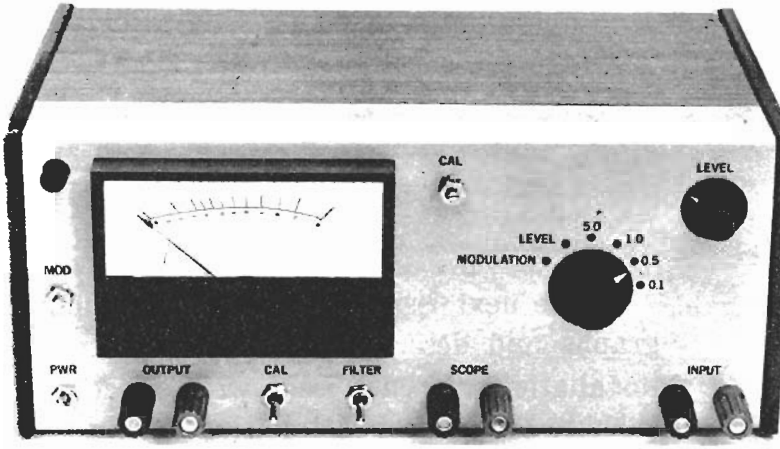
Build a Direct-Reading Wow & Flutter Meter



By HARRY KOLBE

EVERYBODY who leans toward the serious side of audiophilia talks about wow and flutter. But almost nobody does anything about it—or them—depending on how many different bad guys you find amongst the three words. In fact not too many hi-fi fans know how one goes about making meaningful measurements of wow and flutter.

But most of us can talk intelligently about wow and flutter because we've heard these culprits at work. Wow and flutter are the retchings of music from record or tape when subjected to periodic and queasingly regular variations in the speed of turntable or tape deck. If these draws and swells go slowly (under 6 cps) they're called *wow*; if more quickly (up to 250 cps) they're called *flutter*. So they're a little different, one from the other, while remaining close cousins under the skin.

Our Wow & Flutter Meter almost for the first time enables a non-pro, outside-the-lab hobbyist to substantiate what he believes he's hearing. Our meter also helps to determine exactly how much wow and flutter he has to deal with in terms of percentage of speed variation. And it's an instrument any experienced hobbyist can build and calibrate successfully.

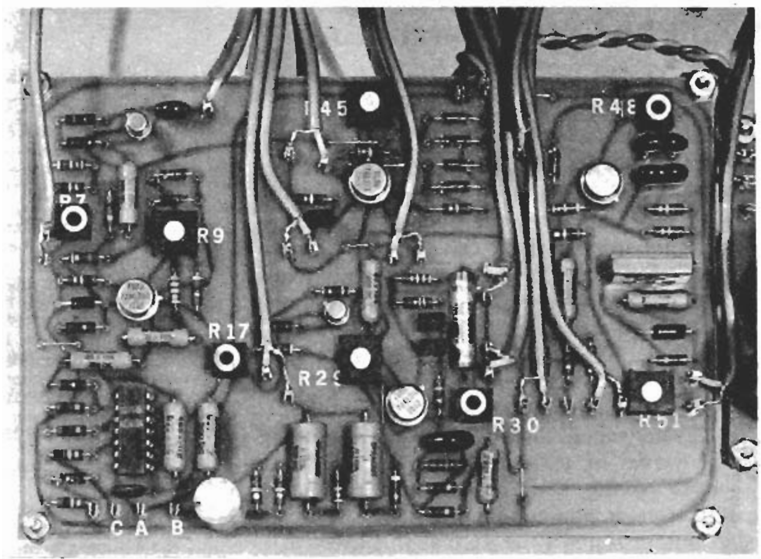
Though wow and flutter could be the result of either a positive speed variation (with record or tape going faster than spec and then back to spec) or a negative swing (slower than and then back to spec), the direction of swing means little. It's the swing or variation itself that causes the trouble and typically may be due to an out-of-round rotating component.

Essentially, speed variations frequency-modulate program material. You can hear the problem best on a sustained musical tone, such as a long organ note. As turntable or transport speed increases, tone frequency increases proportionally. As speed decreases, frequency dips.

Many years ago researchers came up with a numerical way of specifying degree of speed variation. The unit of measurement is RMS percentage of speed variations. RMS stands for Root-Mean Square, a term often used in AC voltage measurements. The RMS concept is a convenient way to transform a periodically-changing quantity into an equivalent steady (non-changing) quantity.

Let's relate RMS percentage to wow and flutter. We'll take a turntable with a particularly bad case of wow at a frequency of 4 cps. This means the turntable speeds up or slows down significantly four times each second. If you draw the pattern of speed variation

Fig. 1—Majority of components are mounted on pc board, shown almost half-size at right. IC mounting sockets could be utilized on your board if you don't like soldering directly to IC leads. Tolerance of components is not critical but best overall meter accuracy is assured with values and tolerances called for in Parts List. Be sure to use shielded cable where called for on schematic. Solder shield wire only at points designated in schematic.



on a piece of graph paper you end up with a curve shaped like a sine wave.

The RMS reading of this periodically-changing function (speed vs time) is a convenient average value that makes it easy to compare turntable specs and, in general, to talk about flutter and wow. You use standard AC calculation formulas to compute RMS percentage—only now, instead of working with peak and peak-to-peak voltages, you use *peak-to-peak percentage speed error.*

Thus, a faulty turntable might display ± 5% peak speed variations, running both faster and slower than spec. The peak-to-peak percentage variation would be 10% so the RMS percentage would work out this way: 0.707 x Peak Variation = 0.707 x 5% = 3.54% RMS.

In this issue we're presenting Part I, which tells how our Wow & Flutter Meter operates, how you can use it, the functions of the various components and circuits found in the schematic and a Parts List. In our next issue we'll present detailed construction information, data on calibration, more advice on the use of the instrument and, lastly, some tips on how to cure what our Wow & Flutter Meter has diagnosed.

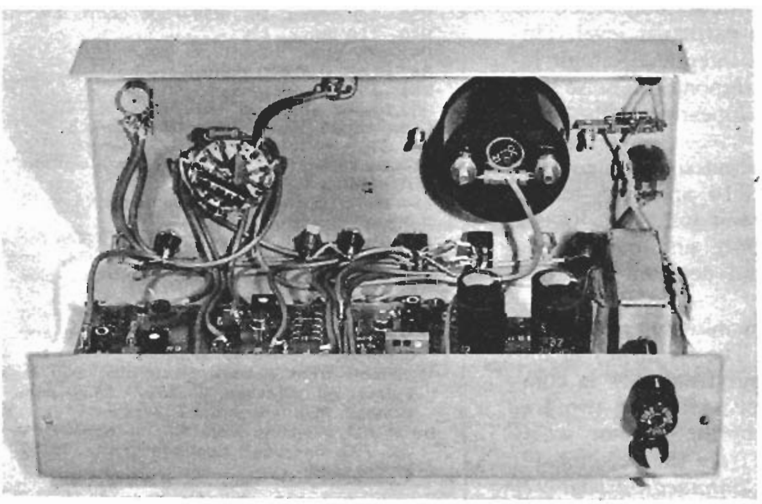


Fig. 2—Power supply is mounted on separate pc board, shown to right of main board. M1 is shown on front panel with C17 connected across its terminals. M1 and C17 are wired to remainder of circuit via shielded cable but two unshielded wires twisted together work as well. Range switch S4 is to left of M1. Between S4 and M1 is pot R41 (Cal). To the left of S4 is pot R1 (Level), while to the right of M1 is pot R56 (Modulation).

Build a Direct-Reading Wow & Flutter Meter

How it Works

The output from your tape deck or preamplifier is fed to pot R1 (*Level*) via binding posts BP1 and BP2. The signal is coupled to the gate of transistor Q1, connected as a source follower. Since Q1 only slightly loads pot R1, the input impedance of the Wow & Flutter Meter is effectively 500,000 ohms—a value sufficiently high to work from any source.

The signal from Q1 is injected into IC1, a device which directly converts incoming sine waves of varying amplitude to square waves having equal amplitude. Normally, IC1 is in a non-conducting state. There is no output signal from IC1 at this time.

When a signal is fed into it, IC1 switches into its conducting state. Ordinarily, there is no output signal from IC1. But when a signal reaches IC1, it switches into a conducting state. The IC conducts as long as a signal is present at the input terminal.

The output of IC1 is a square wave having a pulse width equalling the frequency of the input waveform. If the input is not a pure sine wave, the duty cycle of the square waves from the output of IC1 will vary from waveform to waveform. This unequal duty cycle is the result of the wow and flutter signal component modulating the otherwise-pure 3-kc test signal. It is the parameter we are looking at as the meter needle swings up and down the scale.

Potentiometer R9 provides a DC voltage to IC1, forcing it to conduct only when the input signal reaches a particular level. This method of biasing the integrated circuit insures that it doesn't respond to noise and other spurious signals appearing at the input terminals.

The square-wave output signal is coupled via components C3, R14 and R15 to the input of integrated circuit IC2. This IC is a phase-locked loop device and contains an oscillator, amplifier and detector built into the chip.

The IC's oscillator is initially adjusted via pot R17 to 3,000 cps. The frequency of this oscillator and the input frequency is compared in IC2's detector. After the two frequencies are sampled by the detector, a DC output signal emerges from the detector.

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PARTS LIST

BR1—Motorola HEP-175 or equiv.
BP1-BP6—Insulated five-way binding post
Capacitors: 200 V unless otherwise noted
C1—150 μμf silver mica C4,6—.022 μf
C2,3,15,21,22,27—.01 μf C5—.001 μf
C7—100 μf, 15 V electrolytic C8,9—.1 μf
C10—.0039 μf C11—330 μμf silver mica
C12,13,16—10 μf, 10 V tantalum electrolytic
C14—1 μf, 35 V tantalum electrolytic
C17—10 μf, 25 V electrolytic
C18,19—1000 μμf silver mica
C20—1800 μμf silver mica
C23,24—1000 μf, 15 V electrolytic
C25,26—1000 μf, 25 V electrolytic
D1-D8—1N458 or equiv.
*D9—Motorola MV-1666 (Varicap)
D10,11—Zener diode; 12 Volts @ 1 watt (Motorola HEP-105 or equiv.)
D12—Zener diode; 6.2 Volts @ 1 watt (Motorola HEP-103 or equiv.)
F1—¼-A fuse
IC1—Integrated circuit (Fairchild U5B7710393)
IC2—Integrated circuit (Signetics NE 565) See note below.
IC3-5—Integrated circuit (Fairchild U9T7741393)
M1—VU meter (Simpson 543 or equiv.)
NL1—Neon lamp (NE-2 or equiv.)
Q1,2—2N4220A transistor
Resistors: all ¼-watt, 5% unless otherwise noted
R1—1,000,000-ohm, audio-taper pot.
R2,54—5,600,000 ohms R3—1,200 ohms
R4,36,47—47,000 ohms
R5,15,16—1,000 ohms
R6,11,21,53—10,000 ohms
R7,17—5,000-ohm, single-turn pot.
R8—2,700 ohms
R9,59—1,000-ohm, single-turn pot.
R10—4,700 ohms R12—33,000 ohms
R13—510 ohms R14—6,200 ohms
R18—62,000 ohms
R19,26,27,52—1,000,000 ohms
R20,22,49,50,55—51,000 ohms
R23,44—15,000 ohms R24—12,000 ohms
R25—9,100 ohms R28—1,800,000 ohms
R29,45,51—10,000-ohm, single-turn pot.
R30,48—50,000-ohm, single-turn pot.
R31—1,300 ohms R32—13,000 ohms
R33—330,000 ohms R34—3,300,000 ohms
R35—1,500 ohms R37—5,000 ohms, 1%
R38—620 ohms, 1% R39—500 ohms, 1%
R40—120 ohms, 1%
R41—250-ohm, linear-taper pot.
R42,43,46—100,000 ohms
R56—10,000-ohm, linear-taper pot.
R57,58—68 ohms, ½ watt
R60—82,000 ohms S1—DPDT switch
S2—SPDT switch S3—SPST switch
S4—2-pole, 6-position shorting, rotary ceramic (Centralab PA-2002)
T1—Power transformer; secondary: 25 V @ 0.5 A (Calectro D1-752)
1—10⅛ x 4½ x 6¼-in. cabinet. Ten-Tec MW-10 (Available from Ten-Tec, Inc., Industrial Park, Sevierville, Tenn. $11 plus postage)
Misc.—dry-transfer lettering, fuseholder, neon lamp assembly, printed circuit board and supplies, shielded audio cable.
*Available from Newark Electronics, 500 N. Pulaski Rd., Chicago, Ill. 60624 $3.60 plus postage. Minimum order $10.
Note: IC2 available from Circuit Specialists Co., P.O. Box 3047, Scottsdale, Ariz. 85257 $9 postpaid.

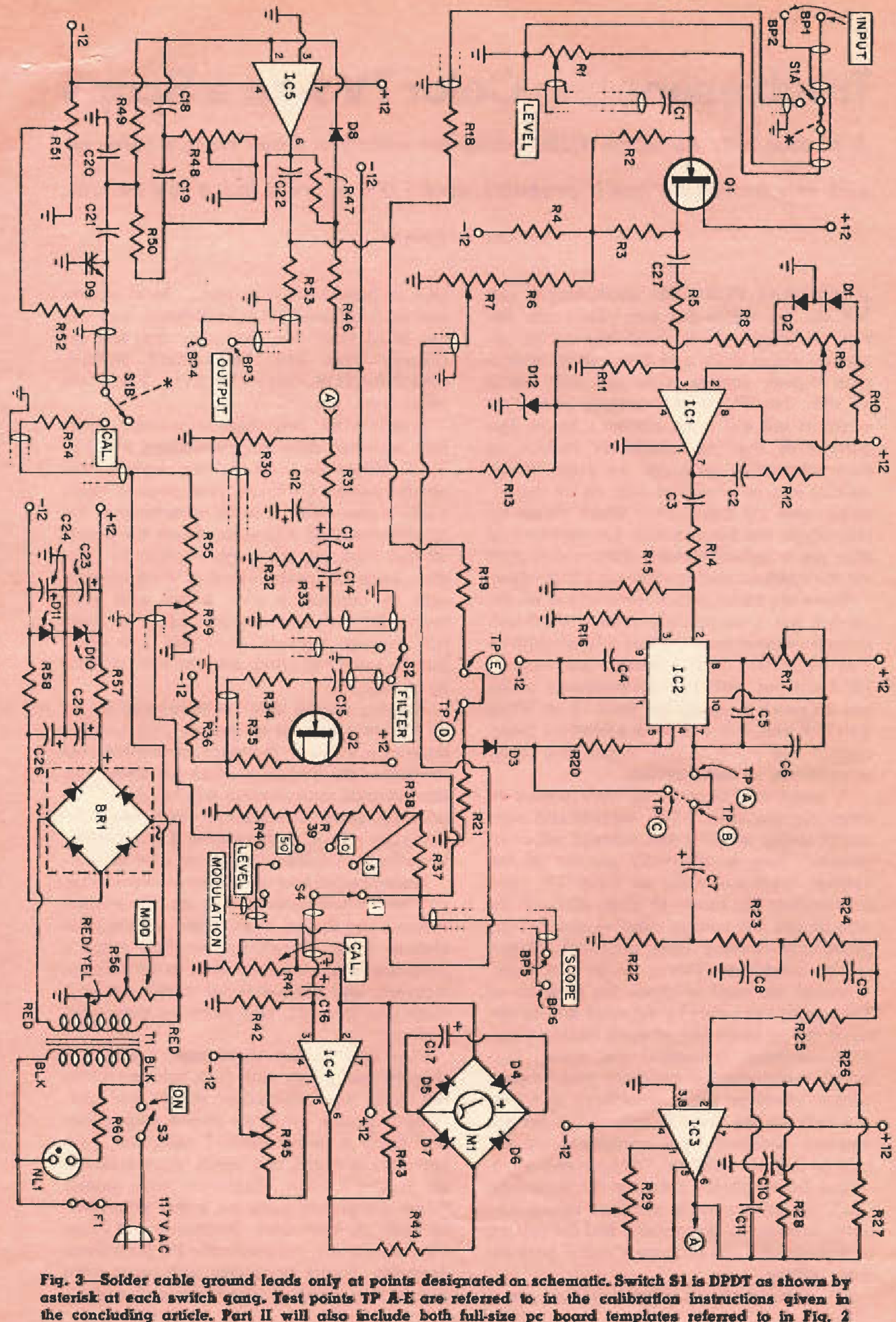

Fig. 3—Solder cable ground leads only at points designated on schematic. Switch S1 is DPDT as shown by asterisk at each switch gang. Test points TP A-E are referred to in the calibration instructions given in the concluding article. Part II will also include both full-size pc board templates referred to in Fig. 2

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The DC output voltage is generated by the detector after it responds to the difference of the two frequencies. For instance, if the square wave coming from IC1 was 3 kc, then the output of IC2's detector would be a DC voltage corresponding to zero cps. Wow and flutter components, however, change the frequency of the incoming test signal, producing a proportional DC voltage.

The frequency-mixing and detecting process within IC2 forces the PLL to follow input frequency variations. As the input signal's duty cycle changes, the detector's output varies correspondingly.

The output of IC2's detector is amplified and appears at pin 7. It is coupled via capacitor C7 to a low-pass filter.

Resistors R22 through R25 and capacitors C8 and C9 form a 200-cps low-pass filter. Any remaining 3,000-cps component is attenuated by this filter, and further reduced in amplitude by integrated circuit IC3. The bandwidth of the signal arriving at point A in the schematic consists mainly of frequencies from 200 cps down to 4 cps.

Wow and flutter frequencies arriving at the junction of components R30 and R31 normally are sent through the weighting network consisting of components C12-C14 and R31-R33. This network shapes the signal to comply with the latest psychoacoustic weighting standards which apply to wow and flutter test procedures.

The signal also can be bypassed around the weighting network via pot R30.

After the signal has been weighted, it is fed to transistor Q2, connected as a source follower. This stage couples the signal to attenuator switch S4. Transistor Q2 also feeds the signal to binding posts BP5 and BP6.

The last integrated circuit in the amplifier chain is IC4. Meter M1 is driven by it. Note that M1 and associate components are in the feedback loop. Meter linearity is assured at low input signal levels.

Meter M1 is a modified VU meter. Since only the ballistics of the movement are required for our purposes, the meter's internal rectifier assembly and matching resistor network are removed before the meter is mounted to the cabinet.

Electrolytic capacitor C17 connects across the terminals of meter M1 to assist the meter's own damping action, which makes a meaningful reading possible.

Calibration is a simple procedure with integrated circuit IC5 connected as a 60-cps modulated test oscillator. Voltage-variable capacitance diode D9 is connected in parallel across one of the frequency-determining capacitors. Our Wow & Flutter Meter is calibrated to its full-scale (5%) reading by modulating the oscillator with 60-cps line frequency via D9. Without the line frequency modulating this 3,000-cps oscillator, the output of IC5 is available to make record and playback measurements.

Our Wow & Flutter Meter's power supply is a conventional bipolar affair. Zener diodes D10 and D11 stabilize the output of each leg of the supply. These diodes also provide a low-impedance path to ground for AC voltages appearing across C23 and C24.

Though our Wow & Flutter Meter is meant to be an instrument that both measures and provides a visual readout of what it finds, scope readings also are possible through use of part of its circuitry. A scope connected to terminals BP5 and BP6 will display essentially the same information as M1 except in pattern form.

Our meter will most often be used with a test tape or record made specifically for the purpose of measuring wow and flutter. Suitable test tapes are available for reel-to-reel machines from Ampex. CBS Laboratories has a test record, BTR-150, available for the purpose of making wow and flutter measurements on a turntable.

Connect the output of your tape deck or preamp-connected turntable to BP1 and BP2 (*Input*). Place the test tape or record on the machine and set it in motion.

Turn range switch S4 to the *Level* position. Then adjust pot R1 (*Level*) for a half-scale reading.

Switch S1 (*Calibrate*) is in its off setting. Switch S2 (*Filter*) is in its on or off position, according to the measurement mode (RMS or peak-to-peak) desired.

Set the range switch to the position giving best meter deflection. The needle may oscillate slowly about a reading. If this occurs, choose the highest point of needle travel as your reading.

If you want to make your own test tape, set the tape recorder in its *Record* mode and connect the machine to binding posts BP3 and BP4 (*Output*). Adjust for optimum level of the recorded signal using only virgin tape. Rewind the reel and set the machine in its *Playback* mode.

Although all test tapes should be played through the deck from end to end, it is permissible to make wow and flutter measurements by running off a section at the beginning of the reel, another at reel midpoint, and a third at the end of the reel.

Complete instructions for building the Wow & Flutter Meter, plus other information, will be presented in Part II in our next issue.

Sidestacked TV Antenna

IC1 = 710 Comparitor

IC3-5 = 741 OP-AMP