BUILD A

DIGITAL MARINE/ AUTO TACHOMETER

BY MICHAEL D. HILKER

Measures rpm in thousands and hundreds for car or boat engine

THE analog meter movement, which has been the traditional display device for automotive and marine tachometers, suffers from two primary disadvantages. First, it is inherently inaccurate. More important, however, it requires the driver or boater to divert some of his attention away from navigating to interpret the meaning of the meter's pointer swing against its scale. In congested traffic, that attention is better given to watching other drivers.

The digital tachometer overcomes the two main disadvantages of the analog-meter tach. It can be made to indicate rpm with a high degree of accuracy. And, because it displays numbers that need no interpretation, instead of having to guess at an ambiguous pointer swing, you can give your whole attention to your driving.

The digital tachometer described in this article can be used with engines with two, three, four, six, eight, 12, or 16 cylinders that operate in the two- or the four-cycle mode. The TTL system derives its power from any 6- to 24-volt dc negative-ground automotive or marine electrical system. It employs a voltage regulator and an inexpensive 555 timer IC clocking oscillator time base.

About the Circuit. The schematic diagram of the auto/marine digital tach is shown in Fig. 1. It is basically a frequency counter that is modified for tachometer use. Only two decades of display are used, with *DIS1* indicating hundreds and *DIS2* indicating thousands of rpm. (Tens and units displays are not used because they would wander so fast that they would be distracting. In any event, two decades of display are sufficient for a tachometer.)

ENGINE TYPE		DISPLAY READOUT
Stroke/Cylinders		at 60 Hz (×100 rpm)
2/4	4/4	18
2/3	4/6	12
2/4	4/8	9
2/6	4/12	6
2/8	4/16	4*

*Halfway between 4 and 5

Because only thousands and hundreds of rpm displays are used, without the tens and units displays, the otherwise poor update of the frequency (between 6.6 Hz at 100 rpm and 659 Hz at 9900 rpm for a four-cycle, eight-cylinder engine) is improved by having the master clock count for only 150 ms. This provides a display update rate of approximately seven times per second.

Each display has its own 7490 decade counter (*IC5* and *IC8*), 7475 latch (*IC6* and *IC9*), and 7447 decoder/driver (*IC7* and *IC10*). The displays themselves can be incandescent or green or yellow common-anode LED-type 7-segment devices. (Note: *It is illegal to use red displays for anything but an emergency indicator in an automobile.*)

The master clock oscillator circuit (*IC3*) must be initially adjusted, according to the type of engine with

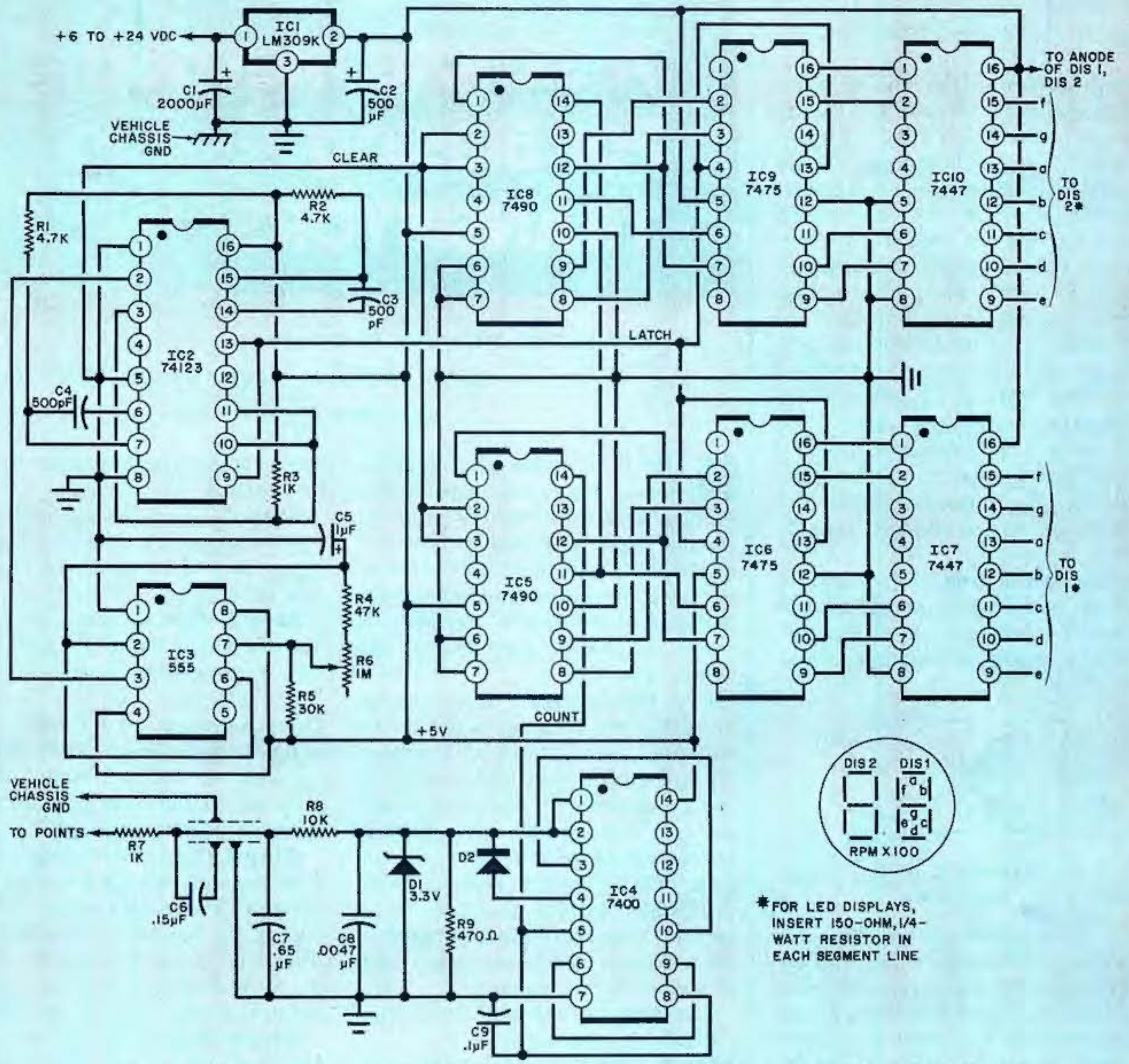


Fig. 1. The tachometer circuit is basically a frequency counter with two decades of display.

PARTS LIST

C1—2000-μF, 30-volt electrolytic capacitor (voltage rating must be greater than actual input potential)
C2—500-μF, 10-volt electrolytic capacitor
C3, C4—500-pF tantalum disc capacitor
C5—1-μF, 10-volt electrolytic capacitor
C6—0.15-μF disc capacitor
C7—0.65-μF disc capacitor
C8—0.0047-μF disc capacitor
C9—0.1-μF disc capacitor
D1—3.3-volt, 500-mW zener diode (HEP-Z0206 or similar)
D2—1N4001 or similar silicon rectifier diode
DIS1, DIS2—7-segment display (see text)
IC1—LM309K 5-volt regulator
IC2—74123 integrated circuit
IC3—555 timer integrated circuit
IC4—7400 integrated circuit
IC5, IC8—7490 integrated circuit
IC6, IC9—7475 integrated circuit
IC7, IC10—7447 integrated circuit
R1, R2—4700-ohm, ½-watt resistor
R3, R7—1000-ohm, ½-watt resistor
R4—47,000-ohm, ½-watt resistor
R5—30,000-ohm, ½-watt resistor
R6—1-megohm potentiometer
R8—10,000-ohm, ½-watt resistor
R9—470-ohm, ½-watt resistor
Misc.—Printed circuit or perforated board and sockets for IC's and displays; suitable housing; heat sink for IC1 (Wakefield No. 680-12 or similar); dry-transfer lettering kit; filter for display; shielded cable; mounting hardware; hookup wire; solder; etc.

which the tach is to be used, before you can operate the tach properly. This, however, is the only calibration required of the system, via potentiometer *R6*. Once set, this adjustment need not be touched again unless you remove the tach and use it with a different type of engine. The number of pulses counted between each update is then equal to approximately 0.167 times the actual number of hertz and corresponds to the engine's rpm, which is displayed by *DIS1* and *DIS2*.

The 74123 dual retriggerable monostable multivibrator IC provides the clear pulses for decade counters *IC5* and *IC8* and latch pulses for latches *IC6* and *IC9*, keyed to the output of *IC3*. The 7400 quadruple dual-input NAND gates in *IC4* provide the gating required for proper operation of the tachometer.

Integrated circuit *IC1* is a 5-volt regulator. Potentials between +6 and

+24 volts dc applied to pin 1 of *IC1* result in a +5-volt regulated output.

Construction. The entire auto/marine digital tachometer can be assembled on two 4" × 3" (10.2 × 7.6-cm) pieces of epoxy-fiberglass (G-10) board that has holes pre-drilled on 0.1" (2.54-mm) centers. Use perforated board that has no copper on either side, sockets for the IC's and displays, a heat sink for *IC1*, and push-in solder clips for component mounting.

You can house the tach in any suitable enclosure, including a cylindrical plastic one that can sit on top of the dashboard, or mount the system in the dash panel in an unused instrument cutout. Don't forget to use *shielded* cable for the hookup between the engine's points and the tach's input.

Calibration & Use. Before you install the tach in your car or boat, it must be properly calibrated. For calibration purposes, you will need a low-

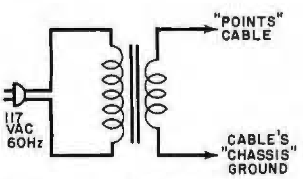


Fig. 2. Low-level 60-Hz source for calibrating tachometer.

level 60-Hz signal source. You can wire the circuit shown in Fig. 2 to obtain the low-level signal required. Wire the secondary of the 6.3-volt power transformer to the inner conductor (labeled "to points" in Fig. 1), via *R7*, and the shield of the tach's input cable.

Connect the lead from the tach labeled "+6 to +24 V dc" and the lead on the other side of *C1*, labeled "vehicle chassis ground," to the vehicle's electrical system or any other dc source capable of delivering about 1 ampere at the appropriate voltage.

Now, referring to the table, adjust R6 for the proper display reading according to the type of engine with which the tach is to be used. The tach is now calibrated and need not be readjusted again unless it is to be used with a different type of engine.

You can now install the tach in your car or boat. After installing the tach, connect the various cables to the appropriate points in your vehicle's electrical system. Then the only thing left to do is use a dry-transfer lettering kit to label the legend "RPM × 100" on the display's filter. ◈

A Simple Method For Biasing TRANSISTORS

An easy step-by-step way to design stable amplifier stages using Ohm's law.

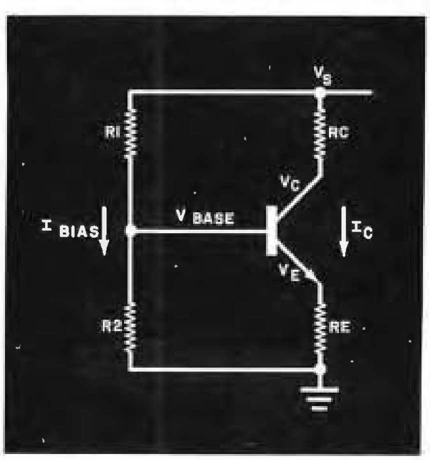
BY MYRON CHERRY

HERE is a simple way of determining the proper biasing of a bipolar transistor amplifier. It works for the majority of applications and has built-in protection against thermal runaway. All you need to know is the material of which the transistor is made (silicon or germanium) and Ohm's law.

First, there are some basic assumptions that can be made based on the superior quality of today's transistors. (1) Collector-to-base leakage current can be ignored. (2) The current gain (beta) is high enough that the base current can be ignored (or considered as a small part of the "bias" current). (3) Emitter current equals collector current. Based on these assumptions, we can use the simplified circuit model shown in the diagram.

The design of the bias circuit then consists of nine steps:

Step 1. Determine the collector current (same as the emitter current). Often this is determined by the load, or the test current given in the transistor specifications can be used. If the power supply is a battery, choose a small current for longer battery life. Typically, medium-signal transistors have a collector current of 1 to 10 mA.



For a small-signal transistor, it would be perhaps 0.1 mA.

Step 2. Determine the supply voltage. This is usually a standard value: 9, 12, or 24 volts depending on the battery or supply.

Step 3. We assume that the emitter voltage is to be 10% of the supply voltage so the emitter resistor is

$R_e = 0.1V_s/I_e$

The assumption for the emitter voltage provides thermal stability, allows for wide variations in beta and protects the emitter-base junction from a possible current overload.

Step 4. Calculate the base voltage. This depends on the semiconductor material, which determines the drop across the junction. For silicon, the drop is 0.7 V, and for germanium, it is 0.3 V. The base voltage is then the emitter voltage plus 0.7 or 0.3

Step 5. Assume that the "bias" current through *R1* and *R2* is 10% as much as the collector current. This is easier than considering that R_e times beta is in parallel with *R2*. In fact, we do not need to know beta if it is high enough because 10% or 20% variation in *R1* and *R2* would cause more change in bias current than the small base current in today's high-beta transistors. In fact, beta often varies from 100 to 300 for the same type of transistor.

Step 6. Calculate *R2* using base voltage and bias current.

$R2 = V_{base}/I_{bias} = V_{base}/0.1I_c$

Step 7. Calculate *R1*

$R1 = (V_s - V_{base})/I_{bias}$

Step 8. Choose collector voltage. Except for an emitter follower, the output signal is always taken from the collector. To avoid clipping, let $V_c = 0.5V_s$.

Step 9. Calculate R_c from I_c and V_c.

$R_c = V_c/I_c = 0.5V_s/I_c$.

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