Optically Isolated 4- To 20-mA Current-Loop Transmitter Is Accurate, Inexpensive

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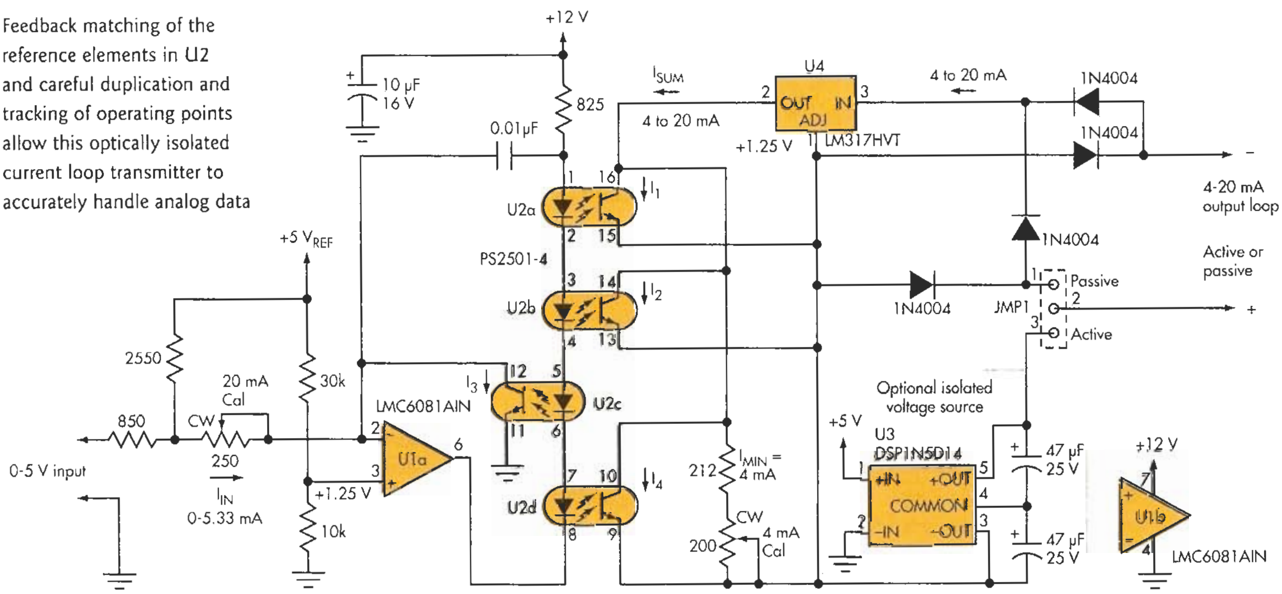

Feedback matching of the reference elements in U2 and careful duplication and tracking of operating points allow this optically isolated current loop transmitter to accurately handle analog data

Galvanically (that is, optically or electromagnetically) isolated 4- to 20-mA current loops offer robust noise immunity and tolerate long cable runs. These advantages, combined with simple unshielded two-wire cabling, make this mature signaling standard popular for transmitting analog data in noisy industrial and process control environments. Unfortunately, the conversion of an analog voltage output to an isolated current-loop signal is relatively complicated. In addition to the actual signal isolator components, multiple floating power supplies are typically required.

The current-loop transmitter in the figure employs an unusual trick to inexpensively implement an optically isolated 4- to 20-mA transmitter: operation of the quad-channel LED/transistor optoisolator (an NEC PS2501-4) in a linear mode. Normally, this would be a dubious idea because LED/transistor optoisolator response is typically very nonlinear and temperature-dependent, making it incompatible with accurate transmission of precision analog data.

Working around this limitation and achieving adequate analog accuracy from this class of component requires meeting two goals:

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- Nonlinearity and temperature-coefficient compensation through feedback matching of reference elements in a multichannel microcircuit so that nonlinearities will cancel.
- Scrupulous duplication and tracking of operating points (voltage and current bias) of the reference elements.

The first is achieved by matching LED/transistor pair U2c to U2a, b, and d. U2c is part of the feedback loop of op-amp U1, causing the LED drive current to be controlled so that $I3 = I_{IN}$. Because all four LEDs in U2 are serially connected, the other three optical pairs receive an identical LED drive current, causing their phototransistors to conduct the same collector currents. That is:

$$I1 = I2 = I3 = I4 = I_{IN}, \text{ which is 0 to 5.33 mA}$$

However, this equality depends not only on the physical matching of the four U2 channels, but also on the match of their bias voltages, which is the second design goal. This goal is achieved through the equality of the 1.25-V set point of U1 to the 1.25-V internal reference of regulator U4.

Remaining circuit details include calibration trims for minimum (4 mA) and full-scale (20 mA) output currents and the option of operation with an external loop-voltage supply (passive mode) or with the dc-dc converter, U3 (active mode). I_{SUM} is:

$$3(I_{IN} + I_{MIN}) = (0 \text{ to } 16 \text{ mA}) + 4 \text{ mA} = 4 \text{ to } 20 \text{ mA}$$