Stompboxology™

Volume 5, Number 1

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Vibrato-Rama!

It's always tempting to lead with, Blank: The Final Frontier, Blank being the effect under discussion. Vibrato hardly qualifies as a frontier, but may earn a wing in the Hall of Misconstrued Effects. As with tremolo, most players first heard vibrato on songs played through old tube amps. Consider recorded examples. From "Wheels" in '61 to "Look Through Any Window" to "It's Only Love," vibrato went underground after a sullen cameo in *Vanishing Point* (1971) before lapsing into a life of sporadic revival: "Heart Shaped World," "You Don't Know How It Feels," "Free Girl Now" (the latter reportedly solid-state vibrato, via Kustom®).

In pure terms, vibrato means rhythmic pitch change, achieved in an axe by shifting string tension through a lever tied to a sprung tailpiece. Amps and stompboxes realize vibrato by electronically emulating the Doppler effect, in which the perceived pitch of a sound source moving toward a listener rises in proportion to the source's velocity; and in which the perceived pitch of a sound source moving away from a listener falls in proportion to the source's velocity. An intuitive understanding of this comes by picturing sound as a series of evenly spaced waves impinging on the ear. If the sound source is moving toward the ear, more waves per second must reach the ear, to account for the velocity difference between source and listener. If the sound source is moving away from the ear, the velocity difference widens the space between each sound wave, so that fewer waves per second meet the ear. Countless films use the Doppler effect to dramatize the passage of a train, whose whistle falls in pitch as the train hurtles by.

Electronic circuits that vary phase make an apparent change in pitch that obtains only while phase is changing. Rhythmic phase shifters form the basis for electronic vibrato. A complete vibrato consists of a subsonic oscillator driving a *phase engine*, the circuit that does the actual shifting. The sound depends on several factors. Total phase change determines intensity, but so does modulation rate, a faster rate sounding deeper. The modulating waveform's shape, and nonlinearities in the phase engine also affect sound, a smooth, linear shift sounding more musical (but tricky to achieve, since common phase engines exhibit nonlinear response). Vibrato depends also on the distribution of phase shift over the audio spectrum. Common phase engines subject different frequencies to varying degrees of shift. Some engines create incidental distortion and amplitude modulation that lends their sound an agreeable flavor.

Tube Amp Vibrato

Of the majors, only Ampeg® and Magnatone® made amps with pure vibrato. Ampeg's two-stage engine (Fig. 1–1) is based on one of the simplest *allpass filters*, circuits that alter phase with little effect on amplitude. Dynamic shift is realized through photocell-based optocouplers used as voltage-controlled resistors. Ampeg drove both photocells off a single neon lamp in a module that, the schematics said, only the factory could supply; apparently a custom fixture.

Magnatone took a topologically similar tack, but duplicated the photocell function using varistors. A *varistor* is an electronic component that exhibits high resistance below threshold voltage, low resistance above threshold. The larger Magnatone amps placed a pair of varistors in series, each isolated from the feeding tube's cathode by a capacitor; and tied to the oscillator through resistors (Fig. 1–3). When the varistors saw low voltage, they acted as a path of some megohms' resistance, shunted by minor parasitic capacitance. When voltage across the varistors peaked, they acted as a low resistance. Magnatone's smaller amps used single stages like the one shown in Fig. 1–2.

Magnatone also made amps with stereo vibrato, consisting of a pair of two-stage phase shifters running in parallel and driving separate speakers. Each received a control feed inverted relative to the other. When one channel's pitch rose the other's fell. Because human hearing uses phase as one means to localize sound, stereo vibrato shifts the sonic image with each cycle.

Rather than dynamically shifting phase, the Vox® AC–15 and AC–30 derive their vibrato from a voltage controlled mixer that alternates between feeds that have traversed different phase-shift networks (Fig. 1–4).

The distinction between vibrato and tremolo blurs in certain Fender® amps, notably the 6G7-A Bandmaster and 6G12-A Concert. These amps feature what's come to be called two-tube or three-tube vibrato. They contain a voltage controlled mixer similar to the one used by Vox, but fed by networks that affect amplitude as well as phase. The result is a mixture of frequency-dependent amplitude modulation and phase shift, plus distortion due to unipolar squashing in the mixer, delivering a sound justifiably renowned for warmth [*captured and made variable in Tremolo-Matic X; see Vol. 4, No. 4—Ed.*].

Stompbox Vibrato

Besides emulating tube amp vibrato, stompboxes realize modes that tube amps cannot. Here's a partial list of options:

- voltage controlled mixer
- operational transconductance (OTA) voltage controlled resistor
- OTA voltage controlled filter
- OTA voltage controlled inductance and/or capacitance
- photocell-based optocoupler
- transistor-based optocoupler
- transistors used as voltage controlled resistors

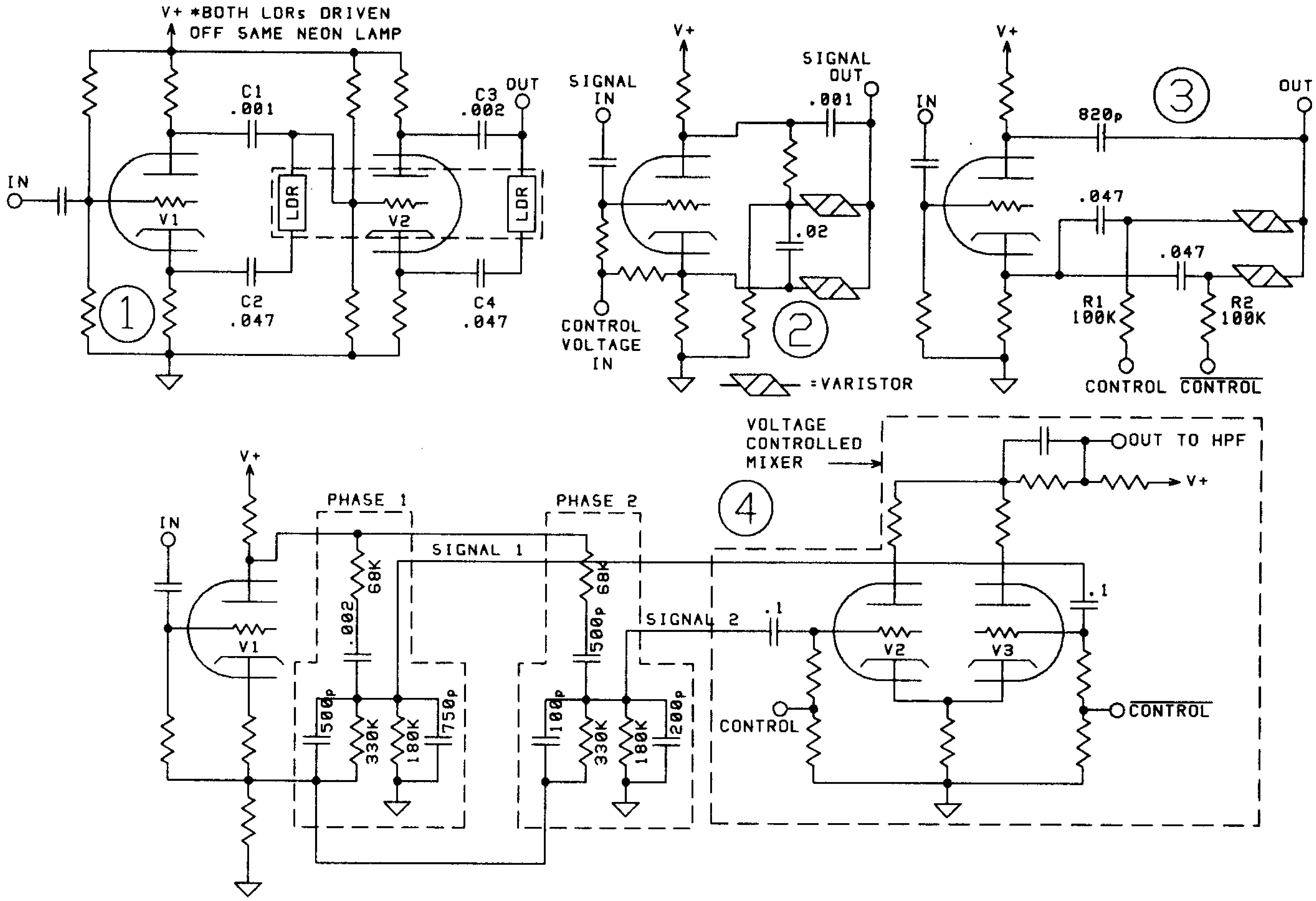


Fig. 1. Tube amp vibrato circuits. 1—Ampeg circuit uses LDR-based optocoupler (custom fixture; both LDRs driven off a single neon lamp). This same basic phase shifter can be created from bipolar or field-effect transistors in place of triodes. 2—Relatively rare circuit found in some Magnatone amps. Triode is configured as an inverter (aka phase splitter). Signal and oscillator control voltage both enter grid. Control voltage emerges intact from cathode, inverted from plate. Opposite-going voltages feed ends of two series varistors. When voltage difference is low, the varistors act as a large resistance; when voltage difference is high, varistors act as low resistance. 3—The more common Magnatone phase-shift stage, in which varistors are driven off inverse control voltages created separately. Note that schematic #1 and schematic #3 are topologically identical; two varistors perform the function of a single photocell. 4—Vox's approach resembles that of Fender's two-tube vibrato in using a voltage controlled mixer to alternate between signals that have undergone different degrees of phase shift, in networks that are characteristic of Vox.

- low-voltage varistors
- bucket brigade devices [*treated at length in Vol. 7, No. 2—Ed.*]

The voltage controlled mixer allows emulation of Vox's vibrato and Fender's combo effect; and, as Tremolo-Matic XII demonstrated, opens a world of options via the uncommitted rhythmic mixer.

The OTA voltage controlled resistor (and, less commonly, an OTA voltage controlled lowpass filter) turns an ordinary op-amp allpass filter into a vibrato engine of the type used in Vibrato-Matic III. OTA voltage controlled inductance and/or capacitance perform a similar function when combined with fixed resistance in this same allpass filter.

Photocell-based optocouplers act in stompboxes exactly as they do in tube amps. As with tremolo, this approach requires a 'fast' photocell that currently demands custom fabrication.

Some vibrato circuits use transistors as if they were voltage controlled resistors in allpass filters. The transistors can be driven directly, or can be part of conventional optocouplers. This method generates a distorted sound that, if not mainstream vibrato, yet has a place.

As for the varistor phase engine, modern varistors come with thresholds from four to several hundred volts. They're used mainly to protect AC-powered gear from voltage spikes. Duplicating the Magnatone circuit using 4V varistors meets several obstacles. First, varistors' parasitic capacitance varies inversely with threshold voltage. Some very high-voltage varistors exhibit less than 100pF, while ten 4V samples measured by the Editor averaged 100 times as much. Audio penetrates this capacitance despite a DC resistance of more than 20 megohms. Second, low-voltage varistors are noisy. The circuits shown in Fig. 2 incorporate more than 20 dB of quasi-companding to reduce noise to a marginally acceptable level. Also, noise varies from sample to sample. Two of ten varistors exhibited noise-bursts sufficient to rule them out. Third, although these varistors indeed turn on at 4V, they need at least 15V to achieve decent depth. That rules them out of single 9V boxes without doubling the control voltage. Yet, with careful tweaking, low-voltage varistor vibrato isn't bad. It sounds noticeably smoother than non-linearized OTA or optocoupler vibrato.

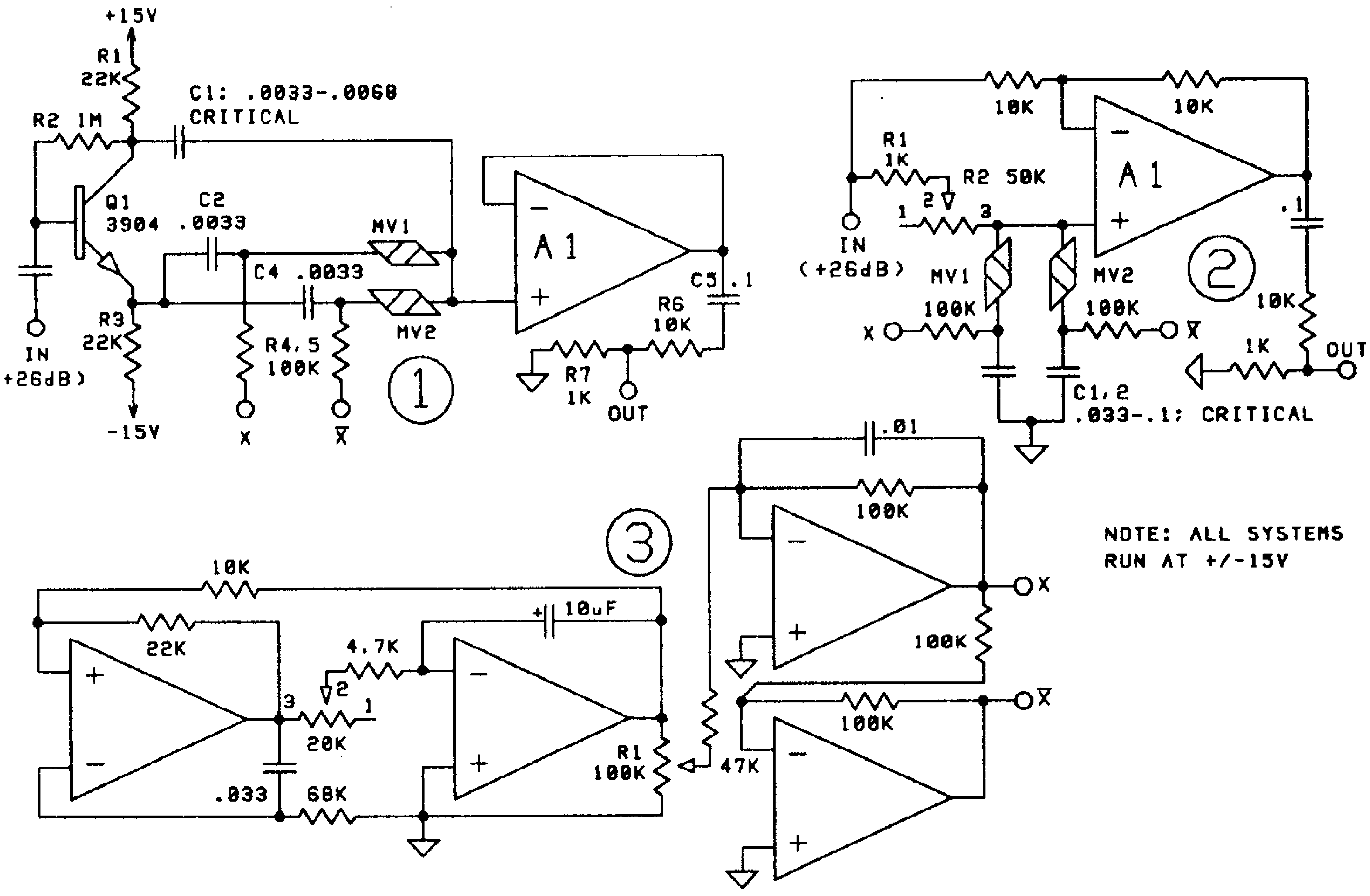
Miscellaneous Pointers

In all phase engines, the builder can alter the frequencies affected by changing capacitor values. Larger caps (e.g., 0.01µF in typical circuits) favor the lower end of the guitar spectrum, smaller caps favor the treble end.

A capacitor is the most common phase-shift element, but not the only one possible. Inductors and simulated inductors substitute for caps in many circuits. Bandpass and band-reject networks shift phase in opposite directions above and below their resonant frequency.

The number of stages quickly hits the point of diminishing return. Optocoupler-based shifters having up to 12 stages deliver absolute phase- and pitch-shift that is prodigious indeed. But these circuits don't sound particularly good as vibrato. Severe pitch-shift injects an element of dissonance, avoided by sticking to one or two stages.

Fig. 2. Experimental circuits to demonstrate the varistor phase engine. MV is a 4V metal oxide varistor, Hosfelt Electronics p/n V8ZA2. Schematic #1 is functionally identical to triode stage in Magnatone amp, but uses a transistor in place of tube. High impedance at output node necessitates buffer A1 (FET-input types, such as 06X, get bias current through the varistors; other types may need a bias resistor to ground at the noninverting input). Schematic #2 shows another varistor phase engine based on conventional op-amp allpass filter. Two of these stages in series gave an agreeable vibrato. Both circuits incorporate a high level of quasi-companding to reduce hiss modulation introduced by varistors. Feedthrough can be trimmed, to some extent, by making one 100K drive resistor a 20K multiturn trimpot in series with 91K. Both circuits were driven by the oscillator shown in schematic #3, which generates two antiphase control feeds.



The dabbler in stereo vibrato learns early that this variant needs only one processed feed. The second feed can be left dry. Magnatone's dual mechanism is desirable when each channel must deliver independently audible vibrato. But in ordinary stereo setups, inversely-shifted feeds give no more dramatic an effect, at a distance, than one processed feed beating against a clean feed.

Beginner's View

Q. I just built VM2 & VM3, dude. They sound fan-freaking-tastic!

A. Glad you like 'em, dude.

Q. Will you 'splain to me how these things work?

A. Start with VM2, the "Vox emulator." This box uses the same preamp and voltage controlled mixer as TM10, which we discussed at length last ish. The differences happen ahead of the mixer. As with TM10, the preamplified signal splits. Each feed traverses a different phase shift network, then each network's output enters one input of the voltage controlled mixer.

Q. Phase shift network, dude?

A. R4-6-27 and C2-15-18 form one phase shift network; R3-5-26 and C3-16-17 form the other.

Q. Those don't look like the networks found in American amps.

A. They aren't. Our British cousins chose an approach that dedicates a triode to making a phase splitter, which drives the phase shift networks. The two outputs bear little amplitude difference but about 90 degrees of phase difference in the midrange. The mixer alternates between these two feeds. The voltage followers in TM10 have been replaced with amps having gains of ~3.2 (IC3-a & -b), to make up voltage lost in the phase shifters.

Q. What does S2, the tremolo switch, do?

A. Subjects one feed to severe lowpass filtering. When S2 is closed, the mixer alternates between feeds having a great amplitude difference. The net effect is amplitude modulation.

Q. How does VM3 work?

A. It contains a single stage very similar to one of six such stages found in Vibrato-Matic in the *Cookbook*. IC2 and R16-19 act as one voltage controlled resistor. The control voltage coming out of IC1-d enters pin-1 of IC2, after passing through a nonlinear transfer block made up of R6-8 and D1-2, to compensate for IC2's nonlinearity.

Q. Meaning what?

A. If you put a single resistor between IC1-d and pin-1 of IC2, most of the phase shift happens in the first 20% of voltage change. This gives rise to a lopsided sound that, if not totally unmusical, could sound better. Smoothness is one of the keys to sweet vibrato. LDR-based optocouplers and OTA-based modulators are highly nonlinear.

Q. How do you linearize the response?

A. First, analyze the type of nonlinearity. In this case, the phase shifter exhibits very high sensitivity at the low end of its control range; low sensitivity at the high end. So we need a transfer network that passes less current at the low end, more current at the high end.

To implement the approach we have to know the voltage at IC2 pin-1; it's close enough to ground (0 volts) to treat as ground. And we have to know the maximum voltage swing at the output of IC1-d; assuming a 7.5V supply, it swings from ~0.7V to ~6.7V.

Assume the voltage at the output of IC1-d is at its negative limit, and has begun to rise. The current flow is only about 70 nanoamps—billionths of an amp—because at that point the only open pathway is R6. This meets our objective of letting through little current at the low end of the control voltage range.

Q. What about the paths in parallel with R6: D1-R7 and D2-R8?

A. As the voltage coming out of IC1-d continues to rise, it reaches the forward conduction point of D1; about 1.8V for a red LED. Above that level, the net resistance between IC1-d and IC2 becomes (R6 in parallel with R7), or about 3.2 megohms. R8 kicks in once the voltage difference exceeds (1.8V +1.8V) = 3.6V, and the net resistance between IC1-d and IC2 drops to ~410K ohms, because R6-7-8 are effectively in parallel.

Q. How'd you get those values for R6-7-8? They seem such a radical departure from theoretical current. If I recall from the *Cookbook*, you could feed as much as 2 milliamps through IC2.

A. Right. The resistor values were found empirically.

Q. What does that mean?

A. Trial and error; sitting at the breadboard with an axe and an amp hooked up to the circuit, changing resistors and caps until the sound got sweet. This is the key to cooking up effects. Sound, not theory or measurement, is the final alembic. Higher current levels and larger cap values gave vibrato, but it sounded mediocre.

Q. What's with D6 and R20?

A. They reduce the maximum negative output swing of IC1-d.

Q. How? And more importantly, why?

A. Take how first. A diode is a unidirectional conductor. As with D3, current flows through D6 in only one direction. Note that we've tied D6's cathode

(continued on page 10)

Project No. G58

Vibrato-Matic II

Solid-state realization of the vibrato/tremolo engine found in the Vox® AC-15 and AC-30.

Circuit Function

Signal Path: Axe output couples through C20 to inverting preamp IC2-a, whose gain is fixed at ~6. Preamp output couples to unity-gain inverter IC2-b; normal and inverted signals drive a pair of passive phase-shift networks comprised of R3-6, 26, & 27, and C2, 3, 15-18. The output of each phase-shift network feeds a noninverting amp (IC3-a & -b) that compensates for voltage losses in the networks. Each signal feeds an input of IC4, an NE570 configured as a voltage controlled mixer. Mixer output is taken off the juncture of R20-R21.

With S2 in the 'tremolo' position, the signal passing through R4 & R27 is shunted by C19, which heavily attenuates treble.

Control Path: IC5-a, -d, and their associated components form a soft triangle generator whose rate is controlled by R32 and whose output couples to depth control pot R33, thence to inverting amp IC5-c, thence to inverting buffer IC5-b. The control path generates two vibrato control voltages, identical in amplitude but each inverted relative to the other. One control signal couples to each VCA control port of IC4.

Use

Pots and switches have these functions:

R32 vibrato rate
R33 vibrato depth
S1 effect/bypass
S2 vibrato/tremolo select

Initial settings: R32, R33 fully CW; S1 effect in, S2 either position. Connect unit to axe and amp, establish desired listening level. With these control settings, deep modulation should be noted.

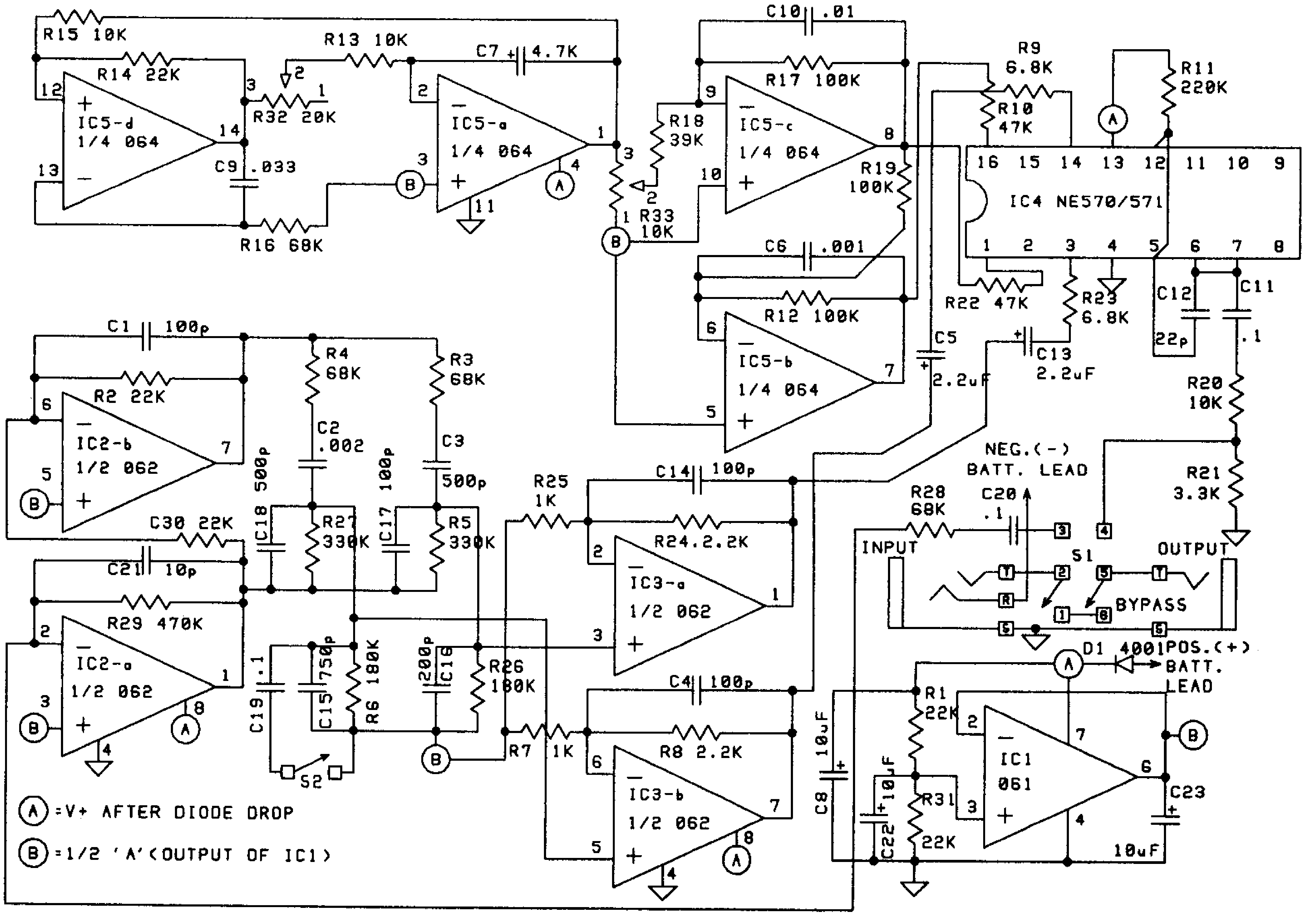
Toggle S2 between vibrato and tremolo and note the changes in sound; take rate and depth controls through their ranges.

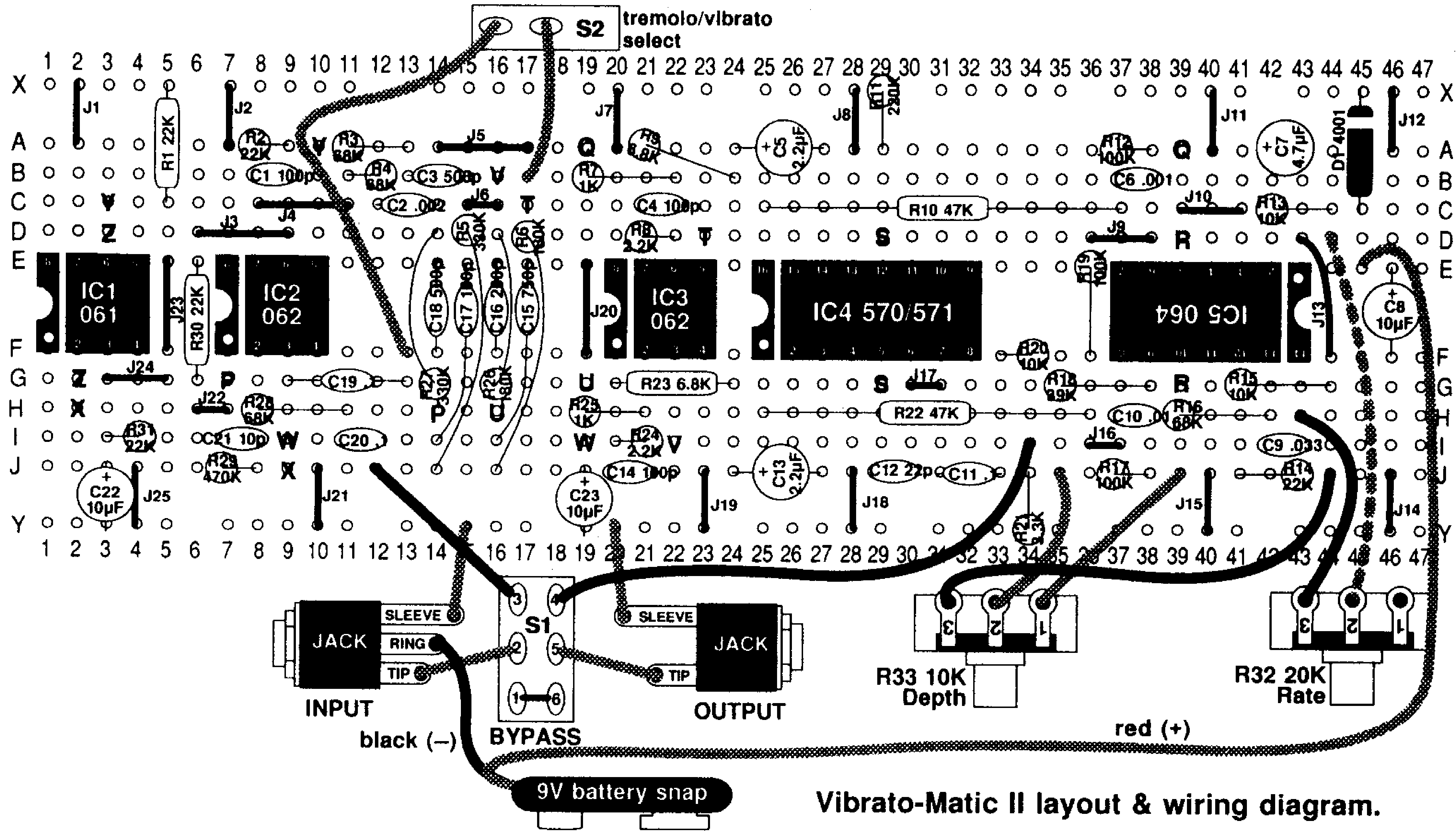
Notes

The cap values given for C2-3 and C15-18 are those used in Vox amps. If these exact values are not readily available, substitution of near values (e.g., 0.0022µF for 0.002µF; 470pF for 500 pF; 220pF for 200pF) gives good results. Tight spacing of the phase-shift components' leads makes it prudent to slip insulating sleeves on these leads, especially R5-6, 26-27; and C15-17. The prototype drew less than 9 ma running off a freshly charged nicad.

This box makes an excellent outboard tremolo/vibrato. Vox's approach avoids dissonance at any depth setting.

Vibrato-Matic II schematic.





Vibrato-Matic II layout & wiring diagram.

Parts List/Soldering Checklist

UCB 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 goes in F1
- ☐ 8-pin for IC2; pin-1 goes in F7
- ☐ 8-pin for IC3; pin-1 goes in F20
- ☐ 16-pin for IC4; pin-1 goes in F25
- ☐ 14-pin for IC5; pin-1 goes in E43

Resistors

☐	R1	22K	(red-red-org)	X5-C5
☐	R2	22K	(red-red-org)	A8-A9
☐	R3	68K	(blu-gry-org)	A11-A13
☐	R4	68K	(blu-gry-org)	B11-B12
☐	R5	330K	(org-org-yel)	D15-J14
☐	R6	180K	(brn-gry-yel)	D17-J16
☐	R7	1K	(brn-blk-red)	B19-B22
☐	R8	2.2K	(red-red-red)	D21-D22
☐	R9	6.8K	(blu-gry-red)	A21-B24
☐	R10	47K	(yel-vio-org)	C25-C37
☐	R11	220K	(red-red-yel)	X29-A29
☐	R12	100K	(brn-blk-yel)	A37-A38
☐	R13	10K	(brn-blk-org)	C42-C44
☐	R14	22K	(red-red-org)	J41-J43
☐	R15	10K	(brn-blk-org)	G41-G44
☐	R16	68K	(blu-gry-org)	H39-H42
☐	R17	100K	(brn-blk-yel)	J37-J38
☐	R18	39K	(org-wht-org)	G35-G38
☐	R19	100K	(brn-blk-yel)	E36-F36
☐	R20	10K	(brn-blk-org)	F33-F34
☐	R21	3.3K	(org-org-red)	J34-Y34
☐	R22	47K	(yel-vio-org)	H25-H36
☐	R23	6.8K	(blu-gry-red)	G20-G24
☐	R24	2.2K	(red-red-red)	I20-I21
☐	R25	1K	(brn-blk-red)	H19-H21
☐	R26	180K	(brn-gry-yel)	D16-G16
☐	R27	330K	(org-org-yel)	D14-G14
☐	R28	68K	(blu-gry-org)	H8-H11
☐	R29	470K	(yel-vio-yel)	J7-J8
☐	R30	22K	(red-red-org)	E6-G6
☐	R31	22K	(red-red-org)	I3-I4

Bare Wire Jumpers

☐	J1	X2-A2
☐	J2	X7-A7
☐	J3	D6-D9
☐	J4	C8-C11
☐	J5	A14-A17
☐	J6	C15-C16
☐	J7	X20-A20
☐	J8	X28-A28
☐	J9	D36-D38
☐	J10	C39-C41
☐	J11	X40-A40
☐	J12	X46-A46
☐	J13	D43-F44
☐	J14	J46-Y46
☐	J15	J40-Y40
☐	J16	I36-I37
☐	J17	G30-G31
☐	J18	J28-Y28
☐	J19	J23-Y23
☐	J20	E19-F19
☐	J21	J10-Y10
☐	J22	H6-H7
☐	J23	E5-F5
☐	J24	G3-G5
☐	J25	J4-Y4

Capacitors

☐	C1	100pF	B8-B9
☐	C2	.002µF	C12-C14
☐	C3	500pF	B13-B15
☐	C4	100pF	C21-C22
☐	C5	2.2µF	A24-A27 ('+' lead to A24)
☐	C6	.001µF	B37-B38
☐	C7	4.7µF	A42-A43 ('+' lead either way)
☐	C8	10µF	E46-F46 ('+' lead to E46)
☐	C9	.033µF	I42-I43
☐	C10	.01µF	H37-H38
☐	C11	.1µF	J31-J33
☐	C12	22pF	J29-J30
☐	C13	2.2µF	J24-J27 ('+' lead to J24)
☐	C14	100pF	J20-J21
☐	C15	750pF	E17-I16
☐	C16	200pF	E16-F16
☐	C17	100pF	E15-I14
☐	C18	500pF	E14-F14
☐	C19	.1µF	G9-G13
☐	C20	.1µF	I11-I12
☐	C21	10pF	I7-I8
☐	C22	10µF	J3-Y3 ('+' lead to J3)
☐	C23	10µF	J19-Y19 ('+' lead to J19)

Flying Jumpers (insulated wire)

☐	PP	G7-H14
☐	QQ	A19-A39
☐	RR	D39-G39
☐	SS	D29-G29
☐	TT	C17-D23
☐	UU	H16-G19
☐	VV	B16-I22
☐	WW	I9-J19
☐	XX	H2-J9
☐	YY	C3-A10
☐	ZZ	D3-G2

Semiconductors

☐	D1	1N4001	X45-C45 (banded end to X45)
☐	IC1	TL061 op amp; pin-1 to F1	
☐	IC2	TL062 dual op amp; pin-1 to F7	
☐	IC3	TL062 dual op amp; pin-1 to F20	
☐	IC4	NE570; pin-1 to F25	
☐	IC5	TL064 quad op amp; pin-1 to E43	

Potentiometers (T=terminal; NC= no connection)

☐	R32	20K	T1 NC; T2 to D44; T3 to H43
☐	R33	10K	T1 to J39; T2 to J35; T3 to J44

Jacks (T=terminal)

- ☐ input jack (1/4" 3-terminal/stereo): tip to T2 of S1; ring to negative ('–') lead of battery (black wire coming off battery snap); sleeve to Y15
- ☐ output jack (1/4" 2-terminal/mono): tip to T5 of S1; sleeve to Y20

Switches (T=terminal)

- ☐ S1 (DPDT stomp switch): T1 to T6; T2 to tip of input jack; T3 to J12; T4 to I34; T5 to tip of output jack
- ☐ S2 (SPST slide or toggle switch): one terminal to F13, other terminal to B17

Project No. G59

Vibrato-Matic III

The god of Stompbox Tone often decrees that the simpler the circuit, the sweeter the sound. VM3 offers a case in point.

Circuit Function

Signal Path: Axe feed couples through C4 to inverting preamp IC3-b, whose gain is fixed at ~6. Preamp output couples through R15 and a switchable capacitor bank selected by S2, to a voltage controlled phase shifter made up of IC3-c, IC2, and the associated components (IC2 is half an LM13600 transconductance amp configured as a single-ended voltage controlled resistor).

IC2 is biased off the output of IC3-a to counteract the DC offset that otherwise appears at the output of IC3-c, introduced by the voltage drop across the Darlington buffer transistor inside IC2. This measure keeps IC3-c's output bias close to 1/2V+, avoiding loss of headroom.

Control Path: IC1-b, -c, and their associated components form a soft triangle generator whose rate is controlled by R25 and whose output couples to vibrato depth control pot R24, thence through R21 to inverting amp IC1-d (whose negative output excursion is limited by D6-R20, to reduce control voltage feedthrough), thence to a nonlinear transfer block made up of R6-8, D1-2. The output of this block ties to IC2 pin 1, the control input.

Use

Pots & switches have these functions:

R24	vibrato depth
R25	vibrato rate
S1	effect/bypass
S2	capacitor select (determines frequencies affected by phase shift)

Initial settings: R24, R25 fully CW; S1 effect in; S2 any position. Connect unit to axe and amp; establish desired listening level. Strong vibrato should be noted. Take rate and depth controls through their ranges, and the capacitor-select switch through its three positions and note the effects on tone.

Notes

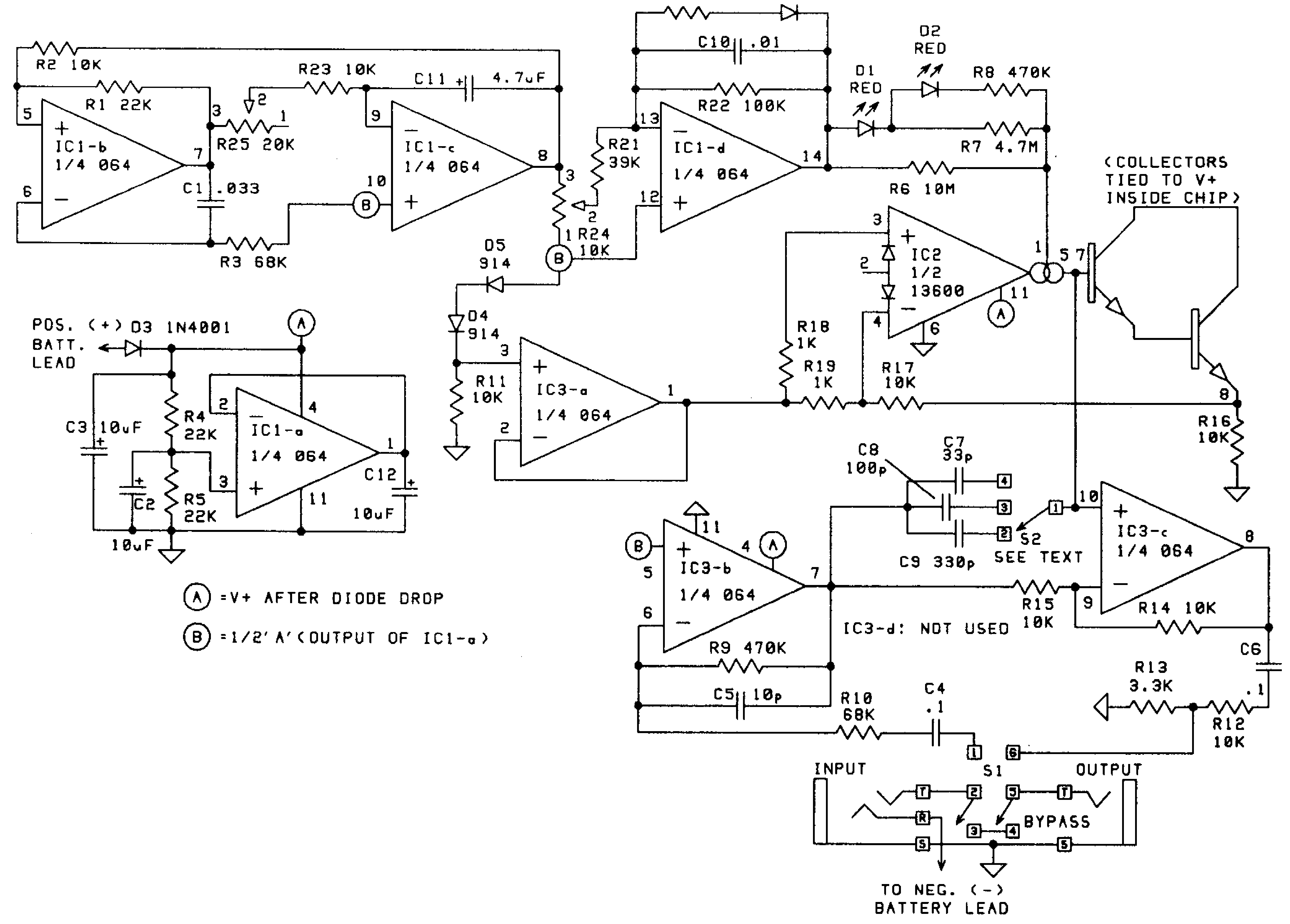
Low-power op amps mean long battery life. The prototype drew less than 2.4 ma from a 9V nicad.

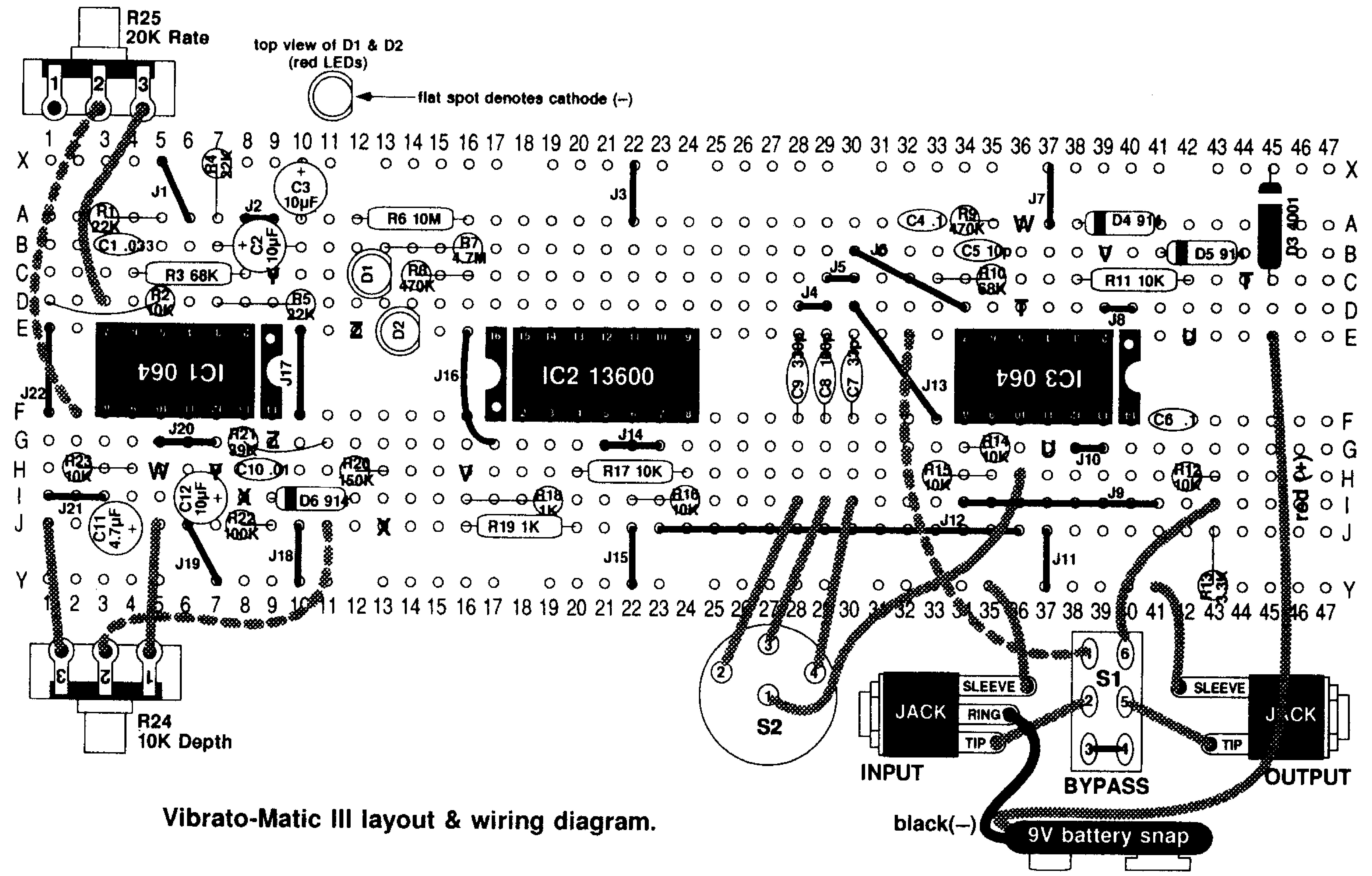
The preamp's fixed gain may have to be altered to suit axes having very high or very low output; replace R9 with a 1M-A pot to give variable preamp gain.

Because feedthrough is sensitive to the op-amp's negative voltage swing, use of types other than TL064 is not recommended.

This box delivers rich, sweet vibrato from a single stage; selectable phase-shift caps let the player choose from several timbres. In fact, the builder desiring an even wider spectrum of sound can go to a six-position rotary switch, using these capacitor values: 33pF, 100pF, 220pF, 330pF, 470 pF, and 0.001µF (circuit board columns 25–27 have been left open to accommodate the three additional caps). Each change in capacitance results in a distinctive change in timbre. The player looking to add basic vibrato to a stompbox repertoire need look no further.

Vibrato-Matic III schematic.





Vibrato-Matic III layout & wiring diagram.

Parts List/Soldering Checklist

UCB 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 goes in E9
[ ] 16-pin for IC2; pin-1 goes in F17
[ ] 14-pin for IC3; pin-1 goes in E40

Resistors

[ ] R1 22K (red-red-org) A3-A5
[ ] R2 10K (brn-blk-org) D1-D5
[ ] R3 68K (blu-gry-org) C4-C8
[ ] R4 22K (red-red-org) X7-A7
[ ] R5 22K (red-red-org) D7-D10
[ ] R6 10M (brn-blk-blu) A12-A16
[ ] R7 4.7M (yel-vio-grn) B13-B16
[ ] R8 470K (yel-vio-yel) C14-C16
[ ] R9 470K (yel-vio-yel) A34-A35
[ ] R10 68K (blu-gry-org) C33-C35
[ ] R11 10K (brn-blk-org) C38-C42
[ ] R12 10K (brn-blk-org) H42-H43
[ ] R13 3.3K (org-org-red) J43-Y43
[ ] R14 10K (brn-blk-org) G34-G35
[ ] R15 10K (brn-blk-org) H33-H35
[ ] R16 10K (brn-blk-org) I22-I24
[ ] R17 10K (brn-blk-org) H20-H24
[ ] R18 1K (brn-blk-red) I16-I19
[ ] R19 1K (brn-blk-red) J16-J20
[ ] R20 150K (brn-grn-yel) H12-H13
[ ] R21 39K (org-wht-org) G8-G11
[ ] R22 100K (brn-blk-yel) J8-J9
[ ] R23 10K (brn-blk-org) H2-H4

Bare Wire Jumpers

[ ] J1 X5-A6
[ ] J2 A8-A9
[ ] J3 X22-A22
[ ] J4 D28-D29
[ ] J5 C29-C30
[ ] J6 B30-D34
[ ] J7 X37-A37
[ ] J8 D39-D40
[ ] J9 I34-I41
[ ] J10 G38-G39
[ ] J11 J37-Y37
[ ] J12 J23-J36
[ ] J13 D30-F33
[ ] J14 G21-G23
[ ] J15 J22-Y22
[ ] J16 E16-G17
[ ] J17 E10-F10
[ ] J18 J10-Y10
[ ] J19 J6-Y7
[ ] J20 G5-G7
[ ] J21 I1-I3
[ ] J22 E1-F1

Capacitors

[ ] C1 .033µF B3-B4
[ ] C2 10µF B7-B10 ('+' lead to B7)
[ ] C3 10µF X10-A10 ('+' lead to X10)
[ ] C4 .1µF A32-A33
[ ] C5 10pF B34-B35
[ ] C6 .1µF F41-F42
[ ] C7 33pF E30-F30
[ ] C8 100pF E29-F29
[ ] C9 330pF E28-F28
[ ] C10 .01µF H8-H9
[ ] C11 4.7µF J3-J4 (polarity irrelevant)
[ ] C12 10µF I6-I7 ('+' lead to I7)

Semiconductors

[ ] D1 red LED C12-C13 (cathode, denoted by flat spot on body of LED, goes in C13)
[ ] D2 red LED E13-E14 (cathode, denoted by flat spot on body of LED, goes in E14)
[ ] D3 1N4001 X45-C45 (cathode, denoted by white band, goes in X45)
[ ] D4 1N914 A38-A41 (cathode, denoted by dark band, goes in A38)
[ ] D5 1N914 B41-B44 (cathode goes in B41)
[ ] D6 1N914 I9-I12 (cathode goes in I9)
[ ] IC1 TL064 quad op amp pin-1 goes in E9
[ ] IC2 LM13600 OTA pin-1 goes in F17
[ ] IC3 TL064 quad op amp pin-1 goes in E40

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

[ ] TT D36-C44
[ ] UU G37-E42
[ ] VV H16-B39
[ ] WW H5-A36
[ ] XX I8-J13
[ ] YY H7-C9
[ ] ZZ G9-E12

Potentiometers (T=terminal)

[ ] R24 10K T1 to J5; T2 to J11; T3 to J1
[ ] R25 20K T1 NC; T2 to F2; T3 to D3

Switches (T=terminal)

[ ] S1 (DPDT stomp switch) T1 to E32; T2 to input jack tip; T3 to T4; T5 to output jack tip; T6 to I43
[ ] S2 (3- or 6-position rotary switch; see text) T1 (center terminal) to H36; T2 to I28; T3 to I29; T4 to I30

Jacks (T=terminal)

[ ] input jack (1/4", 3-terminal 'stereo' jack) tip to T2 of S1; ring to negative (black, '–') battery lead; sleeve to Y35
[ ] output jack (1/4" 2-terminal 'mono' jack) tip to T5 of S1; sleeve to Y42

Leads from 9V battery snap

[ ] black (negative, '–') lead to ring of input jack
[ ] red (positive, '+') lead to E45

Project No. G60

Vibrato-Matic IV

Solid-state realization of the LDR-based, two-stage vibrato found in several classic Ampeg amps.

Circuit Function

Signal Path: Axe feed couples through C6 to the first phase shifter, made up of Q1, C4, C5, and LDR1. The output of this stage couples through C7 to a similar phase shifter made up of Q2, C8, C9, and LDR2. The output of the second phase shifter couples through C10 to Q3, configured as a source-follower to buffer the output signal, which couples through C11 to the output path. All three FETs are biased off a reference voltage obtained at the junction of R17-R18.

Control Path: IC1-c, -d, and associated components form a soft triangle oscillator whose rate is controlled by R23 and whose output feeds depth control pot R25, whose wiper ties through R4 to inverting amp IC1-a. R24 controls the static DC offset at the output of IC1-a, and thus allows waveform symmetry trim. The output of IC1-a feeds a nonlinear transfer block made up of D1-3 and R6-8, which drives D4 & D5 wired in series. As the diodes light, the photocells' resistances drop, and phase shifts.

Use

Pots & switch have these functions:

R23	vibrato rate
R24	waveform symmetry
R25	vibrato depth
S1	effect/bypass

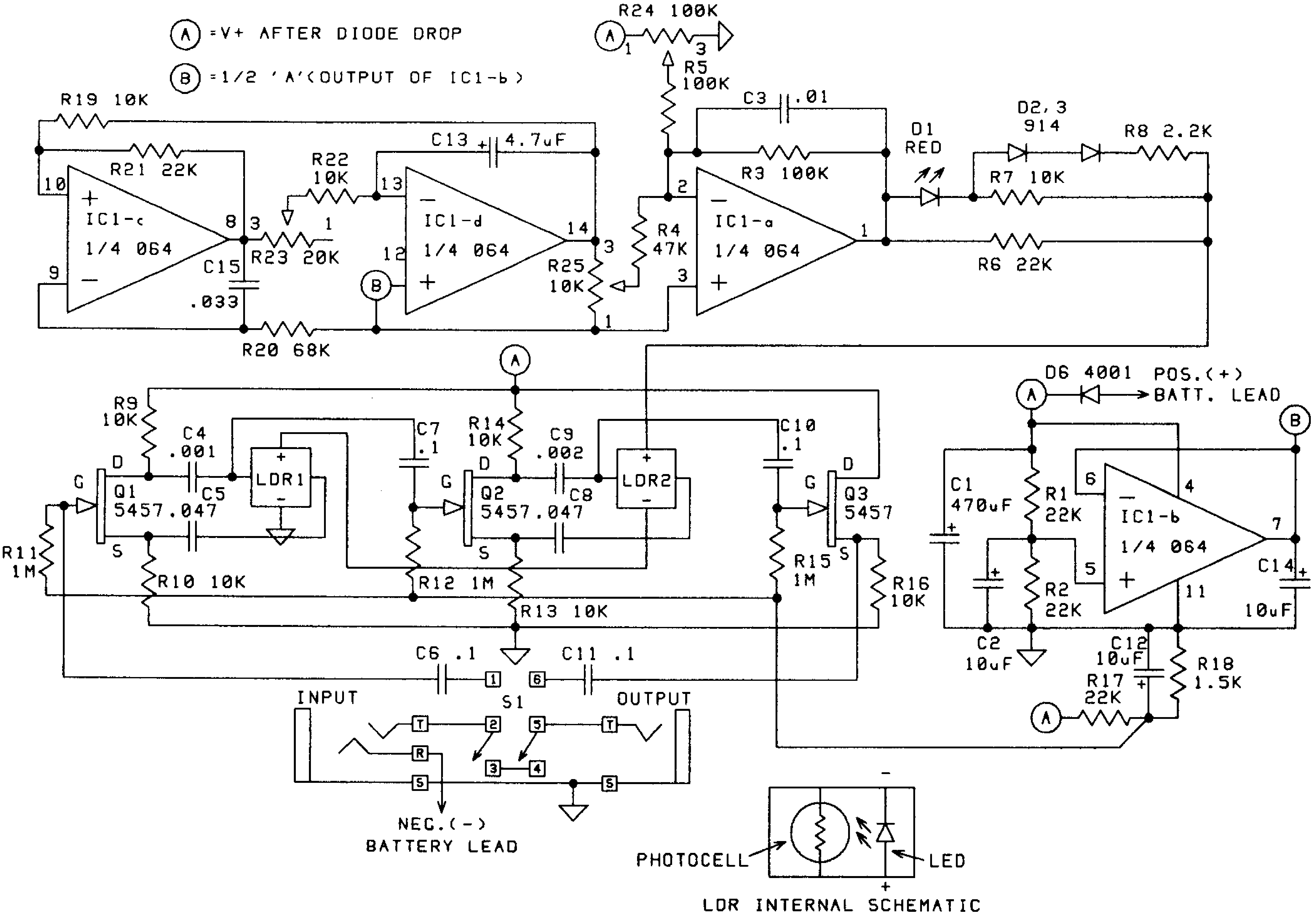
Initial settings: R23, R25 fully CW; R24 straight up; S1 effect in. Connect unit to axe and amp, establish desired listening level. In this state deep vibrato should be noted. Take rate and depth controls through their ranges and note the effect on sound. Turn R25 to 11 o'clock, R23 straight up. Adjust R24 to get the smoothest-sounding vibrato.

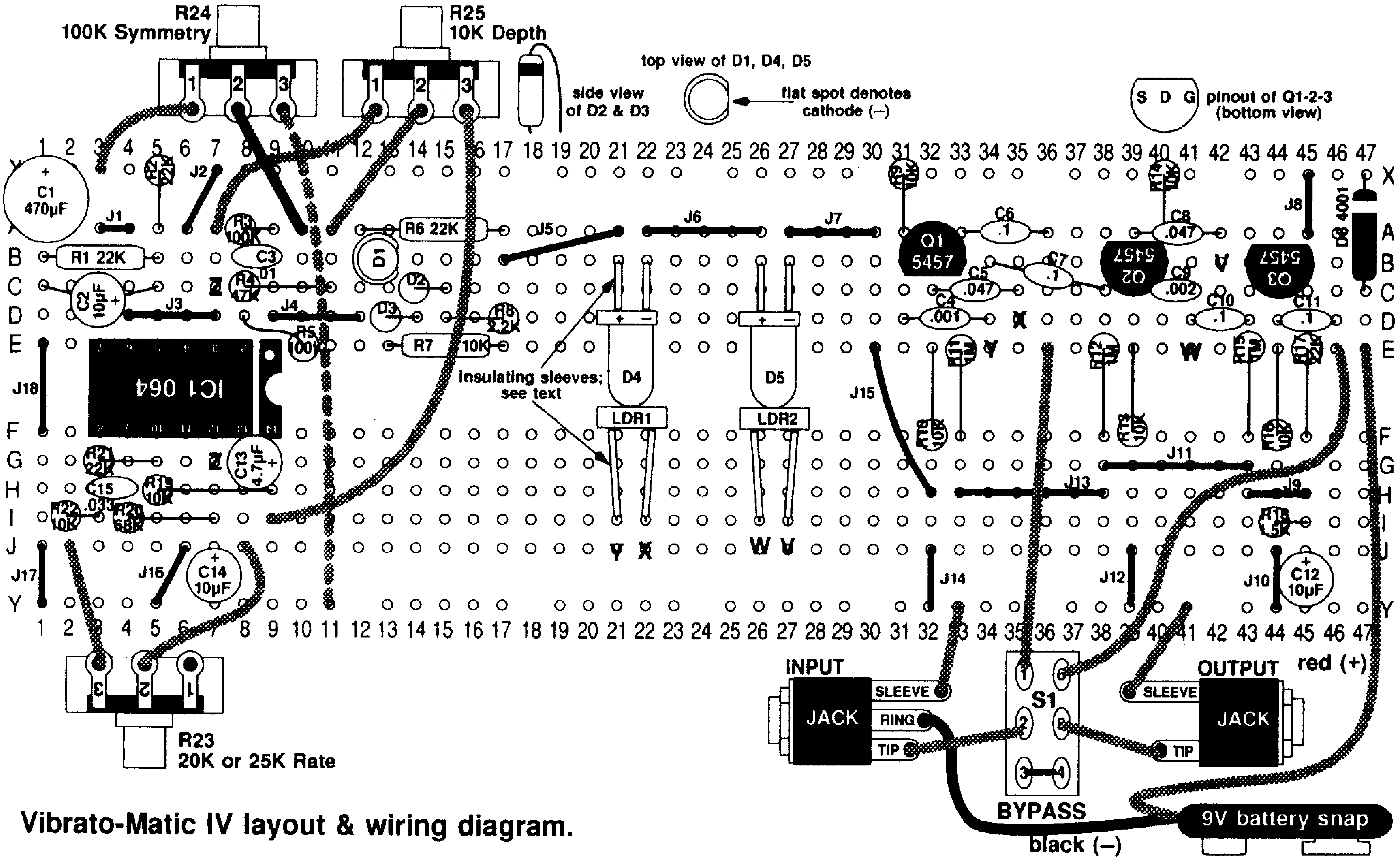
Notes

VM4 is fundamentally identical to the vibrato found in several Ampeg amps, but uses field-effect transistors in place of vacuum tubes. Op amps could have been used here, but discrete FETs are much quieter, allowing a unity-gain signal path with no noise reduction measures. Running @ 7.5V, the FETs have about 3V of headroom.

LDR1 and LDR2 are cadmium selenide photocells (Mouser Electronics part number 621-CL7P7HL), driven by D4 and D5, which are 'super-bright' orange LEDs (Hosfelt Electronics part number 25-277; any type whose output peaks near 620 nm and is advertised as a 'super-bright' type should work). While commercial optocouplers (CLM6000, VTL2C2) could have been used, they give poor vibrato depth due to slow decay. The CdSe photocell specified decays quickly and gives excellent results in pulsing effects. The layout diagram shows the coupler parts bare, but they must be wrapped in aluminum foil to exclude light; and their leads must be insulated to prevent shorting by the foil [*for more detail regarding construction of optocouplers, see Vol. 4, No. 3—Ed.*].

Vibrato-Matic IV schematic.





Vibrato-Matic IV layout & wiring diagram.

Parts List/Soldering Checklist

UCB 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 goes in E9

Resistors

☐	R1	22K	(red-red-org)	B1-B5
☐	R2	22K	(red-red-org)	X5-A5
☐	R3	100K	(brn-blk-yel)	A8-A9
☐	R4	47K	(yel-vio-org)	C8-C11
☐	R5	100K	(brn-blk-yel)	D8-E10
☐	R6	22K	(red-red-org)	A12-A17
☐	R7	10K	(brn-blk-org)	E13-E17
☐	R8	2.2K	(red-red-red)	D15-D17
☐	R9	10K	(brn-blk-org)	X31-A31
☐	R10	10K	(brn-blk-org)	E32-F32
☐	R11	1M	(brn-blk-grn)	E33-F33
☐	R12	1M	(brn-blk-grn)	E38-F38
☐	R13	10K	(brn-blk-org)	E39-F39
☐	R14	10K	(brn-blk-org)	X40-A40
☐	R15	1M	(brn-blk-grn)	E43-F43
☐	R16	10K	(brn-blk-org)	E44-F44
☐	R17	22K	(red-red-org)	E45-F45
☐	R18	1.5K	(brn-grn-red)	I44-I45
☐	R19	10K	(brn-blk-org)	H5-H9
☐	R20	68K	(blu-gry-org)	I4-I7
☐	R21	22K	(red-red-org)	G3-G5
☐	R22	10K	(brn-blk-org)	I2-I3

Bare Wire Jumpers

☐	J1	A3-A4
☐	J2	X7-A6
☐	J3	D4-D7
☐	J4	D9-D12
☐	J5	B17-A21
☐	J6	A22-A26
☐	J7	A27-A30
☐	J8	X45-A45
☐	J9	H43-H45
☐	J10	J44-Y44
☐	J11	G38-G43
☐	J12	J39-Y39
☐	J13	H33-H38
☐	J14	J32-Y32
☐	J15	E30-H32
☐	J16	J6-Y5
☐	J17	J1-Y1
☐	J18	E1-F1

Capacitors

☐	C1	470µF	X1-A1 ('+' lead to X1)
☐	C2	10µF	C1-C5 ('+' lead to C5)
☐	C3	.01µF	B8-B9
☐	C4	.001µF	D31-D34
☐	C5	.047µF	C32-C35
☐	C6	.1µF	A33-A36
☐	C7	.1µF	B34-C38
☐	C8	.047µF	A39-A42 (note that C8 partly overflies the lead of R14)
☐	C9	.002µF	C40-C41
☐	C10	.1µF	D41-D43
☐	C11	.1µF	D44-D46
☐	C12	10µF	J45-Y45 ('+' lead to J45)
☐	C13	4.7µF	G8-G9 (polarity irrelevant)
☐	C14	10µF	J7-Y7 ('+' lead to J7)
☐	C15	.033µF	H3-H4

Semiconductors

☐	D1	red LED B12-B13 (cathode, denoted by flat spot on body of LED, goes in B13)
☐	D2	1N914 C14-C15 (banded end must face C15)
☐	D3	1N914 D13-D14 (banded end must face D14)
☐	D4	orange LED; see text; anode (+) lead in B21, cathode (–) lead in B22
☐	D5	orange LED; see text; anode (+) lead in B26, cathode (–) lead in B27
☐	D6	1N4001 X47-C47 (banded end to X47)
☐	IC1	TL064 quad op amp; pin-1 to E9
☐	LDR1	CdSe photocell; see text; one lead in I21, one lead in I22
☐	LDR2	CdSe photocell; see text; one lead in I26, one lead in I27
	Q1, 2, 3	2N5457 or MPF102 field-effect transistor; mount as follows:
☐	Q1	S to B31, D to B32, G to B33
☐	Q2	S to B40, D to B39, G to B38
☐	Q3	S to B45, D to B44, G to B43

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

☐	VV	J27-B42
☐	WW	J26-E41
☐	XX	J22-D35
☐	YY	J21-E34
☐	ZZ	C7-G7

Potentiometers (T=terminal, NC=no connection)

☐	R23	20K or 25K; T1 NC; T2 to J8; T3 to J2
☐	R24	100K; T1 to X3; T2 to A10; T3 to Y11
☐	R25	10K; T1 to A7; T2 to A11; T3 to I9

Switches (T=terminal)

☐ S1 (DPDT stomp switch) T1 to E36; T2 to input jack tip; T3 to T4; T5 to output jack tip; T6 to E46

Jacks (T=terminal)

☐ input jack (1/4", 3-terminal 'stereo' jack) tip to T2 of S1; ring to negative (black, '–') battery lead; sleeve to Y33

☐ output jack (1/4" 2-terminal 'mono' jack) tip to T5 of S1; sleeve to Y41

Leads from 9V battery snap

☐ black (negative, '–') lead to ring of input jack

☐ red (positive, '+') lead to E47

Beginner's View

(continued from page 3)

(the negative terminal; the vertical line on the schematic symbol, the banded end on the part itself) to the output terminal of IC1-d. Whether D6 conducts depends on the voltage difference between its two ends. With R24 at minimum, no AC control signal is getting through R21. The resting DC potential at IC1-d's output, and at pin-13, is very close to 1/2V+—'B' inside a circle on the schematic. In this state D6 does not conduct, because no voltage difference exists across it.

Now assume that R24 is turned fully clockwise; the maximum control voltage is coming through. Gain supplied by IC1-d equals (R22÷R21), or about 2.6. This is enough to cause the control voltage to clip at both positive and negative limits at the output of IC1-d. When the triangle wave coming off IC1-c swings to its negative limit, the same signal clips at the positive limit at the output of IC1-d, because this op amp inverts the signal. Positive clipping is intentional; we want the maximum positive voltage that IC1-d can deliver. Because the signal is positive, and D6's cathode faces the output terminal, D6 does not conduct. D6 and R20 act as if they aren't in the circuit.

When the triangle wave out of IC1-c swings to its positive limit, the output of IC1-d tries to swing to its negative limit; but once the output of IC1-d swings 0.6 volts below 'B', D6 conducts current. R20 now appears in parallel with R22, so the gain of IC1-d falls from (R22÷R21) to (R22 in parallel with R20) ÷ (R21); or about (60,000 ÷ 39,000) = 1.5. This keeps the output of IC1-d from clipping at its negative limit, but does not affect the positive swing.

Q. What's the point of this maneuver?

A. To reduce feedthrough.

Q. What's feedthrough?

A. Feedthrough is the percentage of the control voltage that appears at the output of IC3-c along with the audio signal. Because the control voltage is rhythmic, feedthrough manifests as audible pulses, sometimes called *beating*. In the prototyping stage of this box, we found that, when S2 selected C7, feedthrough reached an excessive level; and that feedthrough peaked at the negative control limit. D6 and R20 were added to limit the negative swing out of IC1-d and thus reduce feedthrough.

Q. What's the point of C10?

A. To soften the edges of the control voltage in IC1-d. Sharp edges generated anywhere inside a stompbox tend to bleed through to the output.

Q. I'm checking out VM4, dude. The notion of building optocouplers right on the board looks a little intimidating.

A. First time, yeah, the assembly takes plenty of patience. But the board has extra space around the parts to make it easy for a less experienced builder. And once you've built one, succeeding couplers become a snap.

Q. I have to insulate the couplers' leads?

A. Unless you can shield them from light without shorting the leads, which aluminum foil will do.

Q. You mean wrap 'em in foil?

A. Photocells react to ambient light. Wrapping them in foil is the simplest way I know to keep out light. The procedure isn't as hard as it looks. Vol. 4, No. 3 treats the process in great detail.

Q. I'm looking at the schematic for VM4, dude. D1-3 and R6-8 bear an uncanny resemblance to the nonlinear transfer block used in VM3.

A. You called it, dude. Although the stage being tuned is an optocoupler instead of an OTA, the fundamental action is the same.

Q. You say this box has 3V of headroom. That doesn't seem like much.

A. It's plenty for all but the hottest pickups. The nominal gain of the signal path is 1. If your pickups put out more than 3V, turn down the volume at the axe.

Q. What's the point of Q3? Why not feed the junction of C9 and the LDR out to the amp?

A. Q3 acts as a source follower. It prevents loading losses.

Q. What's a source follower?

A. The FET equivalent of an emitter follower.

Q. Okay, I'll bite: What's an emitter follower?

A. You see the term 'follower' a lot in electronics. Op-amp *voltage followers*, bipolar transistor *emitter followers*, and field-effect transistor *source followers* all perform basically the same functions. First, they show the signal feeding them a very high impedance. In the case of an op amp or an FET, this can exceed 10 million ohms. The BPT's input impedance is lower, but may exceed 100,000 ohms. Second, all three followers exhibit low output impedance. The actual impedance is not that important here, only that it's low enough to drive the succeeding stage without significant voltage loss. All three types of followers make perfect buffers.

Q. What's a buffer?

A. What we've just been describing: a stage with high input impedance, low output impedance. Buffers are used to avoid voltage loss due to divider action, which we discussed at length last ish.

Q. Can vacuum tubes make buffers?

A. Sure. They're called *cathode followers*.

Q. Why'd you choose those values for C4-5-8-9?

A. Those are the values found in Ampeg amps. Changing caps alters the frequencies affected by the phase shift. If you breadboard the circuit, try 470pF for C4 and 820pF for C9; or both 470 pF; etc. The smaller the caps, the higher the frequencies emphasized by phase shift. Smaller caps make a sound more to my taste, and more like that of Vibrato-Matic from the *Cookbook*.

Q. This low-voltage varistor phase engine intrigues me, dude.

A. After a good bit of experimenting, I can take varistors or leave 'em. They give smooth vibrato, but every one tested so far has been noisy—some samples prohibitively so; they suffer feedthrough, and they need a lot more than 9V of control voltage to give decent depth. The biggest obstacle is parasitic capacitance. Some samples measured 0.014µF.

Q. Last question, dude: What's the point of cooking up three vibrato stompboxes?

A. Each box sounds different, and the differences aren't subtle. The grand objective is to take control of your sound. If your amp has no vibrato, or if you hanker for a fresh take on this effect, then fire up that soldering iron, dude.

References

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Coming in Vol. 5, No. 2: Supplemental Sustain Issue

- *Upward Sustain*
- *Downward Sustain*
- *Dual-Mode Sustain*
- *Beginner's View*
- *Sustain-O-Matics III, IV, V*
- *and, as always, a few surprises*