SEE1123 INSTRUMENTATION & ELECTRICAL MEASUREMENT

Electrical Measurement

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4.0 Permanent Magnet Moving Coil (PMMC)

Permanent Magnet Moving Coil is the important element behind analog electrical meters such as ammet The basic electrical measuring instruments can be traced to Hans Oersted's discovery in 1820 of the relationship between current and magnetism. He investigated the deflection of a magnetic compass needle by current flowing in a wire. Subsequent research benefitted from Oersted's discovery. The earliest galvanometer was said to be invented Johann Schweigger of Nuremberg in 1820. In the early designs the magnetic field effect due to the current was increased by using multiple turns of wire. The term "galvanometer", was derived from name of the Italian researcher Luigi Galvani, who discovered that electric current could cause a frog's leg to move.

4.0 Permanent Magnet Moving Coil (PMMC) (cont)

Initially “tangent” galvanometers were developed. These instruments relied on the Earth's magnetic field to restore force for the compass needle and as such they have to be properly positioned before use. Then as research progressed, instruments used opposing magnets and as such they become independent of the Earth's field and would operate in any orientation. The mirror galvanometer was invented by William Thomson. He used small magnets attached to a small lightweight mirror, suspended by a thread. Instead of moving a mirror, it moved a mirror. The mirror reflected a beam of light which then projects onto a meter scale. It is sufficient for small currents to cause a significant amount of light deflection.

The actual starting point of electric circuit analysis was based on Georg Ohm’s (1789-1854) experiments who formulate Ohm's Law. Ohm’s law defined the fundamental relationship between voltage, current and resistance. This also benefitted measurement of electrical quantity.

4.0 Permanent Magnet Moving Coil (PMMC) (cont)

The early design of the moving-magnet galvanometer faced the problem of being affected by any magnets or iron masses near it. Furthermore its deflection was not linearly proportional to the current. In 1881 Jacques d'Arsonval obtained the patent for the moving-coil galvanometer. The electrical meter movements being used today has the same basic construction designed by d'Arsonval. As such the basic moving-coil meter is also known as a d'Arsonval meter movement or a permanent-magnet moving coil (PMMC) meter movement.

To reduce friction, the moving-coil mechanism is set in a jewel and pivot suspension system to reduce friction. Another method of suspension which is more expensive but more sensitive is the "taut-band" suspension system. A typical full-scale current for a jewel and pivot suspension system can reach as high 50μA whereas for a taut-band system can only reach a full-scale current of 2μA.

4.0 Permanent Magnet Moving Coil (PMMC) (cont)

The PMMC meter is basically a low level dc ammeter. To increase the range of current it can measure, resistors can be connected in parallel. It can also be made to function as a dc voltmeter by connecting suitable values of resistances in series with the coil. To construct ac ammeters and voltmeters, suitable rectifier circuits can be connected to the PMMC instrument. PMMC meters combined with precision resistors and batteries can be used to design ohmmeters. Multi-range meters combine ammeter, voltmeter and ohmmeter functions all in one device.

4.0 Permanent Magnet Moving Coil (PMMC) (cont)

A galvanometer is an instrument which serves as a basis for an ammeter and a voltmeter. Galvanometers can be applied in bridge and potentiometer measurements to indicate zero current. Hence a galvanometer should have the characteristics of being sensitive, should have a stable zero, a short periodic time and nearly critical damping. By 1888 Edward Weston commercialized this form of instrument, which became a standard component in electrical equipment. This design is being used in today's moving-vane meters.

Nowadays in many applications galvanometer-type analog meters are displaced by digital instruments which integrated analog to digital converters with numerical display. Digital instruments are more precise and accurate. In terms of power consumption or cost, analog meters may have the edge. The best digital display galvanometers can measure a current as small as one hundredth billionth (10-11) of an amp.

er and voltmeter.

4.1 Voltage Measurement

In order to use PMMC to measure voltage, a slight modification has to be performed on the PMMC by placing a resistors in series with the PMMC.

SINGLE RANGE VOLTMETERS

A voltmeter measures voltages of either dc or ac. The typical commercial voltmeter being used today most likely use an electromechanical mechanism in which current flowing via turns of wire is converted into voltage. Analog voltmeters move a pointer across a scale in proportional to the voltage. Digital voltmeters display voltage using an analog-to-digital converter. Voltmeters are manufactured in a wide range of styles. Portable instruments, which can also measure current and resistance in the form of a multimeter, are standard test instruments used in electrical and electronics application. By suitable calibration, parameters such as pressure, temperature, flow or level can be converted to a voltage.

4.1 Voltage Measurement (cont)

The pmmc can be converted to a dc voltmeter by connecting a multiplier Rs in series with the pmmc as in figure 4.1. The purpose of adding the multiplier is to extend the voltage range of the pmmc and to limit current via the pmmc to a maximum full-scale deflection current so that it will not damage the pmmc. The value of the multiplier resistor can be obtained by firstly determining the sensitivity,S, of the pmmc. The sensitivity is equal to the reciprocal of the full-scale deflection current, as follows

Sensitivity = 1/Ifs (Ω/V)

4.1 Voltage Measurement (cont)

Voltage is measured by placing the voltmeter across the resistance of interest. This is the same as placing the total voltmeter resistance in parallel with the circuit resistance. As such, it is desirable to make the voltmeter resistance a lot higher than the circuit resistance. An increase in the current through the coil caused an increase in the magnetic field generated around the coil. The coil will move further if the magnetic field around the coil gets stronger.

To determine the value of multiplier resistance for specific voltage range, multiply the sensitivity by the range and subtract the internal resistance of the pmmc i.e.:

Rs = (S x Range) – Internal Resistance

4.2 Loading Effect

The loading effect is caused by the internal resistance of a voltmeter.

As voltmeters are placed in parallel with the measured circuit, that will affect the overall current in the circuit, potentially affecting the voltage being measured. An ideal voltmeter should have a extremely high resistance, so that no current is drawn from the measured circuit.

When a voltmeter is connected to the circuit, the voltmeter becomes part of the circuit. As a result the voltmeter's own resistance changes the ratio of resistance of the voltage divider circuit. Subsequently the overall voltage will be lowered. This is called the loading effect.

4.3 Current Measurement

Current can be measured using an ammeter of an osciloscope.An ammeter is a device constructed to measure electrical current. The measured unit is in Amperes. In order to increase the measuring range, resistors are added externally with permanent magnet moving coil.

Example 4.8:

Determine the shunt resistance required to change a 1mA meter movement, with a 100Ω internal resistance, into an ammeter which can measure up to 10mA.

Solution:

$V_m = I_m R_m = 1mA \times 100\Omega = 0.1V$
$V_{sh} = V_m = 0.1V$
$I_{sh} = I - I_m = 10mA - 1mA = 9mA$
$R_{sh} = V_{sh}/I_{sh} = 0.1V/9mA = 11.11\Omega$

4.3 Current Measurement (cont)

Exercise:

Describe briefly two types of measurements that can be done using oscilloscope.

1) **Frequency**
    - Signal repeated
    - Measured in Hertz (Hz)
2) **Voltage**
    - Amount of electrical potential between two points
    - Refer to amplitude