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Electrical and Electronic Measurements Interview Questions

INSIDE

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Units, standards, errors and uncertainty

1. What is the difference between the accuracy and the precision of an instrument?

Accuracy is how close a reading is to the true value. Precision is how closely repeated readings of the same quantity agree with each other. An instrument can be precise but inaccurate if it has a constant systematic error, such as a zero offset. Precision alone says nothing about closeness to the true value.

2. Why are the percentage limiting errors of the quantities added when a result is found as a product or quotient of them?

For $R = xy$ or $R = x/y$, the worst case is when every error pushes the result the same way, so the fractional limiting errors add in magnitude: $\delta R/R = \delta x/x + \delta y/y$. This is a worst-case figure. Independent random errors are often combined by root sum square, which gives a smaller value.

3. The power in a resistor is found from $P = I^2R$. The current is measured as 2.0 A with a limiting error of 1 %, and the resistance is 50 ohm with a limiting error of 2 %. What is the worst-case limiting error in the power?

The worst-case limiting error in the power is 4 %.

> **WORKING**
>
> 1. $P = I^2R$, so $\delta P/P = 2\,\delta I/I + \delta R/R$
> 2. $\delta P/P = 2(1\,\%) + 2\,\%$
> 3. $\delta P/P = 4\,\%$

4. Why does averaging many readings reduce random error but not systematic error?

Random errors are equally likely to be positive or negative, so they partly cancel in the mean, and the standard deviation of the mean falls as $\sigma/\sqrt{n}$. A systematic error, such as a miscalibrated scale, shifts every reading the same way, so averaging leaves it unchanged. It has to be found by calibration against a better standard.

Bridges, potentiometers and the Q-meter

5. Why does the result of a Wheatstone bridge not depend on the calibration of its detector?

At balance the detector current is zero, so the unknown follows from the ratio of the known arms alone, using $R_1R_4 = R_2R_3$. The detector only has to be sensitive enough to show zero, not to read a value. Accuracy then depends on the stability and tolerance of the known resistors.

6. Why is a Kelvin double bridge used instead of a Wheatstone bridge for low resistances?

Lead and contact resistances are comparable to a low unknown resistance, and in a Wheatstone bridge they add directly to it as error. The Kelvin double bridge uses four terminals on the low resistance and a second pair of ratio arms. When the two ratios are equal, the link resistance drops out of the balance equation.

7. A Maxwell inductance-capacitance bridge balances with the standard capacitor $C_1 = 0.1\ \mu$F in parallel with $R_1 = 10\ \text{k}\Omega$, and the other two arms $R_2 = 2\ \text{k}\Omega$ and $R_3 = 5\ \text{k}\Omega$. Find the unknown inductance.

The unknown inductance is 1 H.

WORKING

1. Balance condition: $L_x = R_2 R_3 C_1$
2. $L_x = 2000 \times 5000 \times 0.1 \times 10^{-6}$
3. $L_x = 10^7 \times 10^{-7} = 1$ H

8. Why can a DC potentiometer measure an emf more accurately than a moving-coil voltmeter?

At balance no current flows from the source under test, so there is no drop across its internal resistance and the potentiometer reads the true emf. A voltmeter draws current and reads the lower terminal voltage. The accuracy then rests on the standard cell and the slide wire, after standardisation.

Measuring voltage, current, power, energy and power factor

9. Why does a PMMC meter read zero on a pure sinusoidal ac signal?

The deflecting torque of a PMMC movement is proportional to the instantaneous current, and the moving system is too slow to follow it, so the pointer settles at the average value. The average of a symmetrical sine wave over a cycle is zero. Measuring ac with a PMMC needs a rectifier in front of it.

10. Why does a rectifier-type ac voltmeter read wrongly on a non-sinusoidal waveform?

The meter responds to the average of the rectified wave, but its scale is marked in rms using the sine-wave form factor of 1.11. For any other waveform the form factor is different, so the reading is in error. A true-rms meter avoids this by responding to the rms value directly.

11. A PMMC movement has a coil resistance of 100 ohm and a full-scale current of 1 mA. What shunt resistance makes it read 100 mA at full scale?

The required shunt resistance is about 1.01 ohm.

WORKING

1. Shunt current at full scale: $I_{sh} = I - I_m = 100 - 1 = 99$ mA
2. The shunt and the coil have the same voltage: $R_{sh} I_{sh} = R_m I_m$
3. $R_{sh} = \dfrac{100 \times 1 \times 10^{-3}}{99 \times 10^{-3}}$
4. $R_{sh} \approx 1.01\ \Omega$

12. How does the two-wattmeter method measure three-phase power, and when does one reading go negative?

For a three-wire load, the total power is the sum of the two readings, $P = W_1 + W_2$. For a balanced load the readings are $V_L I_L \cos(30^\circ \pm \phi)$, where V_L is the line voltage and I_L the line current. One reading is zero at a power factor of 0.5 and goes negative below it, so it must be subtracted in the sum.

13. Why does an induction-type energy meter have a permanent braking magnet?

The driving torque on the disc is proportional to the power. The magnet induces eddy currents in the moving disc, which give a retarding torque proportional to its speed. At steady speed the two torques balance, so speed is proportional to power and the number of revolutions is proportional to energy.

Instrument transformers

14. Why must the secondary of a current transformer never be left open while the primary carries current?

With the secondary open there are no secondary ampere-turns to oppose the primary. The primary current is set by the line, so all of it becomes magnetising current and drives the core deep into saturation. The flux changes rapidly and induces a dangerously high voltage across the secondary terminals, and the core overheats.

15. What is the difference between a current transformer and a potential transformer in how they are connected and loaded?

A current transformer is connected in series with the line. Its primary current is set by the load, and its secondary works close to a short circuit with a low burden. A potential transformer is connected across the line, with the primary voltage set by the system, and its secondary works close to open circuit with a high-impedance burden.

16. What are the ratio error and the phase-angle error of a current transformer, and what causes them?

The ratio error is the amount by which the actual current ratio differs from the nominal ratio. The phase-angle error is the angle by which the reversed secondary current differs from being in phase with the primary current. Both arise because the magnetising and core-loss components of the primary current do not reach the secondary. A low burden and a good core reduce them.

Digital voltmeters, multimeters and energy meters

17. What is a 3½ digit digital voltmeter, and what is its resolution on a 2 V range?

A 3½ digit display has three full digits from 0 to 9 and a leading half digit that shows only 0 or 1, so it counts up to 1999. Resolution is one count. On a range with a full scale of 1.999 V, one count is 1 mV, so the meter resolves 1 mV.

18. A 3½ digit voltmeter on its 20 V range (full scale 19.99 V, one count is 10 mV) is specified as ±(0.5 % of reading + 2 counts). It reads 10.00 V. What is the worst-case error?

The worst-case error is ±0.07 V.

> **WORKING**
>
> 1. Reading error: $0.5\,\% \times 10.00 = 0.05$ V
> 2. Counts error: $2 \times 10\ \text{mV} = 0.02$ V
> 3. Worst case: $0.05 + 0.02 = 0.07$ V

19. Why does a dual-slope DVM reject mains-frequency noise?

It integrates the input over a fixed time. If that time is a whole number of mains periods, such as 20 ms for a 50 Hz supply, the integral of an interfering mains-frequency signal over the interval is zero. The result is also independent of the integrator's resistor, capacitor and clock frequency, since the same ones are used in both slopes.

20. What is the difference between a flash converter and a successive-approximation converter?

A flash converter compares the input with all reference levels at once using $2^n - 1$ comparators, so it is the fastest type but needs many comparators and is limited in resolution. A successive-approximation converter uses one comparator and a DAC to settle one bit per clock cycle, so it is slower but cheaper and reaches higher resolution.

Time and frequency measurement

21. A counter measures a 5 kHz signal with a gate time of 1 s. What is the percentage error due to the ±1 count gating error?

The gating error is ±0.02 %.

> **WORKING**
>
> 1. Count: $N = fT = 5000 \times 1 = 5000$
> 2. Error of one count: $1/N = 1/5000 = 2 \times 10^{-4}$
> 3. As a percentage: $0.02\,\%$

22. Why is the period mode better than the frequency mode of a counter for measuring a low-frequency signal?

In frequency mode the counter counts input cycles in a fixed gate time. At low frequency the count is small, so the ±1 count error is a large fraction of it. In period mode it counts clock pulses over one input period, and a high-frequency clock makes the count large and the error small.

23. Why is a 10x oscilloscope probe compensated, and what is the condition for correct compensation?

The probe's series resistor and parallel capacitor form a divider with the scope's input resistance and capacitance. The divider ratio is the same at all frequencies only when $R_p C_p = R_s C_s$. Otherwise a square wave shows overshoot or rounded edges. The probe's trimmer capacitor is adjusted until the square wave has flat tops.

24. What is aliasing in a digital storage oscilloscope, and how is it avoided?

Aliasing occurs when the scope samples at less than twice the highest frequency in the signal, the Nyquist rate. Higher-frequency components then appear on screen as false lower-frequency ones. It is avoided by sampling several times faster than the signal bandwidth, or by filtering out the high frequencies before sampling.

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