Tech Note JAU20-11

Ammeters and Shunts

An ammeter is a device designed to accurately measure and display electrical current in a readable form, which could be a moving coil meter, a LED bargraph display or a digital panel meter. The basic unit of electrical current is amps.

When designing an ammeter, external resistors, or shunt resistors (or sometimes known as current resistors), are connected in parallel with the moving coil meter or digital panel meter to extend or convert the range. This arrangement divides the current being measured so the majority flows through the shunt resistor and a small portion goes to the meter. Shunt resistors are calibrated: for example, the Jaycar QP-5416 has a voltage drop of 200mV across it when the current flowing through it is 200A. This calibrated information is stamped on the side of the shunt.

Moving coil meter - examples

For example, take a Jaycar QP-5010 moving coil meter with a 0 - 1mA movement and 200Ω coil resistance. If we wanted to extend the range of the 0 - 1mA meter to 1A, 10A or 100A, we would have to do two things: re-label the meter's scale so that it read correctly, and add an appropriate shunt resistor that would extend the range accordingly.

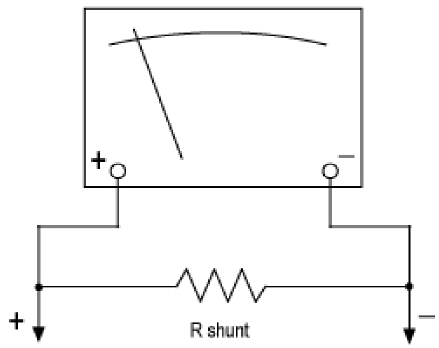

Fig 1. Moving coil ammeter:
FSD = 1mA (no shunt resistor)
FSD = 200A (with 1mΩ shunt resistor)

To create a 0 - 1A ammeter, having a 1A full scale deflection (FSD), we need to determine the shunt resistance required to bypass the majority of the current so that only 1mA flows through the coil movement.

	FSD	R_{shunt}	Total
Volts (V)	0.2V (calculated)	0.2V	0.2V
Current (I)	0.001A (1mA)	0.999A (calculated)	1A
Resistance (R)	200Ω	0.2002Ω	

Using Ohm's Law: V = R x I, calculate FSD voltage across the meter: V = 200 x 0.001, or 0.2V.

Now the current through the shunt resistor is the difference between the total current (1A) and the current through the meter (1mA). Therefore the current through the shunt resistor is 0.999A.

Using Ohm's Law again, calculate the shunt resistance: R_{shunt} = 0.2V/ 0.999A. Therefore, R_{shunt} = 0.2002Ω, or typically 0.2Ω. This can also be expressed as 200mΩ. The tolerance of the shunt resistor should be typically 0.5%.

The next important parameter to determine is the power rating of the shunt resistor for power dissipated. In this example, R_{shunt} would be subjected to currents up to 1A, therefore, the power dissipation in R_{shunt} (for 1A) is V times the current through the shunt resistor: 0.2V x 0.999A, or 0.2W. Note, if a shunt resistor overheats it can permanently change the resistance of the shunt, and hence the accuracy of the measurement. To prevent overheating, the power rating of the shunt should be at least two to three times the power dissipation expected in R_{shunt}. In this example the minimum power rating of the shunt resistor would be 0.4W or preferably higher.

We could do the same exercise for a 4A, 100A or 200A FSD ammeter design using a 0-1mA meter. The shunt resistors would now be 0.05Ω (50mΩ) Jaycar QP-5410) for the 4A ammeter; 0.002Ω (2mΩ) two Jaycar QP-5414 wired in series for the 100A ammeter; and 0.001Ω (1mΩ) Jaycar QP-5416 for the 200A ammeter. You could also select the 0-50µA or 0-1A moving coil meters and extend the range by adding an appropriate shunt resistor using the above method.

Shunt resistors have four screw terminals: two high current terminals for measuring system current, and two low current terminals for connecting to the moving coil meter or digital panel meter. Illustrated below is the Jaycar QP-5416 200A shunt resistor.

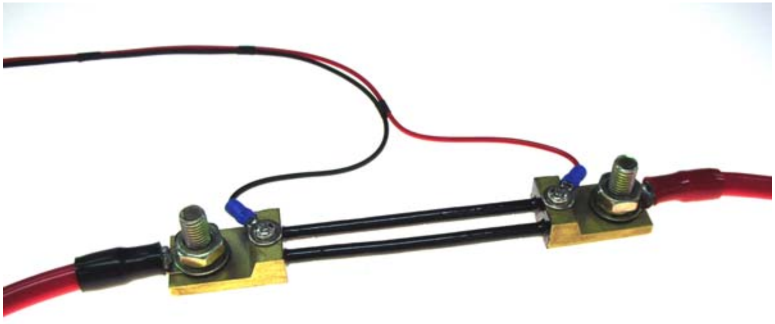

Fig 2. Typical shunt resistor QP-5416

Digital panel meters – examples

Digital panel meters can also be used to create an ammeter by adding a shunt resistor across the voltage input. Instead of using a moving coil meter with a range of 0-1mA as described in the above example, the Jaycar QP-5570 digital panel meter (or voltmeter) with a 200mV input could be used.

The current through the voltmeter can be considered negligible if the voltmeter input impedance is high enough, and the shunt resistor can be sized according to how many volts or millivolts of drop will be produced per amp of current. To setup an ammeter with a 2A, 20A, or 200A range using a 200mV digital panel meter, we would have to do two things: select and wire up the appropriate decimal point on the digital panel meter, and connect the digital panel meter input across the inner screw terminals of the shunt resistor.

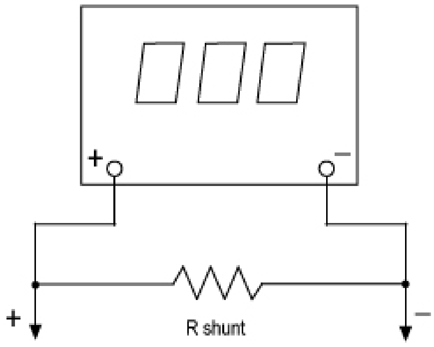

Fig 3. Digital ammeter:
Input voltage = 200mV
FSD = 200A (with 1mΩ shunt resistor)

To design a 0 - 2A ammeter, use Ohm's Law to determine the shunt resistance required to create a 200mV drop across the shunt resistor when 2A of current is flowing through it. R shunt = 200mV/2A ie, 100mΩ or two Jaycar QP-5410 50mΩ shunts wired in series.

The next important parameter to determine is the power rating of the shunt resistor. In this example, R_{shunt} would be subjected to currents up to 2A. Therefore, the power dissipation in R_{shunt} (for 2A) is, V times the current through the shunt resistor: 0.2V x 2A, or 0.4W. Now, remember from the moving coil example, the power rating should be at least two to three times the power dissipation in R_{shunt}. In this example the minimum power rating of the shunt resistor would be 0.8W or preferably higher.

We could do the same exercise for 200A ammeter design using a 200mV digital panel meter; in this case the shunt resistors would now be 0.001Ω (1mΩ) at 80W. The recommended 1mΩ shunt resistor for the 200A ammeter would be QP-5416. This resistor is specifically designed for high currents ranging between 100A and 200A. Other 1mΩ shunt resistors are available for lower currents as listed in the table.

Recommended Current Range	Rshunt	Voltage Drop at Max Current	Jaycar Cat No.
Up to 50A	1mΩ	50mV	QP-5412
Up to 100A	1mΩ	100mV	QP-5414
Up to 200A	1mΩ	200mV	QP-5416