD534 off 12V, but I thought you said the chip liked ±15V.

A. It does. If you have a breadboard with a variable dual power supply, audition RMM4 at ±15, then at progressively lower voltages. What seems to be harmonic distortion emerges at lower supply voltages.

Q. What's the difference between pure-sine oscillators and derived-sine oscillators?

A. Pure-sine oscillators generate only a sinewave, without generating squarewaves or triangle waves. They're quieter than other types and generally exhibit lower distortion. Most varieties use delicately balanced feedback paths that cannot tolerate rapid change without shifting briefly into chaotic modes.

Derived-sine oscillators generate triangle waves and, often, incidental squarewaves. They realize the sine by passing the triangle through a nonlinear transfer network. Derived-sine oscillators respond smoothly to rapid changes in rate. This makes them the best choice for voltage-controlled oscillation.

Project. No. G211
Ring Modu-Matic

Simple, versatile, well behaved ring modulator.

Circuit Function

Axe feed couples through C5-R5 to noninverting preamp IC3-a, whose gain is fixed at 11; and to voltage follower IC4-b. Preamp output couples through R11 to the signal input of IC5, an LM3080 transconductance amp configured as a balanced modulator.

IC1-c, -d, and the associated components form a triangle oscillator whose rate varies under control of R25, over two ranges selected by S2. Triangle output passes through lowpass filter IC1-a, whose corner frequency is controlled by dual pot R26. The filtered carrier signal couples through C11 to buffer IC4-a, thence through R13-R14 to the carrier input of IC5, nulled by trimpot R24.

Modulator output is taken at IC5 pin-6, coupling through C8 to one end of R27, whose other end ties to the output of voltage follower IC4-b. The output signal is taken off the wiper of R27, coupling through C9 to the output path. R27 varies the mix from wet to dry.

The power supply for IC3, IC4, and IC5 is locally regulated at 5V by IC2.

Preamp output also couples through D3 to peak detector IC3-d, whose output feeds comparator IC3-c through R16. When an audio input signal is present, the output of IC3-c flips high, turning Q1 off, enabling the triangle oscillator. When the audio input is muted, IC3-c's output flips low, turning Q1 on, disabling the triangle oscillator. By this means the oscillator is gated and the effect is silent at rest.

Use

Pots and switches have these functions:

R24	IC5 carrier feedthrough trim
R25	oscillator frequency
R26	lowpass filter corner frequency
R27	dry/wet output mix
S1	effect/bypass
S2	oscillator range high/low

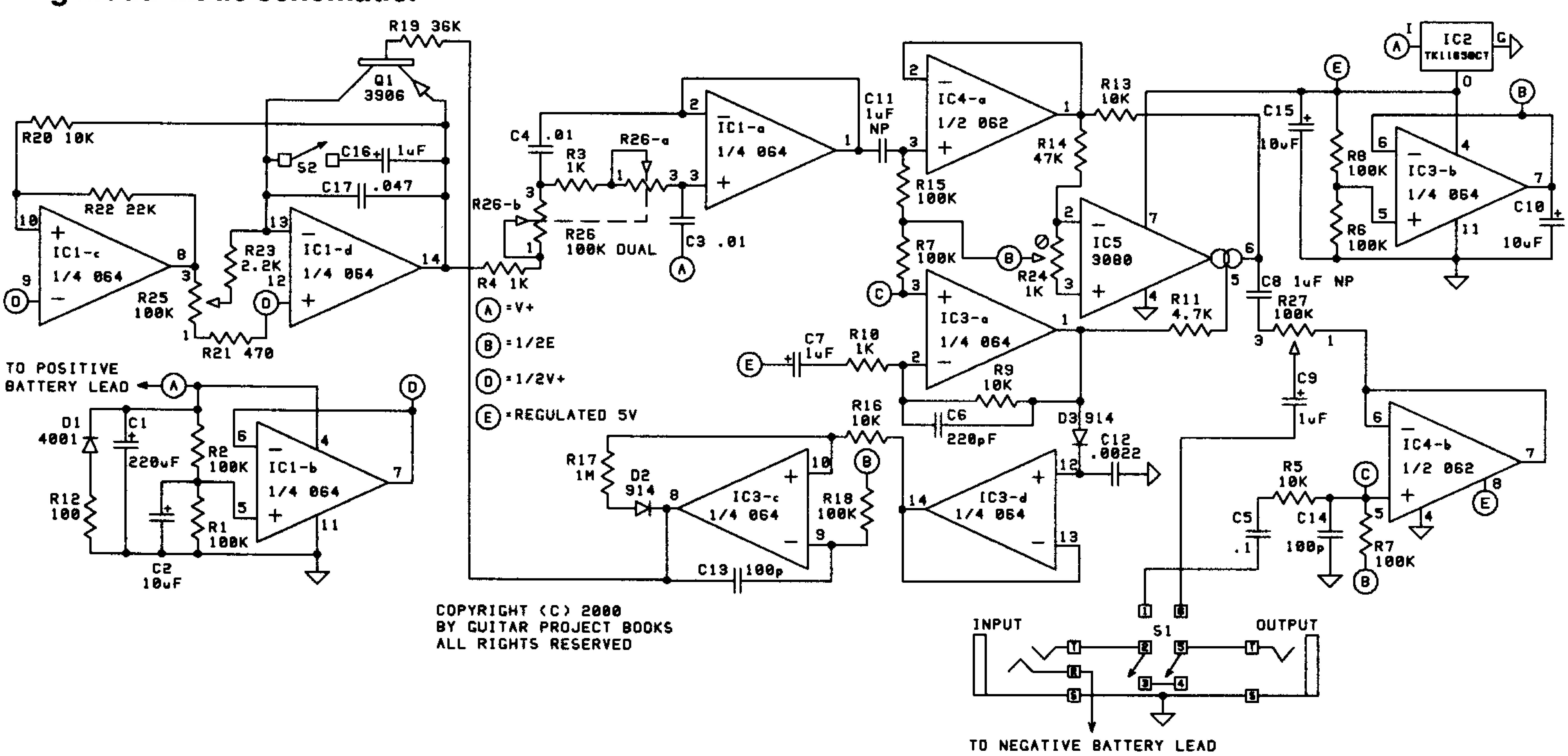
Q1 is omitted from the initial assembly to inactivate the gate to allow feedthrough trim by this procedure: Toggle S2 to the high range, center R25 and R26, turn R27 fully CW. Connect unit to axe whose volume pot is turned all the way down; connect unit to amp. Slowly turn amp volume up until a constant tone is heard. Trim R24 until this tone reaches a minimum. Then disconnect the unit from axe and amp, and install Q1.

Reconnect unit to axe and amp, establish desired listening level, take the several controls through their ranges and note the effect on sound.

Notes

RMM is capable of a wide range of sounds, from musical to harsh to special effect. At extremely low modulation frequencies a tremolo/vibrato effect will be heard. Use of carrier frequencies in the range of 3–5 KHz results in a form of treble boost that eludes simple frequency manipulation.

Ring Modu-Matic schematic.



Q. You've gated all four Ring Modu-Matics. The control circuit is similar, but not identical, among the four, and also appears to be one you didn't discuss in the *Cookbook*, or in *Let's Go Gating* [*Vol. 6, No. 2—Ed.*].

A. In fact, the ringmod gates (Fig. 4) follow the block diagram presented in Vol. 6, No. 2. But there was nothing to gain by discussing every possible embodiment of a given block. Here the nature of the switching task dictated a simple circuit that generates a high/low control voltage. The surety of muting took precedence over the gate's ability to remain open for prolonged periods while a note decays.

Q. In four gates you've used three different threshold-setting mechanisms for the comparator. Ring Modu-Matic and RMM2 set the threshold at 1/2V+. RMM3 uses a reference voltage one diode drop below 1/2V+. RMM4 uses a divider that varies slightly above and slightly below ground. Why not use the same circuit in all?

A. No particular reason. Though they're all crude, the gates show a slight rise in sophistication from RMM to RMM4.

Q. The level detector in RMM2/3/4 uses a circuit I haven't seen before.

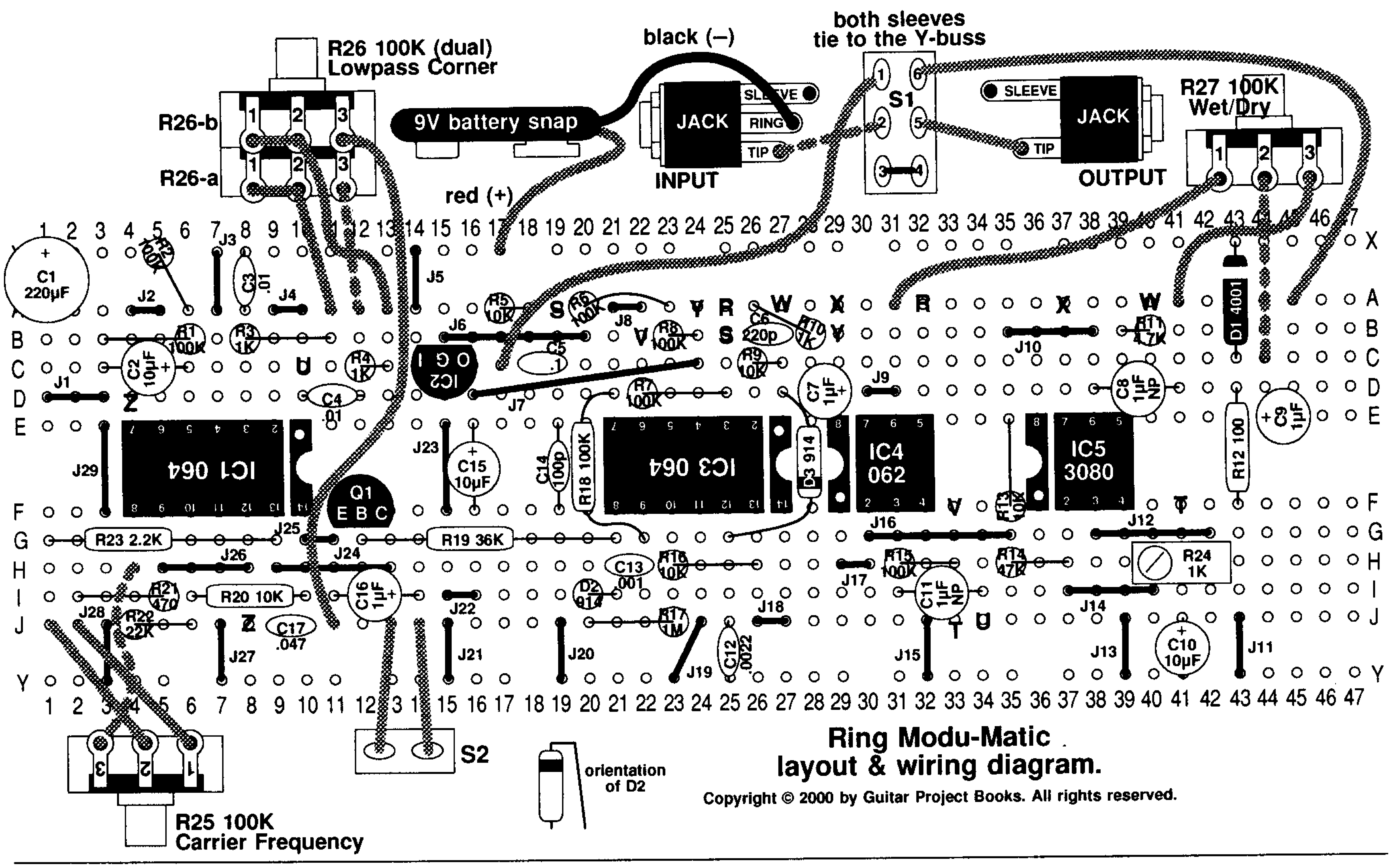
A. You're referring to two caps and a diode (Fig. 6).

Q. Yes. What's the purpose of this circuit, and how does it work?

A. It's an auto-variable decay circuit whose function is explained in Fig. 6. This circuit causes the gate to close with no audible delay when you mute the strings of your axe.

Q. How do you know where on an oscillator to apply the electronic control?

(continued on page 12)



Ring Modu-Matic layout & wiring diagram.

Parts List/Soldering Checklist

Circuit Board Radio Shack p/n 276-170; Hosfelt p/n 42-183; or DC Electronics p/n J4-404

IC Sockets

- [ ] 14-pin for IC1; pin-1 to E10
- [ ] 14-pin for IC3; pin-1 to E27
- [ ] 8-pin for IC4; pin-1 to F29
- [ ] 8-pin for IC5; pin-1 to F36

Resistors

[ ]	R1	100K	(brn-blk-yel)	B3-B6
[ ]	R2	100K	(brn-blk-yel)	X5-A6
[ ]	R3	1K	(brn-blk-red)	B8-B11
[ ]	R4	1K	(brn-blk-red)	C12-C13
[ ]	R5	10K	(brn-blk-org)	A17-A18
[ ]	R6	100K	(brn-blk-yel)	A20-A23
[ ]	R7	100K	(brn-blk-yel)	D22-D25
[ ]	R8	100K	(brn-blk-yel)	B23-B24
[ ]	R9	10K	(brn-blk-org)	C26-C27
[ ]	R10	1K	(brn-blk-red)	A26-B28
[ ]	R11	4.7K	(yel-vio-red)	B39-B40
[ ]	R12	100	(brn-blk-brn)	D43-F43
[ ]	R13	10K	(brn-blk-org)	E35-F35
[ ]	R14	47K	(yel-vio-org)	H35-H37
[ ]	R15	100K	(brn-blk-yel)	H31-H33
[ ]	R16	10K	(brn-blk-org)	H23-H26
[ ]	R17	1M	(brn-blk-grn)	J20-J23
[ ]	R18	100K	(brn-blk-yel)	D21-G22
[ ]	R19	36K	(org-blu-org)	G12-G21
[ ]	R20	10K	(brn-blk-org)	I6-I10
[ ]	R21	470	(yel-vio-brn)	I2-I5
[ ]	R22	22K	(red-red-org)	J4-J6
[ ]	R23	2.2K	(red-red-red)	G1-G9

Bare Wire Jumpers

[ ]	J1	D1-D3
[ ]	J2	A4-A5
[ ]	J3	X7-A7
[ ]	J4	A9-A10
[ ]	J5	X14-A14
[ ]	J6	B15-B20
[ ]	J7	D16-C24
[ ]	J8	A21-A22
[ ]	J9	D30-D31
[ ]	J10	B35-B38
[ ]	J11	J43-Y43
[ ]	J12	G38-G42
[ ]	J13	J39-Y39
[ ]	J14	I37-I40
[ ]	J15	J32-Y32
[ ]	J16	G30-G35
[ ]	J17	H29-H30
[ ]	J18	J26-J27
[ ]	J19	J24-Y23
[ ]	J20	J19-Y19
[ ]	J21	J15-Y15
[ ]	J22	I15-I16
[ ]	J23	E15-F15
[ ]	J24	H9-H13
[ ]	J25	G10-G11
[ ]	J26	H5-H8
[ ]	J27	J7-Y7
[ ]	J28	J3-Y3
[ ]	J29	E3-F3

Capacitors

[ ]	C1	220µF		X1-A1 (+ lead to X1)
[ ]	C2	10µF		C3-C6 (+ lead to C6)
[ ]	C3	0.01		X8-A8
[ ]	C4	0.01		D10-D12
[ ]	C5	0.1		C18-C19
[ ]	C6	220pF		B26-B27
[ ]	C7	1µF		D28-D29 (+ lead to D29)
[ ]	C8	1µF	nonpolar	D38-D41
[ ]	C9	1µF		E44-E45 (+ lead to E44)
[ ]	C10	10µF		J41-Y41 (+ lead to J41)
[ ]	C11	1µF	nonpolar	I31-I34
[ ]	C12	0.0022		J25-Y25
[ ]	C13	0.001		H21-H22
[ ]	C14	100pF		E19-F19
[ ]	C15	10µF		E16-F16 (+ lead to E16)
[ ]	C16	1µF		H11-H14 (+ lead to H14)
[ ]	C17	0.047		J9-J10

Flying Jumpers (<u>insulated</u> wire)

[ ]	RR	A25-A32
[ ]	SS	A19-B25
[ ]	TT	J33-F41
[ ]	UU	C10-J34
[ ]	VV	B22-F33
[ ]	WW	A27-A40
[ ]	XX	A29-A37
[ ]	YY	A24-B29
[ ]	ZZ	D4-J8

Semiconductors

- [ ] D1 1N4001 X43-C43 (banded end to X43)
- [ ] D2 1N914 I20-I21 (banded end faces I21)
- [ ] D3 1N914 D27-G25 (banded end faces G25)
- [ ] IC1 TL064 quad op amp; pin-1 to E10
- [ ] IC2 TK11650CT (Digi-Key) low-dropout 5V regulator; input (I) to C14, ground (G) to C15, output (O) to C16
- [ ] IC3 TL064 quad op amp; pin-1 to E27
- [ ] IC4 TL062 dual op amp; pin-1 to F29
- [ ] IC5 LM3080 OTA; pin-1 to F36

(note: do not install Q1 until feedthrough has been trimmed; see text)

- [ ] Q1 2N3906; emitter (E) to F11, base (B) to F12, collector (C) to F13

Trimpot

- [ ] R24 50K multiturn trimpot; leads go in H40-41-42

Potentiometers (T=terminal)

- [ ] R25 100K T1 to J2, T2 to J1, T3 to H4
- [ ] R26 100K dual
  - R26-a T1 to T2 and to A11, T3 to A12
  - R26-b T1 to T2 and to A13, T3 to J11
- [ ] R27 100K T1 to A31, T2 to C44, T3 to A41

Jacks (T=terminal)

- [ ] input jack (1/4" 3-terminal/stereo): tip to T2 of S1, ring to negative (–) battery lead, sleeve to any point on the Y-buss
- [ ] output jack (1/4" 2-terminal/mono): tip to T5 of S1, sleeve to any point on the Y-buss

Switches (T=terminal)

- [ ] S1 (DPDT stomp switch): T1 to C17; T2 to tip of input jack; T3 to T4; T5 to tip of output jack; T6 to A45
- [ ] S2 (SPST slide or toggle switch): one terminal to J13, one terminal to J14

9V Battery Leads

- [ ] black (negative, –) lead solders to ring of input jack
- [ ] red (positive, +) lead solders to X17

Project. No. G212

Ring Modu-Matic II

Raucous squarewave modulator; reversible ramp generator shifts the carrier tone.

Circuit Function

Signal path: Axe feed couples through C7-R5 to noninverting preamp IC4-a, whose gain is fixed at 11. Preamp output couples to synchronous detector Q2–IC4-d, driven by the squarewave coupled through R11. Signal couples through C9 to divider R8-R10 (which gives system about 20 dB of quasi-companding), thence to the output path

Control path: Preamp output also couples through C3-R3 to inverting amp IC4-b, whose gain varies 0–10 under control of R32. IC4-b output couples to a positive peak detector made up of IC3-a and its associated components. IC3-a output drives comparator IC3-d, whose output is normally low, but flips high in the presence of a positive voltage communicated through R20. Comparator output drives a variable attack network comprised of R21-31 and C15, buffered by voltage follower IC3-c, whose output couples through R22 to unity-gain inverter IC3-b. IC3-b and IC3-c outputs couple, respectively, to terminal-1 and -3 of S2, whose pole couples to frequency range control pot R30. Toggling S2 to T3 selects a rising voltage, toggling S2 to T1 selects a falling voltage to drive the voltage controlled squarewave oscillator, IC1-IC2. Oscillator output couples through R11 to Q2's gate, thus controlling the modulation frequency. Comparator output also couples through R23 to the base of Q1, which deactivates the VCO when the comparator output is low, quieting the effect.

Use

Pots & switches have these functions:

R30	frequency range
R31	ramp time, 50 ms – 1 sec
R32	trigger sensitivity
S1	effect/bypass
S2	ramp select negative/positive

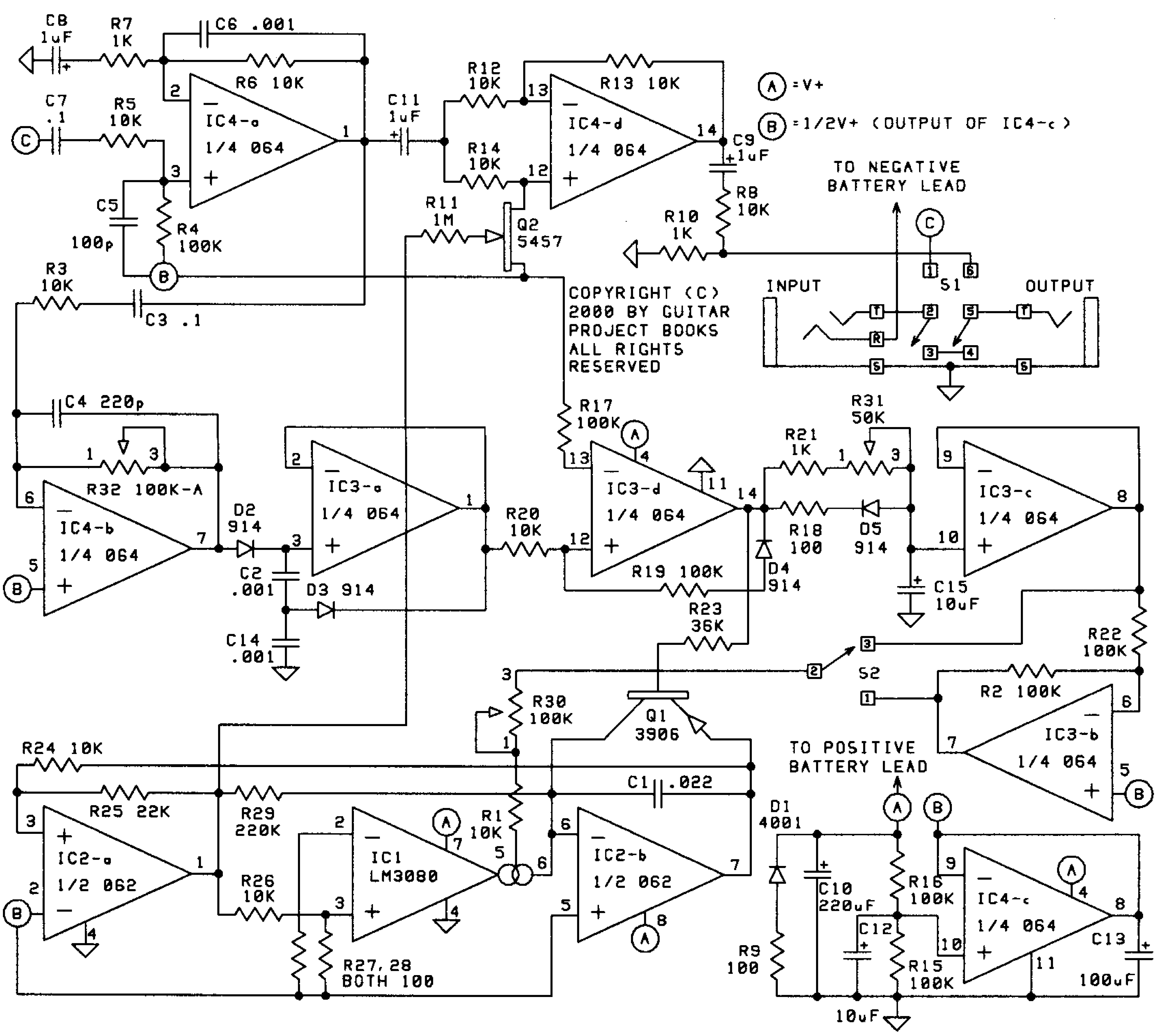
Initial settings: R30 fully CW, R31 and R32 straight up, S1 effect in, S2 either position. Connect unit to axe and amp, establish desired listening level. In this state a dramatic and severe frequency shift should be heard each time a note or chord is struck. If necessary, adjust trigger sensitivity control R32.

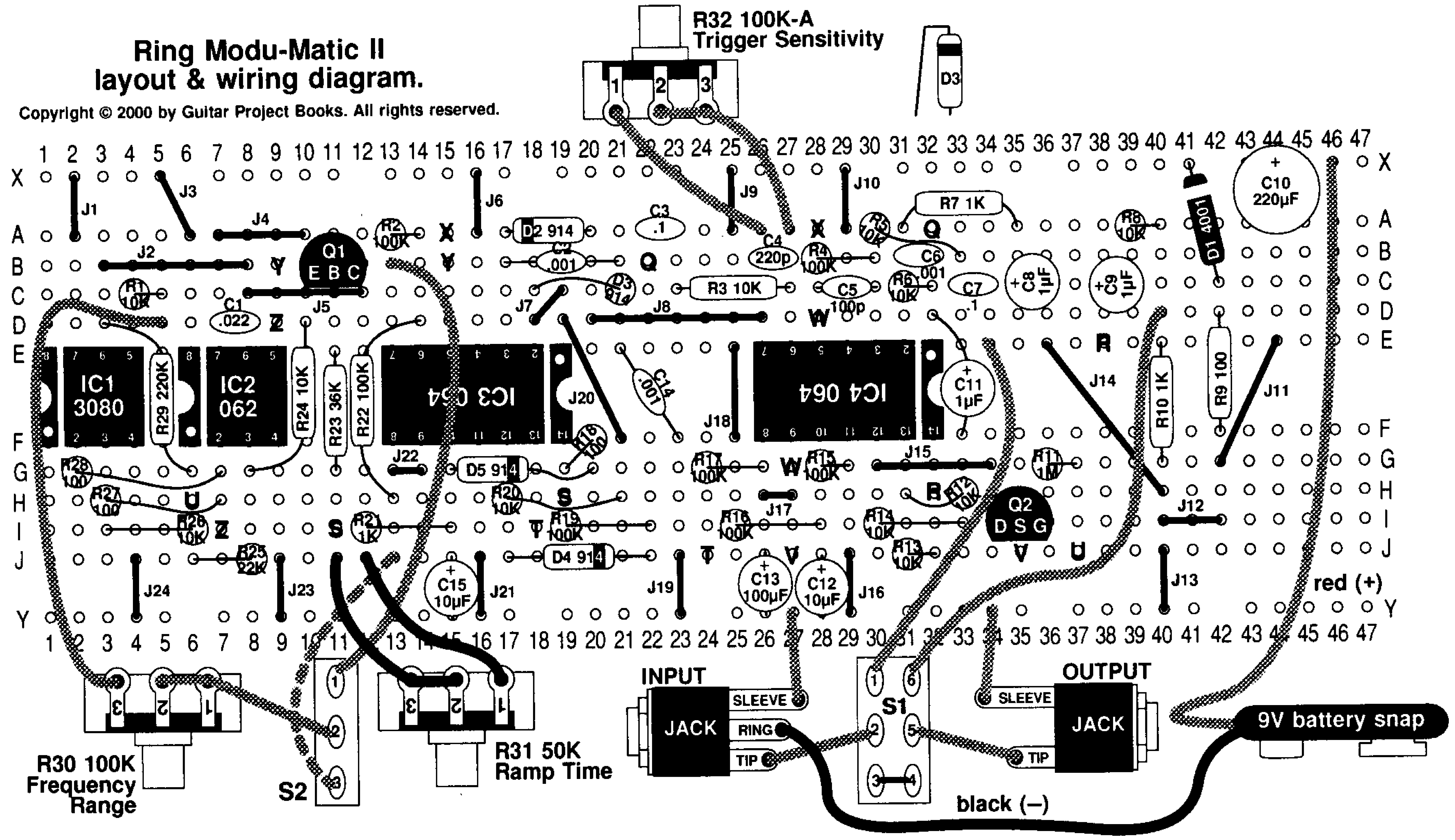
With a suitable trigger threshold established, take ramp time and frequency range controls through their ranges and note the effect on sound; reverse the ramp direction setting of S2 and repeat the checkout sequence.

Notes

The least musical of the Ring Modu-Matics, RMM2 is yet the most dramatic. Its radical sound is more special effect than musical effect. The box generates a great variety of sounds, ranging from eighties video game to sci-fi cliché. The effect responds greatly to changes in axe tone control, and EQ in or before the amp. Hot pickups will need reduced gain to avoid clipping in the preamp (which may not be audible due to the nature of the effect).

Ring Modu-Matic II schematic.





Ring Modu-Matic II layout & wiring diagram.

Parts List/Soldering Checklist

Circuit Board Radio Shack p/n 276-170; Hosfelt p/n 42-183; or DC Electronics p/n J4-404

IC Sockets

- [ ] 8-pin for IC1; pin-1 to F1
- [ ] 8-pin for IC2; pin-1 to F6
- [ ] 14-pin for IC3; pin-1 to E19
- [ ] 14-pin for IC4; pin-1 to E32

Resistors

[ ]	R1	10K	(brn-blk-org)	C4-C5
[ ]	R2	100K	(brn-blk-yel)	A13-A14
[ ]	R3	10K	(brn-blk-org)	C23-C27
[ ]	R4	100K	(brn-blk-yel)	B28-B30
[ ]	R5	10K	(brn-blk-org)	A30-B33
[ ]	R6	10K	(brn-blk-org)	C31-C32
[ ]	R7	1K	(brn-blk-red)	A31-A35
[ ]	R8	10K	(brn-blk-org)	A39-A40
[ ]	R9	100	(brn-blk-brn)	D42-F42
[ ]	R10	1K	(brn-blk-red)	E40-G40
[ ]	R11	1M	(brn-blk-grn)	G36-G37
[ ]	R12	10K	(brn-blk-org)	H31-H33
[ ]	R13	10K	(brn-blk-org)	J31-J32
[ ]	R14	10K	(brn-blk-org)	I30-I33
[ ]	R15	100K	(brn-blk-yel)	G28-G29
[ ]	R16	100K	(brn-blk-yel)	I25-I28
[ ]	R17	100K	(brn-blk-yel)	G24-G26
[ ]	R18	100	(brn-blk-brn)	G19-F20
[ ]	R19	100K	(brn-blk-yel)	I19-I22
[ ]	R20	10K	(brn-blk-org)	H17-H21
[ ]	R21	1K	(brn-blk-red)	I12-I15
[ ]	R22	100K	(brn-blk-yel)	D14-H13
[ ]	R23	36K	(org-blu-org)	E11-G11
[ ]	R24	10K	(brn-blk-org)	D10-G8
[ ]	R25	22K	(red-red-org)	J6-J8
[ ]	R26	10K	(brn-blk-org)	I3-I6
[ ]	R27	100	(brn-blk-brn)	H3-H7
[ ]	R28	100	(brn-blk-brn)	G2-G7
[ ]	R29	220K	(red-red-yel)	D3-G6

Bare Wire Jumpers

[ ]	J1	X2-A2
[ ]	J2	B3-B8
[ ]	J3	X5-A6
[ ]	J4	A7-A10
[ ]	J5	C8-C12
[ ]	J6	X16-A16
[ ]	J7	D18-C19
[ ]	J8	D20-D26
[ ]	J9	X25-A25
[ ]	J10	X29-A29
[ ]	J11	E44-G42
[ ]	J12	I40-I42
[ ]	J13	J40-Y40
[ ]	J14	E36-H40
[ ]	J15	G30-G34
[ ]	J16	J29-Y29
[ ]	J17	H26-H27
[ ]	J18	E25-F25
[ ]	J19	J23-Y23
[ ]	J20	D19-F21
[ ]	J21	J16-Y16
[ ]	J22	G13-G14
[ ]	J23	J9-Y9
[ ]	J24	J4-Y4

Capacitors

[ ]	C1	0.022	D7-D8
[ ]	C2	0.001	B17-B21
[ ]	C3	0.1	A22-A23
[ ]	C4	220pF	B26-B27
[ ]	C5	100pF	C28-C30
[ ]	C6	0.001	B31-B32
[ ]	C7	0.1	C33-C34
[ ]	C8	1µF	C35-C36 (+ lead to C35)
[ ]	C9	1µF	C38-C39 (+ lead to C38)
[ ]	C10	220µF	X44-A44 (+ lead to X44)
[ ]	C11	1µF	D32-F33 (+ lead to D32)
[ ]	C12	10µF	J28-Y28 (+ lead to J28)
[ ]	C13	100µF	J26-Y26 (+ lead to J26)
[ ]	C14	0.001	E21-F23
[ ]	C15	10µF	J15-Y15 (+ lead to J15)

Flying Jumpers (<u>insulated</u> wire)

[ ]	QQ	B22-A32
[ ]	RR	H32-E38
[ ]	SS	I11-H19
[ ]	TT	I18-J24
[ ]	UU	H6-J37
[ ]	VV	J27-J35
[ ]	WW	D28-G27
[ ]	XX	A15-A28
[ ]	YY	B9-B15
[ ]	ZZ	D9-I7

Semiconductors

[ ]	D1	1N4001	X41-C42 (banded end to X41)
[ ]	D2	1N914	A17-A20 (banded end to A17)
[ ]	D3	1N914	C18-C21 (banded end to C18)
[ ]	D4	1N914	J17-J22 (banded end to J22)
[ ]	D5	1N914	G15-G20 (banded end to G20)
[ ]	IC1	LM3080 OTA; pin-1 to F1	
[ ]	IC2	TL062 dual op amp; pin-1 to F6	
[ ]	IC3	TL064 quad op amp; pin-1 to E19	
[ ]	IC4	TL064 quad op amp; pin-1 to E32	
[ ]	Q1	2N3906 (beta = ~250)	emitter (E) to B10, base (B) to B11, collector (C) to B12
[ ]	Q2	2N5457	drain (D) to I34, source (S) to I35, gate (G) to I36

Potentiometers (T=terminal)

[ ]	R30	100K	T1 to T2 and to terminal-2 of S2; T3 to D5
[ ]	R31	50K	T1 to J12, T2 to T3 and to J11
[ ]	R32	100K audio-taper	T1 to A26, T2 to T3 and to A27

Jacks (T=terminal)

- [ ] input jack (1/4" 3-terminal/stereo): tip to T2 of S1; ring to negative (–) battery lead, sleeve to Y27
- [ ] output jack (1/4" 2-terminal/mono): tip to T5 of S1; sleeve to Y34

Switches (T=terminal)

- [ ] S1 (DPDT stomp switch): T1 to E34, T2 to tip of input jack, T3 to T4, T5 to tip of output jack, T6 to D40
- [ ] S2 (SPDT slide or toggle switch): T1 to B13, T2 to terminals 1 & 2 of R30, T3 to J13

9V Battery Leads

- [ ] black (negative, –) lead to ring of input jack
- [ ] red (positive, +) lead to A46

Project. No. G213

Ring Modu-Matic III

Ring Modulator whose carrier frequency varies under control of a subsonic oscillator.

Circuit Function

Signal path: Axe feed couples through C4 to inverting preamp IC3-a, whose gain is fixed at 20 (26 dB). Preamp output couples through C9 to the signal input of IC4, an AD534 or MPY634 analog multiplier.

IC2 is configured as a voltage controlled sine oscillator whose rate varies according to the voltage applied to R6, and the capacitor selected by S2. IC2's output couples through C7 to the carrier input of IC4.

The modulated signal output couples through C5 to divider R13-R14, which gives the system just over 20 dB of quasi-companding noise reduction. The final output is taken at the juncture of R13-R14.

Control path: IC1-a, -c, -d, and associated components form a soft triangle oscillator whose rate varies under control of R29, whose amplitude varies under control of R30, and whose DC offset varies under control of R31. The resultant control voltage ties through R6 to IC2, an XR2206 function generator configured as a voltage controlled sine oscillator whose frequency range spans ~2 Hz to ~ 5 KHz, depending on the cap selected by S2 and the control voltage applied to R6. IC2's output couples through C7 to the Y (carrier) input of IC4.

Preamp output also couples through D3 to a level detector/comparator consisting of IC3-c, -d, and associated components. R32 varies comparator threshold, such that the output of IC3-c is low in the absence of an input signal. This turns Q1 on, which mutes oscillator IC2. When an input signal is present, comparator output flips high, turning Q1 off, allowing IC2 to oscillate.

The system runs off a regulated 12V supply furnished by IC5.

Use

Pots and switches have these functions:

R28	sine shape trim
R29	subsonic oscillator rate
R30	subsonic oscillator depth
R31	static oscillator frequency
R32	oscillator gate threshold
S1	effect/bypass
S2	oscillator frequency range select

Initial settings: S1 effect in, S2 in center position (C14 selected), R28 any position, R29 fully CW; R30, R31, R32 fully CCW. In this state the comparator output is high and the oscillator is on. Connect unit to axe whose volume pot is turned all the way down; do not connect an amp at this point. Connect one lead of an AC voltmeter to the free lead of R15, the other meter lead to ground (e.g., J15); trim R28 to read 1.77VAC. This makes the signal generated by IC2 a sinewave of about 6V peak.

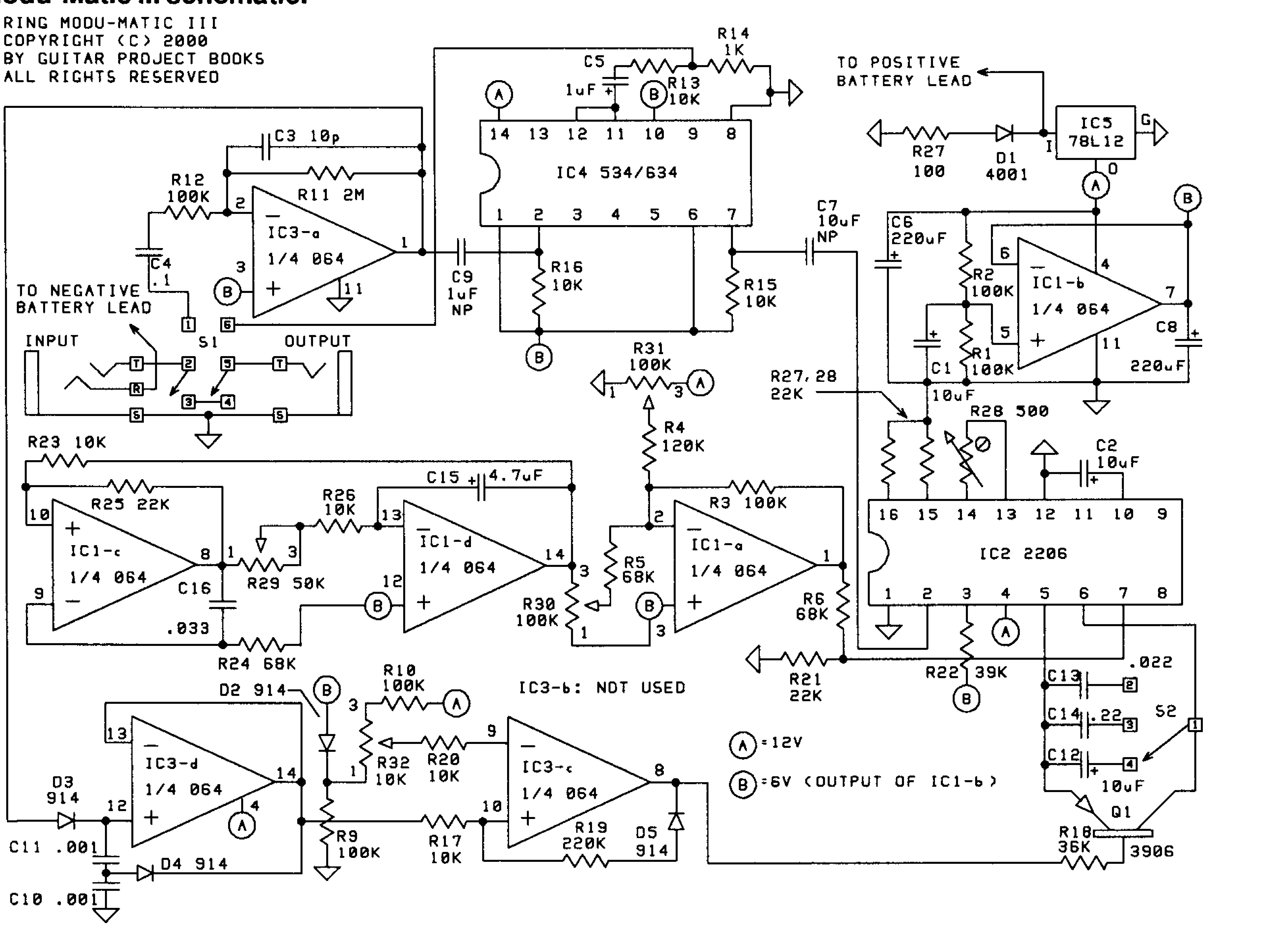
Next, connect unit to amp, establish desired listening level. In this state the oscillator tone will be heard at rest, because the gate is open. Holding the strings muted with one hand, turn R32 clockwise until the oscillation shuts off. Strum a chord; the ring-modulated output should be heard, but should mute without perceptible delay when the strings are muted.

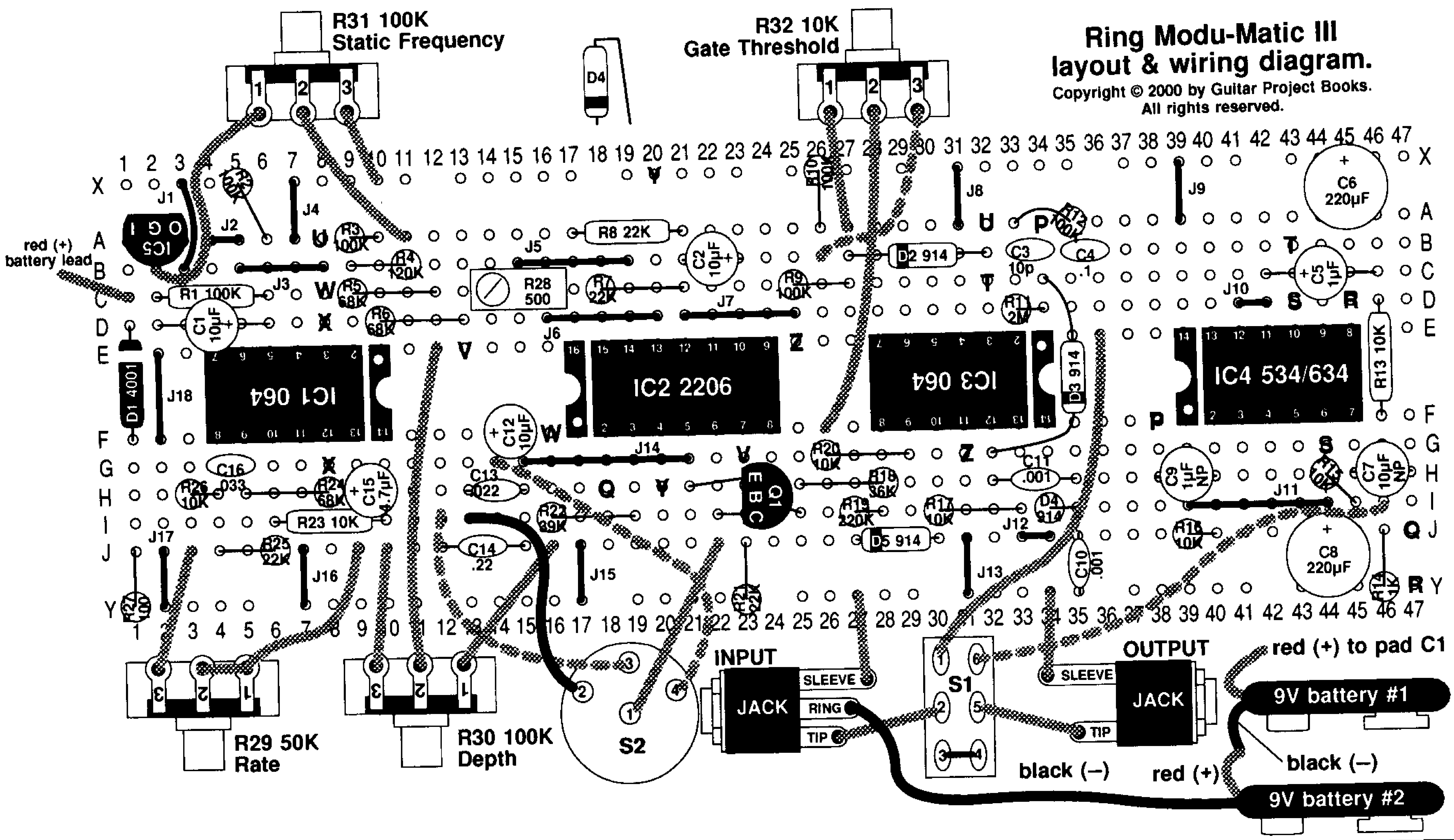
Take the various controls through their ranges and note the different sounds obtainable.

Notes

The prototype drew 16.5 ma. High-output axes will need reduced preamp gain to avoid clipping, achieved by replacing R11 with a lower value or substituting a 2M pot for R11. Patient experimentation with this box reveals the origins of sound effects in many classic sci-fi films and TV series.

Ring Modu-Matic III schematic.





Parts List/Soldering Checklist

Circuit Board Radio Shack p/n 276-170; Hosfelt p/n 42-183; or DC Electronics p/n J4-404

IC Sockets

- [ ] 14-pin for IC1; pin-1 to E10
- [ ] 16-pin for IC2; pin-1 to F17
- [ ] 14-pin for IC3; pin-1 to E34
- [ ] 14-pin for IC3; pin-1 to F39

Resistors

[ ]	R1	100K	(brn-blk-yel)	C2-C6
[ ]	R2	100K	(brn-blk-yel)	X5-A6
[ ]	R3	100K	(brn-blk-yel)	A9-A10
[ ]	R4	120K	(brn-red-yel)	B9-B11
[ ]	R5	68K	(blu-gry-org)	C9-C12
[ ]	R6	68K	(blu-gry-org)	D10-D13
[ ]	R7	22K	(red-red-org)	C18-C21
[ ]	R8	22K	(red-red-org)	A17-A21
[ ]	R9	100K	(brn-blk-yel)	C25-C27
[ ]	R10	100K	(brn-blk-yel)	X26-A26
[ ]	R11	2M	(red-blk-grn)	D33-D34
[ ]	R12	100K	(brn-blk-yel)	A33-A35
[ ]	R13	10K	(brn-blk-org)	D46-F46
[ ]	R14	1K	(brn-blk-red)	J46-Y46
[ ]	R15	10K	(brn-blk-org)	H44-I45
[ ]	R16	10K	(brn-blk-org)	J39-J40
[ ]	R17	10K	(brn-blk-org)	I30-I33
[ ]	R18	36K	(org-blu-org)	H25-H28
[ ]	R19	220K	(red-red-yel)	I27-I28
[ ]	R20	10K	(brn-blk-org)	G26-G29
[ ]	R21	22K	(red-red-org)	J23-Y23
[ ]	R22	39K	(org-wht-org)	I16-I19
[ ]	R23	10K	(brn-blk-org)	I6-I10
[ ]	R24	68K	(blu-gry-org)	H5-H8
[ ]	R25	22K	(red-red-org)	J4-J6
[ ]	R26	10K	(brn-blk-org)	H3-H4
[ ]	R27	100	(brn-blk-brn)	J1-Y1

Bare Wire Jumpers

[ ]	J1	X3-B3
[ ]	J2	A4-A5
[ ]	J3	B5-B8
[ ]	J4	X7-A7
[ ]	J5	B15-B19
[ ]	J6	D16-D20
[ ]	J7	D21-D25
[ ]	J8	X31-A31
[ ]	J9	X39-A39
[ ]	J10	D41-D42
[ ]	J11	I39-I44
[ ]	J12	J33-J34
[ ]	J13	J31-Y31
[ ]	J14	G15-G21
[ ]	J15	J17-Y17
[ ]	J16	J7-Y7
[ ]	J17	J2-Y2
[ ]	J18	E2-F2

Capacitors

[ ]	C1	10µF	D2-D6 (+ lead to D6)
[ ]	C2	10µF	B21-B23 (+ lead to B23)
[ ]	C3	10pF	B33-B34
[ ]	C4	0.1	B35-B36
[ ]	C5	1µF	C42-C46 (+ lead to C42)
[ ]	C6	220µF	X45-A45 (+ lead to X45)
[ ]	C7	10µF NP	H45-H47
[ ]	C8	220µF	J44-Y44 (+ lead to J44)
[ ]	C9	1µF NP	H38-H40
[ ]	C10	0.001	J35-Y35
[ ]	C11	0.001	H32-H35
[ ]	C12	10µF	F14-F15 (polarity irrelevant)
[ ]	C13	0.022	H13-H15
[ ]	C14	0.22	J12-J15
[ ]	C15	4.7µF	H9-H10 (polarity irrelevant)
[ ]	C16	0.033	G4-G5

Flying Jumpers (<u>insulated</u> wire)

[ ]	PP	A34-F38
[ ]	QQ	H18-J47
[ ]	RR	D45-Y47
[ ]	SS	D43-G44
[ ]	TT	C32-B43
[ ]	UU	A8-A32
[ ]	VV	E13-G23
[ ]	WW	C8-F16
[ ]	XX	D8-G8
[ ]	YY	X20-H20
[ ]	ZZ	E25-G31

Semiconductors

[ ]	D1	1N4001	D1-F1 (banded end to D1)
[ ]	D2	1N914	B27-B32 (banded end to B27)
[ ]	D3	1N914	C34-G32 (banded end to G32)
[ ]	D4	1N914	I34-I35 (banded end to I34)
[ ]	D5	1N914	J27-J30 (banded end to J27)
[ ]	IC1	TL064 quad op amp; pin-1 to E10	
[ ]	IC2	XR2206 VCO; pin-1 to F17	
[ ]	IC3	TL064 quad op amp; pin-1 to E34	
[ ]	IC4	AD534/MPY634 analog multiplier; pin-1 to F39	
[ ]	IC5	78L12 12V positive regulator (TO-92) output (O) to A3, ground (G) to A2, input (I) to A1	
[ ]	Q1	2N3906 PNP transistor; emitter (E) to H21, base (B) to I25, collector (C) to I22	

Trimpot

- [ ] R28 50K multiturn trimpot; terminals go in C14-15-16

Potentiometers (T=terminal)

[ ]	R29	50K	T1 to T2 and to J9, T3 to J3
[ ]	R30	100K	T1 to J16, T2 to E12, T3 to J10
[ ]	R31	100K	T1 to B2, T2 to A11, T3 to X10
[ ]	R32	10K	T1 to A27, T2 to F26, T3 to B26

Jacks (T=terminal)

- [ ] input jack (1/4" 3-terminal/stereo): tip to T2 of S1; ring to negative (–) lead of 9V battery snap #2, sleeve to Y27
- [ ] output jack (1/4" 2-terminal/mono): tip to T5 of S1; sleeve to Y34

Switches (T=terminal)

- [ ] S1 (DPDT stomp switch): T1 to E36; T2 to tip of input jack; T3 to T4; T5 to tip of output jack; T6 to I46
- [ ] S2 (SP3T rotary switch): T1 to J22, T2 to I13, T3 to I12, T4 to G14

9V Battery #1 Leads

- [ ] black (–) lead to red (+) lead of 9V battery #2
- [ ] red (+) lead to C1

9V Battery #2 Leads

- [ ] black (–) lead to ring of input jack
- [ ] red (+) lead to black (–) lead of 9V battery #1

Project. No. G214

Ring Modu-Matic IV

Studio-quality ring modulator.

Circuit Function

Signal couples through C11-R9 to noninverting preamp IC6-b, whose gain varies from 0 – 40 dB under control of R24. Preamp output couples through C8 to the X (signal) input of an AD534/MPY634 precision analog multiplier.

IC1, IC2, and associated components form a low-distortion sinewave oscillator tunable over the approximate range 20 Hz – 5 KHz in two bands, selected by S2. R22 acts as the frequency control The raw sine output (trimmed to 8V peak by R20) couples to FET-based optocoupler IC4, thence through C6 to IC5's Y (carrier) input.

D2, IC3, and associated circuitry form a level detector that turns the FET in IC4 on when signal is present, passing the sinewave carrier to IC5. The FET turns off in the absence of an audio input, effectively gating the carrier input to IC5. R23 sets the gate threshold.

R10, R21, and C12 form an optional carrier feedthrough trim network.

Use

Switches and pots have these functions:

S1	effect/bypass
S2	frequency range select hi/lo
R20	sine amplitude trim
R21	carrier feedthrough trim (optional)
R22	carrier frequency
R23	gate threshold
R24	preamp gain, 0 – 40 dB
R25	output level

Initial settings: Center R22, set S2 in either position. First, trim sine amplitude. Connect one lead of an AC voltmeter to ground ('G1', not 'G'; accessible at jumper J15), the other lead to the output of IC2-b (accessible at the exposed lead of R1). Set the meter scale for 20VAC. Trim R20 to read 2.75V, which corresponds to a sinewave of 8V peak. This value should not change by more than ±0.2V when S2 switches between high and low frequency ranges.

Next, connect unit to an amp, but leave the input jack empty. Turn the gate threshold control R23 fully CCW. This opens the gate, such that the carrier will be heard, though it may be faint. If sufficiently faint, do not install feedthrough trim components R10, R21, C12, and J8. If the carrier tone is intrusive, install them. Once installed, trim R21 for minimum audible carrier.

Next, connect unit to axe and amp. Center preamp gain control R24, adjust gate threshold for easy opening of the gate. Properly adjusted, the gate should remain open for a considerable time while a chord decays, yet close promptly when the player mutes the strings. Take the gain and frequency controls through their ranges and note the different sounds obtainable.

Notes

IC8 is Digi-Key p/n 179-1078-ND or Mouser p/n 580-NMA0515S. The ±15V supply takes RMM4 out of the stompbox category, though careful builders should be able to squeeze it into a stompbox case. IC7 requires a heatsink; *The Stompbox Cookbook* (Envelo-Matic) contains a photo illustrating one possible configuration. The heatsink tab ties to regulator ground, which should not be allowed to contact the enclosure case, or the DC–DC converter output ground ('G1' on the layout diagram).

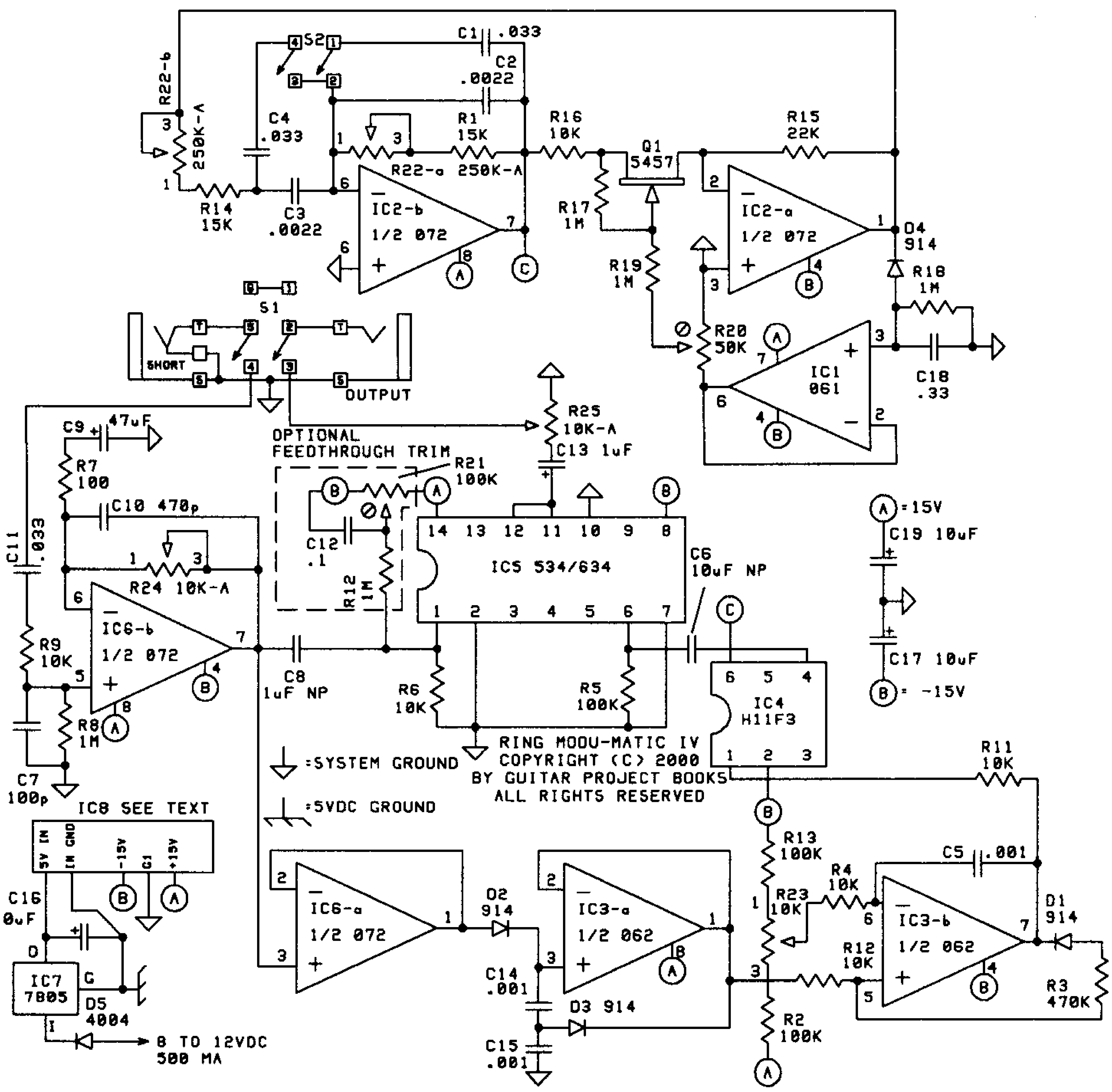
Keep wiring short and neat. Do not twist the leads for S2 or R22. R22 is wired such that carrier tone rises with CCW rotation. If a 250K dual reverse-audio pot is available, it can be used in place of the dual log-taper pot by reversing the pot terminal connections.

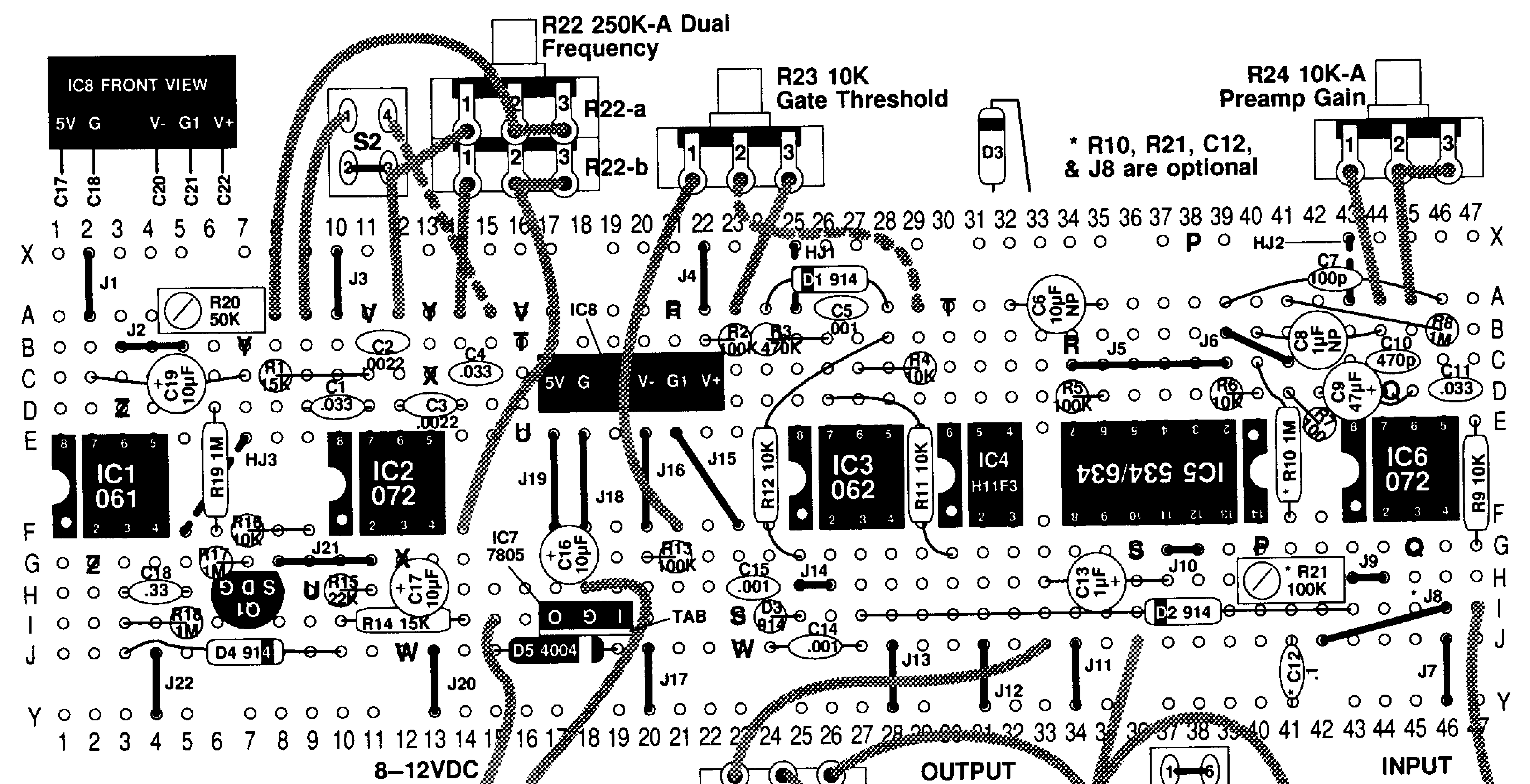
The AD534 used in the prototype exhibited so little carrier feedthrough that no significant improvement occurred with trimming. This might not apply to the MPY634, so the builder will have to assess the need for trimming.

RMM4 suits virtually any signal source, including raw instrument feeds, mic feeds, recordings, and synthesizer tones. Its 26V of internal headroom and variable preamp gain allow a very high signal-to-noise ratio.

Players who've never heard pure-sine ring modulation may be pleasantly surprised at how musical this unmusical effect can sound. Ring modulation with a carrier of 3 to 5 KHz lends new meaning to the concept of treble boost; keep those earplugs handy.

Ring Modu-Matic IV schematic.





Ring Modu-Matic IV layout & wiring diagram.

Parts List/Soldering Checklist

Circuit Board Radio Shack p/n 276-170; Hosfelt p/n 42-183; or DC Electronics p/n J4-404

IC Sockets

- [ ] 8-pin for IC1; pin-1 to F1
- [ ] 8-pin for IC2; pin-1 to F10
- [ ] 8-pin for IC3; pin-1 to F25
- [ ] 6-pin for IC4; pin-1 to F30
- [ ] 14-pin for IC5; pin-1 to E40
- [ ] 8-pin for IC6; pin-1 to F43

Resistors

- [ ] R1 15K (brn-grn-org) C8-C11
- [ ] R2 100K (brn-blk-yel) B22-B23
- [ ] R3 470K (yel-vio-yel) B24-B26
- [ ] R4 10K (brn-blk-org) C27-C29
- [ ] R5 100K (brn-blk-yel) D34-D35
- [ ] R6 10K (brn-blk-org) D39-D40
- [ ] R7 100 (brn-blk-brn) D41-E42
- [ ] R8 1M (brn-blk-grn) A41-B46
- [ ] R9 10K (brn-blk-org) E47-G47
- [ ] *R10 1M (brn-blk-grn) C40-F41
- [ ] R11 10K (brn-blk-org) D26-G30
- [ ] R12 10K (brn-blk-org) B28-G25
- [ ] R13 100K (brn-blk-yel) G20-G21
- [ ] R14 15K (brn-grn-org) I10-I14
- [ ] R15 22K (red-red-org) H10-H11
- [ ] R16 10K (brn-blk-org) F7-F9
- [ ] R17 1M (brn-blk-grn) G6-G7
- [ ] R18 1M (brn-blk-grn) I3-I5

(install hidden jumper HJ3 [E7-F5] before soldering R19

- [ ] R19 1M (brn-blk-grn) D6-F6

Bare Wire Jumpers

- [ ] J1 X2-A2
- [ ] J2 B3-B5
- [ ] J3 X10-A10
- [ ] J4 X22-A22
- [ ] J5 C34-C39
- [ ] J6 B39-C41
- [ ] J7 J46-Y46
- [ ] J8 *J42-I46
- [ ] J9 H43-H44
- [ ] J10 G37-G38
- [ ] J11 J34-Y34
- [ ] J12 J31-Y31
- [ ] J13 J28-Y28
- [ ] J14 H25-H26
- [ ] J15 E21-F23
- [ ] J16 E20-F20
- [ ] J17 J20-Y20
- [ ] J18 E18-F18
- [ ] J19 E17-F17
- [ ] J20 J13-Y13
- [ ] J21 G8-G11
- [ ] J22 J4-Y4

Capacitors

- [ ] C1 0.033 D9-D11
- [ ] C2 0.0022 B11-B12
- [ ] C3 0.0022 D12-D14
- [ ] C4 0.033 C14-C15
- [ ] C5 0.001 A26-A27
- [ ] C6 10µF NP A32-A35

(install hidden jumper HJ2 [X43-A43] before soldering C7)

- [ ] C7 100pF A39-A46
- [ ] C8 1µF NP B40-B44
- [ ] C9 47µF D42-D45 (+ lead to D45)
- [ ] C10 470pF C44-C45
- [ ] C11 0.033 D46-D47
- [ ] C12 *0.1 J41-Y41
- [ ] C13 1µF H33-H37 (+ lead to H37)
- [ ] C14 0.001 J24-J27
- [ ] C15 0.001 H23-H24
- [ ] C16 10µF G17-G18 (+ lead to G17)
- [ ] C17 10µF H12-H13 (+ lead to H12)
- [ ] C18 0.33 H3-H5
- [ ] C19 10µF C2-C7 (+ lead to C2)

Flying Jumpers (insulated wire)

- [ ] PP X38-G40
- [ ] QQ D44-G45
- [ ] RR A21-B34
- [ ] SS I23-G36
- [ ] TT B16-A30
- [ ] UU H9-E16
- [ ] VV A11-A16
- [ ] WW J12-J23
- [ ] XX C13-G12
- [ ] YY B7-A13
- [ ] ZZ D3-G2

Semiconductors

(install hidden jumper HJ1 [X25-A25 before soldering D1)

- [ ] D1 1N914 A24-A28 (banded end to A24)
- [ ] D2 1N914 I27-I43 (banded end to I27)
- [ ] D3 1N914 I24-I25 (banded end to I25)
- [ ] D4 1N914 J3-J10 (banded end to J10)
- [ ] D5 1N4004 J15-J19 (banded end to J19)
- [ ] IC1 TL061 op amp; pin-1 to F1
- [ ] IC2 TL072 dual op amp; pin-1 to F10
- [ ] IC3 TL062 dual op amp; pin-1 to F25
- [ ] IC4 H11F3 optocoupler; pin-1 to F30
- [ ] IC5 AD534/MPY634 analog multiplier; pin-1 to E40
- [ ] IC6 TL072 dual op amp; pin-2 to F43
- [ ] IC7 LM7805 5V positive regulator (TO-220); input (I) to I19, ground (G) to I18, output (O) to I17
- [ ] IC8 5V to ±15V DC-DC converter; see diagram for pinout & placement guide
- [ ] Q1 2N5457 source (S) to H8, drain (D) to H7, gate (G) to H6

Trimpots

- [ ] R20 50K multiturn trimpot; leads go in A5-6-7
- [ ] *R21 100K multiturn trimpot; leads go in H40-41-42

Potentiometers (T=terminal)

R22 250K dual audio-taper

- [ ] R22-a T1 to terminal-3 of S2 and to A12, T2 to T3 and to A8
- [ ] R22-b T1 to A14, T2 to T3 and to F14
- [ ] R23 10K T1 to F21, T2 to A29, T3 to A23
- [ ] R24 10K audio-taper T1 to A44, T2 to T3 and to A45
- [ ] R25 10K audio-taper T1 to sleeve of output jack and to J36, T2 to terminal-3 of S1, T3 to J33

Jacks (T=terminal)

- [ ] input jack (1/4" 3-terminal shorting): tip to T5 of S1; short to sleeve, which ties to sleeve of output jack and to J36
- [ ] output jack (1/4" 2-terminal/mono): tip to T2 of S1; sleeve to sleeve of input jack

Switches (T=terminal)

- [ ] S1 (DPDT stomp switch): T1 to T6; T2 to tip of output jack; T3 to terminal-2 of R25, T5 to tip of input jack
- [ ] S2 (DPST slide or toggle switch): T1 to A9, T2 to T3 and to A12 and to terminal-1 of R22-a; T4 to A15

Miscellaneous

- [ ] wall-wart AC-DC stepdown transformer; output 8–12VDC @ 500 milliamps; positive (+) lead solders to I15; negative (–) lead (i.e., transformer output ground) solders to H18

(continued from page 5)

A. Often you don't, so you make an assumption and test it.

Q. I'm looking at the ramp circuit in RMM2. How does this compare to the ramp circuit in Attack-O-Matic (AOM)? [*Vol. 4, No. 1—Ed.*]?

A. Refer to Fig. 5. You recall that AOM uses a constant-current path to generate the linear curve that defines a true ramp. RMM2's "ramp" is not a ramp at all, but the voltage curve of a capacitor charging through a resistor. The result sounds different from a linear ramp; more like a dynamo revving up to speed.

Q. Why call this curve a ramp?

A. In electronic slang it's not uncommon to see any rising variable referred to as a ramp.

Q. AOM's circuit looks needlessly complex, in that you've used a switched transistor (Q2) to discharge the cap, when you could have used a diode/resistor, as in RMM2.

A. In AOM, the diode/resistor discharge path left too high a residual voltage in the 10µF cap. The switched transistor discharged the cap deeply enough to drop VCA gain essentially to 0. Plus, this approach showed the beginning builder that a PNP transistor could act as a constant-current source and as an electronic switch.

Q. I've been considering two variations on the ringmod theme: (1) multiply a signal against itself; (2) multiply two different audio signals against each other.

A. The first option formed the basis for Distort-O-Matic V. The sound was interesting in that it didn't duplicate the typical diode-clipper. It was also flat, because a signal multiplied against itself has its dynamics converted to dual-mode expansion. The lack of sustain disappoints players accustomed to endless sustain in diode boxes. Greater sustain is achieved by passing the axe feed through an LED-based log amp ahead of the modulator.

Similar considerations apply to multiplying two different tones. The sound is novel, but dynamically flat. Dynamics sound more natural if both inputs undergo upward compression before modulation.

References

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3. Sheingold, D. (Ed.): *Nonlinear Circuits Handbook*, Analog Devices, Inc., 1976, ISBN 0-916550-01-X

4. US Patent No. 4,182,930 [*incidental use of synchronous detector to generate sum and difference terms*]

5. Manufacturers' data sheets for the following integrated circuits: NE602, LM13600, LM3080, LM1496, MC1495, AD534, MPY634

6. *Amateur Radio Handbook*; American Radio Relay League, 1994, ISBN 0-87259-171-9