Auto-ranging 10µA to 10A Current Meter

I often find that I want to monitor supply current to a project I am working on but I need my multimeters for probing the circuit, monitoring supply voltages, etc. Also when measuring current, it's quite easy to blow the meter's fuse or destroy its internal shunt due to excessive current. Hence, I designed this 10µA-10A auto-ranging meter that automatically cuts out if the current exceeds 10.2A.

The design criteria included easy calibration and high accuracy. It's microprocessor controlled and its result is displayed on a standard LCD.

The microprocessor senses the shunt voltage and switches in an appropriate shunt value using Mosfets Q1-Q6 as electronic switches, to select the best range for the measurement being made. As the voltage across the shunt is small, a DC amplifier is placed between the selected shunt and the microcontroller's ADC input.

To enable reasonable tolerance shunt resistors to be employed, electronic switching is used to select a different amplifier gain potentiometer for each range, allowing calibration of each shunt. Placing the shunt between the source of the FET and earth removes the FET's on-resistance from the measurement. However, low on-resistance FETs are still desirable to minimise dissipation. The specified FET for the 10A range has an on-resistance of about 2mΩ, for a maximum dissipation of 200mW, so no heatsinking is needed.

REF1, an LM285Z-2.5V provides the reference voltage for the ADC on pin 2 of PIC16F88 microprocessor IC5. The ADC is a 10-bit type so it can sense 2^{10} or 1024 discrete voltages between 0 and 2.5 V. If we make 1000 the upper limit of each range, the maximum voltage needed on pin 3 (the ADC input) is 1000 ÷ 1023 x 2.5V = 2.44V.

The shunt used for the 10A range is 0.01Ω which gives a voltage of 10A x 0.01V = 0.1V for a full-scale reading. Similarly, the shunt for the 1A range is 0.1Ω which gives the same result and so on. So the amplifier needs a gain of 2.44V ÷ 0.1V = 24.4 times. We use an OPA4344 quad CMOS rail-to-rail op amp (IC1), with each stage cascaded.

Because of the high gain, any mains pick-up (50Hz, 100Hz, etc) will affect the result. So we use a low-pass filter with a cut-off below

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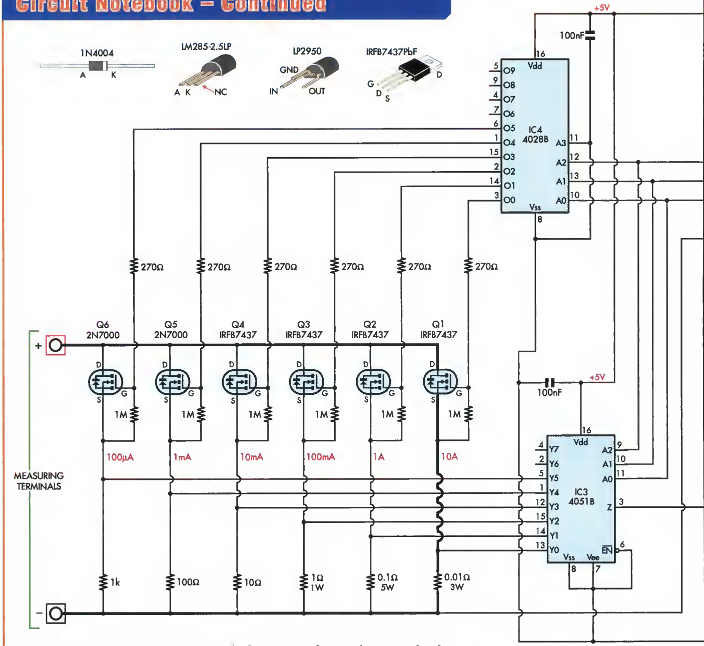


50Hz to attenuate any mains interference. This filter is combined with the gain stages in IC1c and IC1d. The -3dB point of the filter is 16Hz and the roll-off is approximately 84dB/octave.

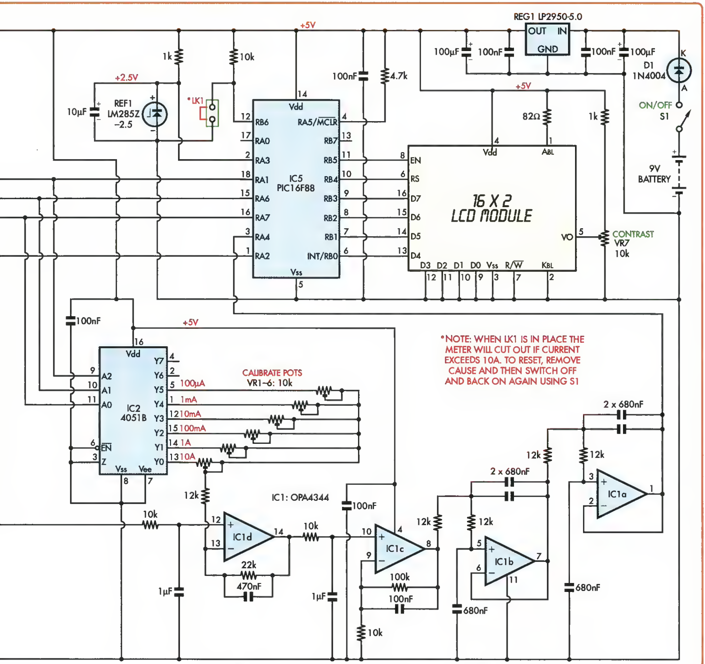
Op amps IC1a & IC1b form a unity-gain active filter with a -3dB point of 13.8Hz. The preceding stage, built around IC1c, provides a gain of 11, as determined by the ratio of the 100kΩ and 10kΩ feedback resistors. It's also set up to provide low-pass filtering with a 100nF capacitor across its feedback resistor and a low-pass filter (10kΩ/1µF) at its pin 10 non-inverting input.

Its input is driven by the preceding stage, built around IC1d, which has a gain of around 2.22, set by the 22kΩ and 12kΩ feedback resistors plus 10kΩ gain adjust trimpot VR6. With VR6 set correctly, the overall gain becomes the desired 24.4 times. IC1d also performs further low-pass filtering, in a similar manner to IC1c.

Depending on which range is being used, 8:1 analog switch IC2 (a 4051B) connects the appropriate trimpot to ground, activating it. IC5 selects the pot using address lines A0-A2 (pin 11-9). A second 4051B, IC3, connects the positive end of the appropriate shunt to the pin 12 non-inverting input of amplifier IC1d via a 10kΩ protection resistor.

At the same time, BCD-to-decimal decoder IC4 (4028B) drives the gate of the appropriate Mosfet (Q1-Q6) high so that current though the measurement terminals flows through the required shunt only. The other Mosfet gates are driven low to switch them off and a 1MΩ resistor between each gate and source keep them off when the unit is powered down.

As well as driving outputs RA1, RA6 and RA7 of IC5 (pins 18, 15 & 16) to select the appropriate measurement range, the microcontroller software constantly performs the analog-to-digital conversions for the measurement voltage present at pin 3, computes the current value, adds the appropriate units and displays this on a two-line alphanumeric



LCD. VR7 provides contrast adjustment.

If LK1 is inserted and a current measurement above 10.2A is registered, IC5 will immediately switch all the Mosfets (Q1-Q6) off, disconnecting the load and protecting the circuit. It's reset by removing the overload condition and power cycling the unit using switch S1.

The meter is powered from a 9V battery. Current flows to micropower low-dropout 5V regulator REG1 via reverse polarity protection diode D1. It can operate down to a battery voltage as low as 6.7V.

To calibrate the unit, connect an accurate ammeter in series with a dummy load and the test terminals, then apply voltage to get a reading of around 8A. Adjust VR6 until the reading on the meter matches that on the reference ammeter. Now increase the dummy load to reduce the current to around 0.8A, then adjust VR5 and continue the procedure until all six ranges have been calibrated.

Note that the required dummy load for the 10A range will be around 1Ω and will need to be rated to dissipate at least 100W. If you have a bench supply, you can use a much lower voltage and thus lower-value dummy resistance with a lesser power rating.

IC1, REF1 and Q1-Q4 are available from element14. The rest of the parts can be bought at Jaycar.

The software (*Autorange Ammeter3.BAS*) is written in PICBasic Pro and the BASIC source code and HEX file are available for download from the Silicon Chip website.

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