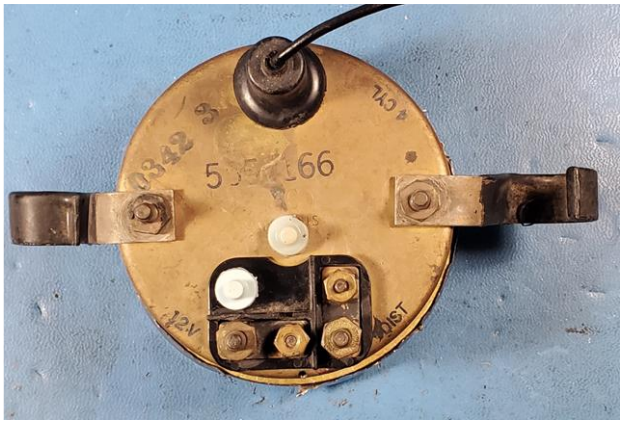
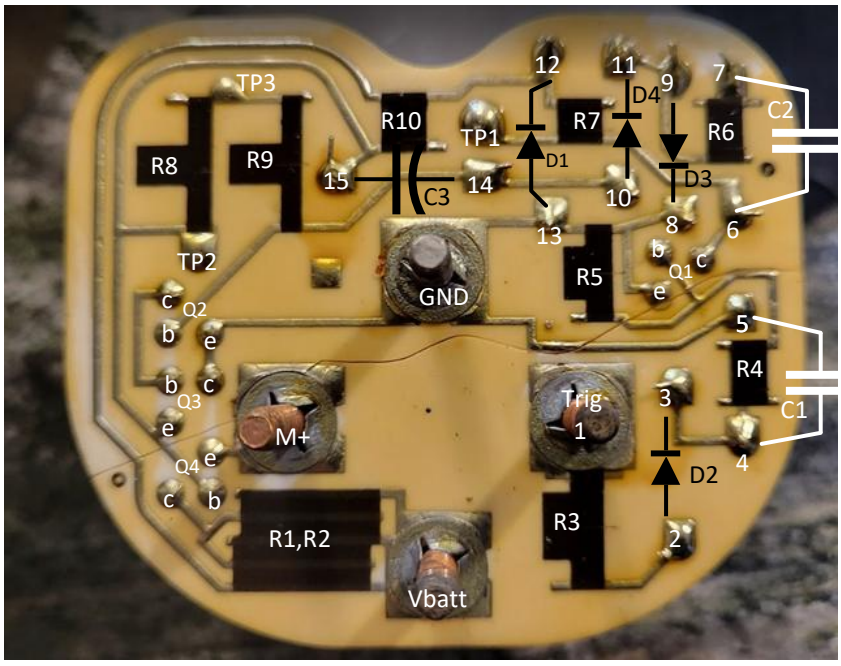
Vintage Mercury Marine Tachometer
Reverse Engineering Report
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R1.0

I was asked to help reverse engineer a vintage Mercury Marine tachometer for a 4 cylinder engine to see how it might be driven and to see if it could be recalibrated for an 8 cylinder engine. The air-core gauge face has a 5K RPM scale. The circuit board on the back of the meter appears have a ceramic-type substrate with thick film resistors connected to the traces.



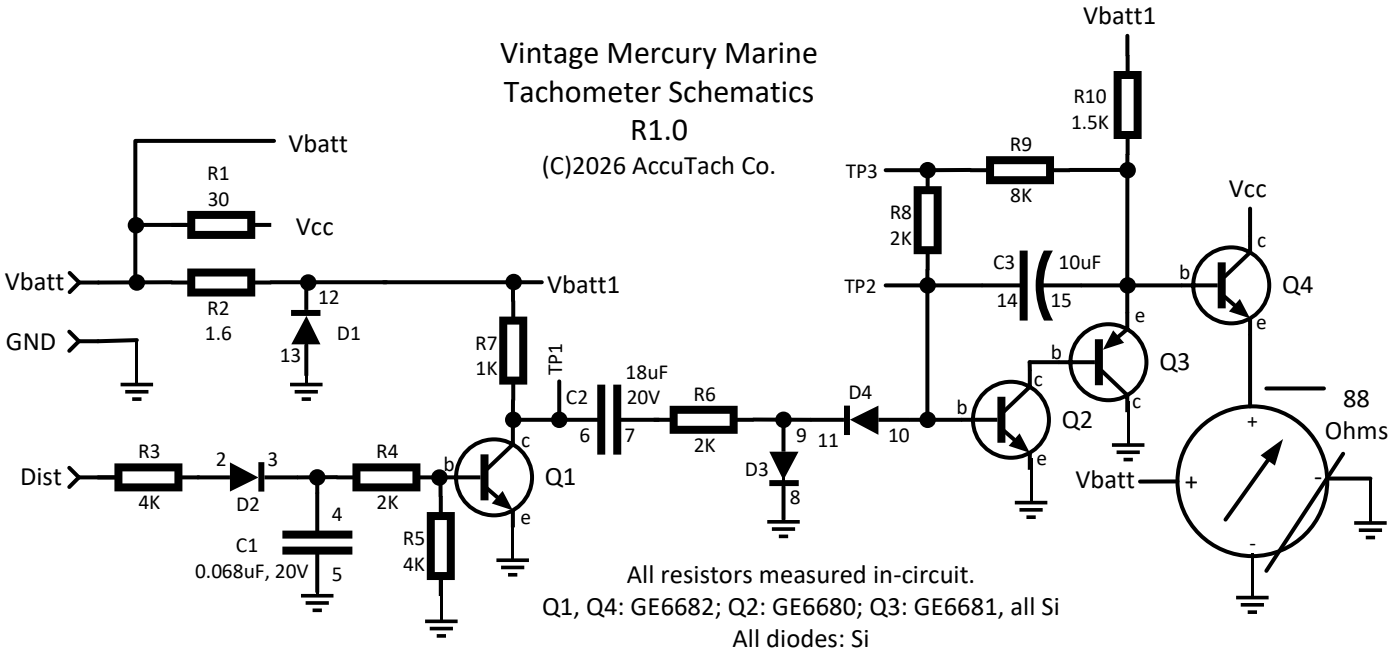


The owner and I have been creating the schematics for this tachometer, working with annotated photos of the circuit board traces and components.



The circuit substrate was cracked, rendering the circuit non-functional. The owner put solder bridges across the cracks in the traces to bring the tachometer back to life. He ultimately bought a different tachometer and sent this one to me. I added small bits of wire to make the circuit more robust, but after working on the circuit for a while, the circuit has finally become somewhat unreliable in spite of my efforts to stabilize it.

FYI, a special solder with a high melting point was used for this tachometer. My soldering iron set to 700 degrees struggled to melt the solder, so a very hot soldering iron will be required to melt the OEM solder.



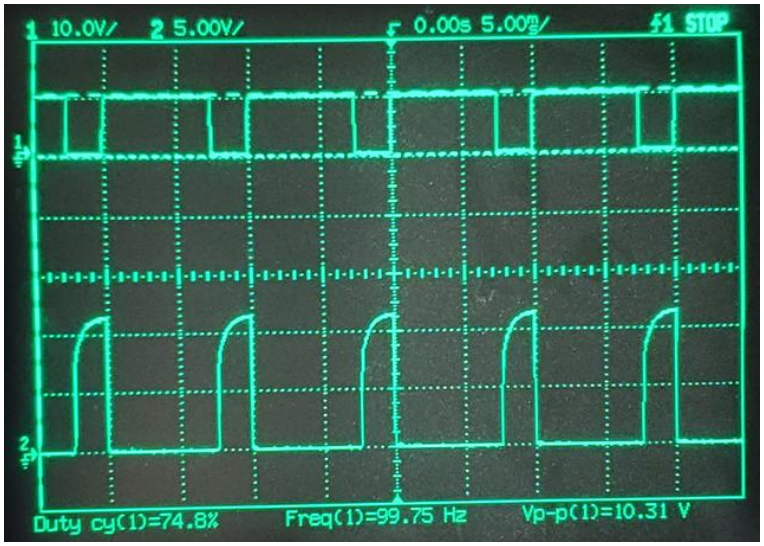
This circuit is a very unusual tachometer circuit. It drives an air-core gauge instead of the usual ammeter. The current through the gauge's deflection winding is controlled by varying the DC current flowing through the winding rather than PWM which is used for more traditional ammeter-based designs.

Here are the scope traces recorded for this tachometer. The calibration signal is a 0-10V square wave shown as the top trace in all of these photos. The bottom trace shows the circuit operation at each point in the circuit. The test frequency was 100Hz for the photos.

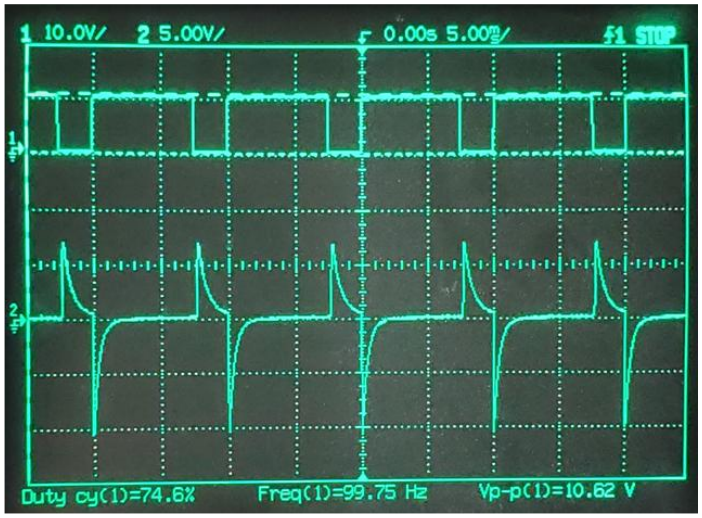
Q1 Base:



Q1 Collector:



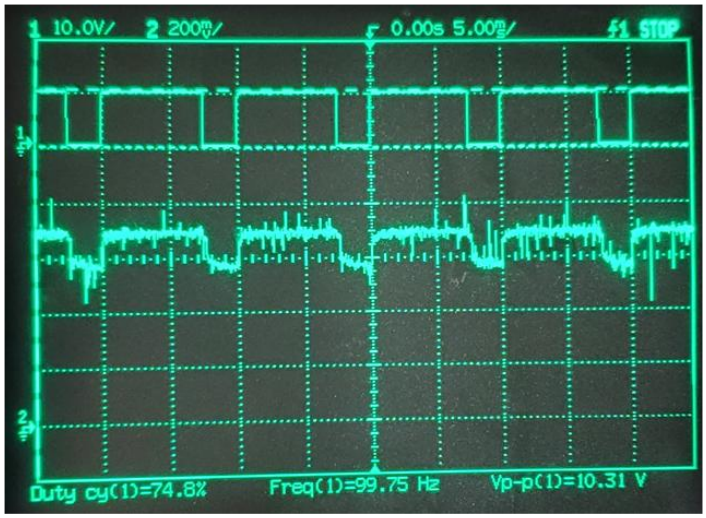
C2-7:



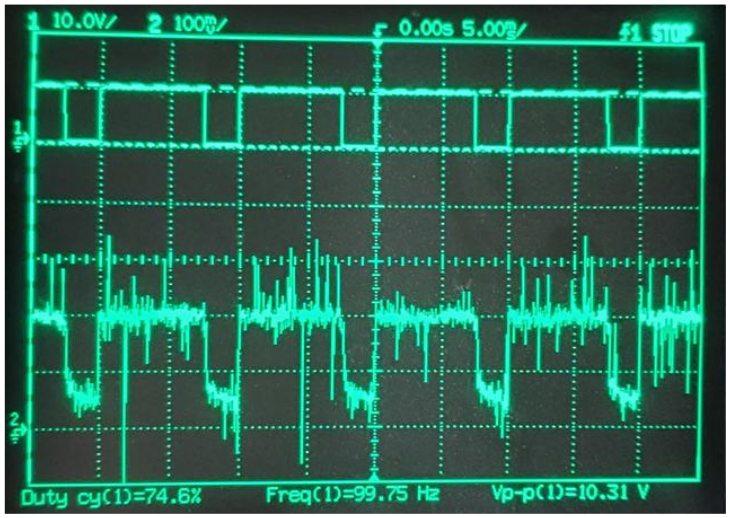
D3-9:



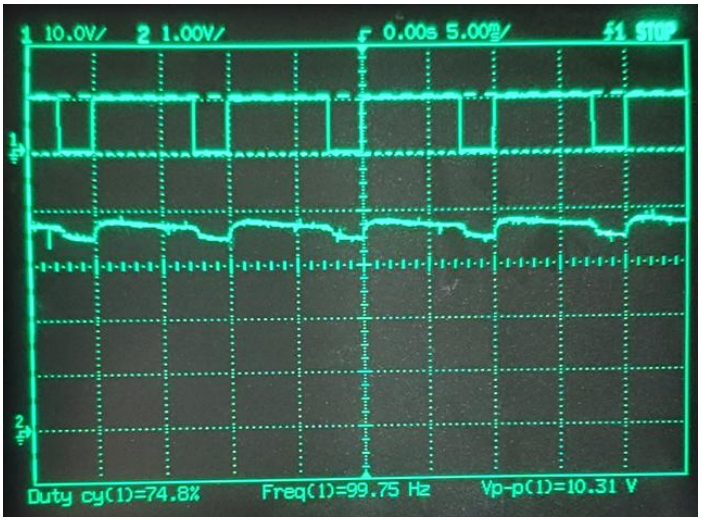
Q2 Base:



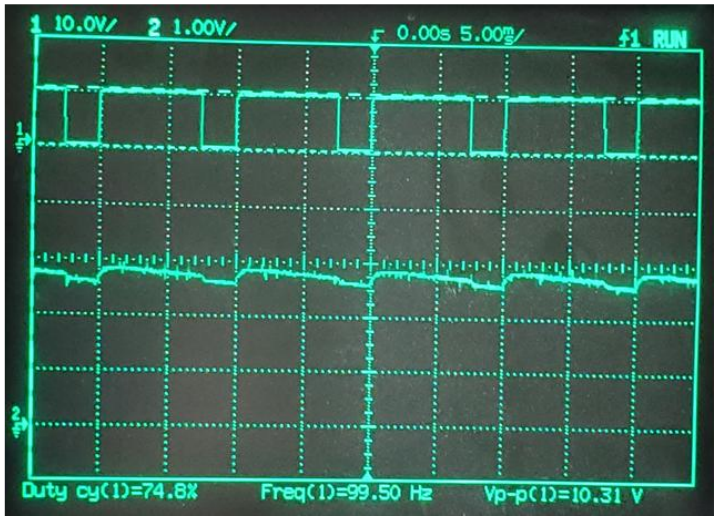
Q2 Collector – Q3 Base:

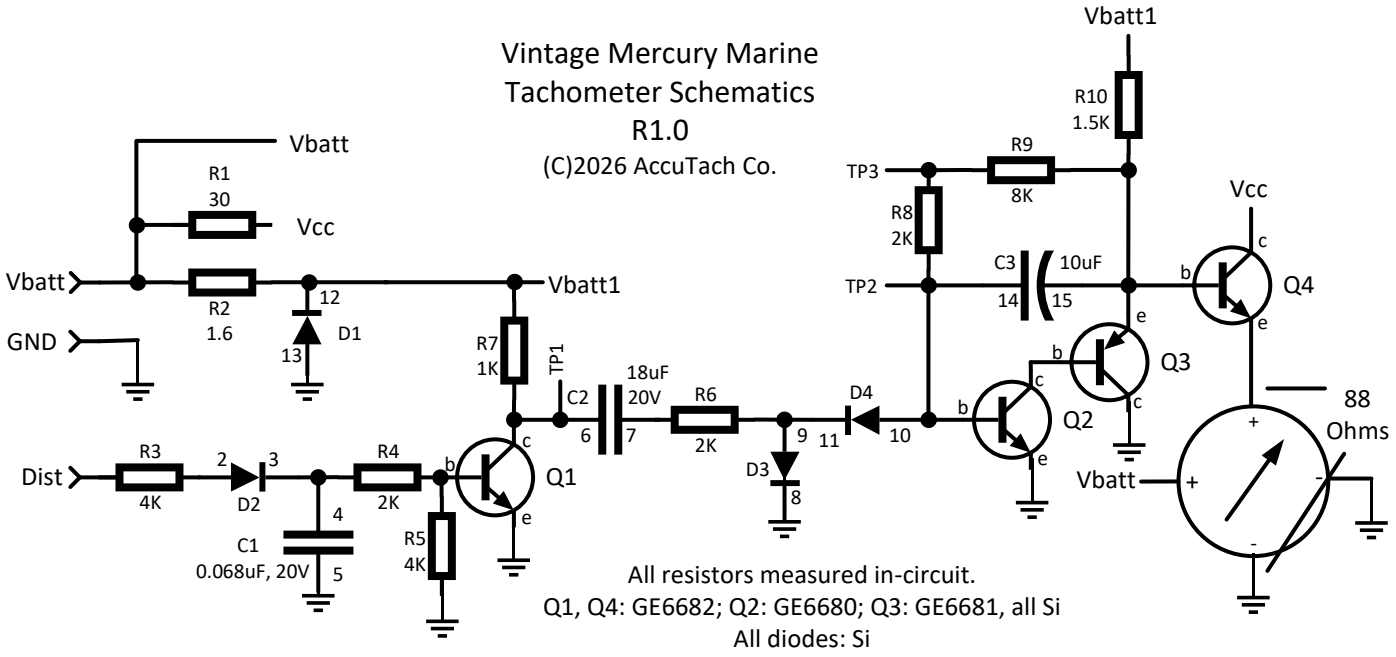


Q3 Emitter-Q4 Base:



Q4 Emitter:





Theory of operation:

Working backwards through the circuit, we first examine the air-core gauge that is driven by the electronics. There is a reference winding that is powered by battery voltage whenever the tachometer is powered up. There is a deflection winding oriented orthogonal to the reference winding. As current increases in the deflection winding, the magnetic field rotates. There is a permanent magnet attached to the needle, and it follows the rotating magnetic field. The electronics in the tachometer convert the ignition frequency signal into a DC current signal that drives the deflection winding.

Q4 drives the deflection winding with a constant current configuration. R10, 9 and 8 appear to bias Q2, Q3 and Q4 into their active regions. R9 and R8 also provide feedback to the base of Q2 as a part of the constant current configuration. The harder Q3 turns on, the more Q4 turns off. The more Q3 turns off, the more Q4 turns on.

The harder Q2 turns on, the more Q3 turns on and the more Q2 turns off, the more Q3 turns off. This transfer function of this part of the circuit means that the harder Q2 turns on, the more Q4 turns off. The more Q2 turns off, the more Q4 turns on. C3 smooths the current signal coming from Q4. It may also help to prevent oscillation.

Moving back to the input, the signal from the coil is filtered and limited to protect Q1 from high voltage spikes from the coil. The 6K ohms of input resistance will keep the base current of Q1 at 42mA with a 250V input spike. There are no specs for Q1, but it is very unlikely that a 42mA spike will damage it. As a result, no external protection circuitry should be required for this tachometer. Q1 inverts the ignition signal. Passing the inverted signal through C2, R6, D3 and D4 effectively re-inverts the signal, but biases it to keep Q2 in the active region as shown in the Q2 base scope trace.

As the ignition signal frequency increases, the duty cycle of the biased signal at the base of Q2 goes down slightly. That reduces the average current flowing into the base of Q2 which ultimately increases the current flowing through the deflection winding increasing needle deflection. As the ignition signal frequency decreases, the duty cycle of the biased signal at the base of Q2 goes up slightly. That increases the average current flowing into the base of Q2 which ultimately decreases the current flowing through the deflection winding decreasing needle deflection.

Calibration is accomplished by changing the capacitance of C2. Increasing the capacitance of C2 increases the low time at the base of Q2 which reduces the current going into the base of Q2, increasing the needle deflection. Decreasing the capacitance of C2 decreases the low time at the base of Q2 which increases the current going into the base of Q2, decreasing the needle deflection.