LOUIS VLEMINCQ
BELGACOM, EVERE, BELGIUM
louis.vlemincq@belgacom.be

ED ONLINE 21104

Monitor Transformer Winding's Temperature Without A Sensor

The use of a copper winding as a temperature sensor is not new. The traditional technique is to disconnect the ac power and the load and to quickly make the measurement using an ohmmeter. But the circuit presented here goes further. It can make the measurement in-circuit and in real time.

The resistance value is derived by injecting a small dc current into the monitored winding and measuring the resulting dc potential. However, care must be taken to avoid serious errors that could be caused by asymmetries in the power-rectifier diodes, mains-synchronous consumption patterns, or thermal gradients. To do that, we alternate the polarity of the stimulus current at a very low frequency and make the voltage measurement in a synchronous manner. This isolates the tiny useful signal against the much higher ac and dc voltages present.

The stimulus current is generated by R2 *(see the figure)*. Its polarity is determined by D4-Q2 or D3-Q1, under the control of the VLF oscillator built around U3b.

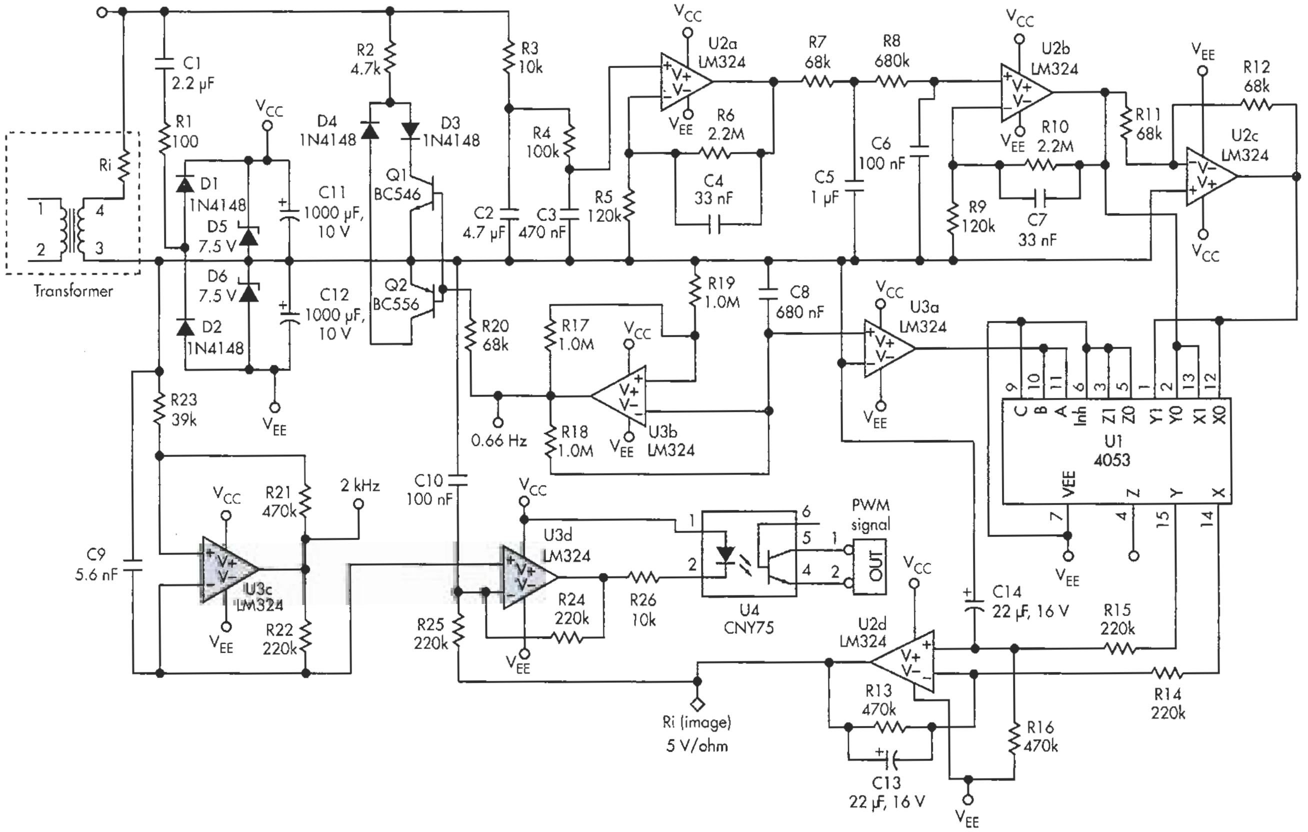
R3 picks up the signal from the transformer and feeds the first of a series of low-pass filters that remove the mains frequency. The filtered and amplified signal then goes to the inverting amplifier, U2c, to generate an anti-phase signal.

Both signals are used by U1, which is connected as a full-wave synchronous demodulator.

This detector cancels any dc error or offset accumulated during the signal processing, and it eliminates frequencies other than that of the modulating signal. The detector's output is collected by a balanced amplifier, U2d, referenced to the negative rail via R16, and again low-pass filtered.

The result is a voltage that is a scaled image of the transformer's resistance. With the gain value and injection resistance used in this example, the factor is 5 V/Ω. This circuit was designed for a 48-V transformer whose cold resistance is 1.5 Ω, resulting in an initial voltage of approximately 0 V with the 7.5-V negative supply. The temperature coefficient of copper is about +0.4%/°C.

The reference signal for the synchronous demodulator is taken on C8, rather than directly, in order to compensate for the phase shifts that are introduced by the multiple low-pass filters. Furthermore, the demodulated output could be compared to a locally



Using the transformer winding as a temperature sensor, this circuit monitors the transformer's temperature while avoiding the pitfalls of other sensorless temperature-detection techniques.

generated threshold voltage—to generate an over-temperature alarm, for instance.

In this example, a more versatile option is shown: the voltage is converted into a low-frequency pulse-width-modulation (PWM) signal and sent to the external world via an optocoupler (U4).

The PWM signal can accommodate both linear and digital interfaces very easily, and it is unaffected by the transfer ratio of the coupler. With a mere pull-up, the signal can be used directly by a microcontroller I/O pin or be low-pass filtered to recover the analog value.

U3c is the master PWM oscillator, and operates at 2 kHz; U3d compares its triangle wave to the output signal.

The whole circuit takes its power from the winding under test, via C1, which is part of a capacitive supply.

On the schematic, C13 and C14 are polarized. In this case, that's okay, but if a different range/scale is adopted, they could become reverse-biased and should be replaced by non-polar devices. The output voltage is also proportional to the transformer's voltage, and if absolute accuracy is required, a correction should be included.

This circuit has a number of benefits:

- It doesn't require a dedicated sensor and therefore can be fitted to any transformer.
- Because the sensed element is the sensor itself, there is no issue of thermal contact or delay between the actual and measured values.
- It requires no additional wiring.
- It's self-powered and draws only negligible extra power from the transformer.
- The low-level test signal is non-intrusive.
- The output configuration is isolated and flexible.
- It's implicitly self-calibrating. If the gain is made such that the cold output has a certain value (0 V, for example), then each additional volt will correspond to a definite temperature rise (34°C in this example).
- The gain and injection components can be adjusted to suit almost any transformer, and the circuit could even be adapted to monitor other types of wound components: motors, magnets, etc.
- All of the above is achieved using only inexpensive, commodity-like components.

LOUIS VLEMINCQ, transmission specialist, has a master's degree in electronics from the Institut de Radio-Cinematographie, Forest, Belgium.