BITS-PILANI, K. K. BIRLA GOA CAMPUS
Semester I, 2022-23
INSTR F311 - ELECTRONIC INSTRUMENTS AND INSTRUMENTATION TECHNOLOGY

Comprehensive examination, Regular [Closed Book] Date: 17/12/2022
Maximum Marks: 70 Duration: 3 hours

Part A (30 Marks, First 60 minutes)

- **This section carries 10 questions. The first 5 questions carry 2 marks each and the next 5 questions carry 3 marks each.**
- **Write the answers to the questions in Part-A on a separate, printed answersheet provided. Write only the final answers.**
- **Rough-work for Part A can be done only on the last three pages of the Main Answersheet.**
- **Use the Main Answersheet to write the answers to the questions in Part B.**
- **Prepare an index behind the cover page of the Main Answersheet.**

First 5 questions: (5 questions x 2 marks = 10 marks)

Q.1 An unknown resistance of value 40 Ω is measured by passing a constant current of 2 mA and measuring the resultant DC voltage across the resistance. The resistance of the lead wires is 2 Ω. What is the difference V_{diff} (in mV) between the voltmeter readings when connected in Two-wire sensing and Four-wire sensing measurement setups?

Q.2 A 0-10 V Digital voltmeter with a 4 ½ digit display is used for measuring DC currents in the range 0-1 mA using an electronic circuit as shown in Fig. Q2. What is the Transimpedance gain R_f (in kΩ) of the amplifier A_1? Assume $R_1 = R_2 = 1$ kΩ

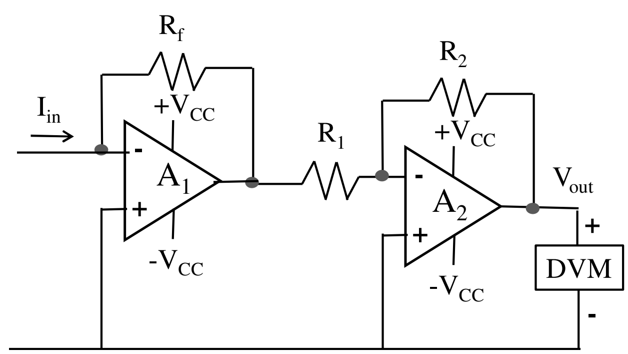

Fig. Q2: Current measurement circuit

Q.3 In a Hall effect device, the current passing through the device is 3 A and a magnetic field of 0.4 T is applied perpendicular to the device. If the Hall-effect coefficient is 600 μΩ/T, calculate the generated Hall voltage e_H (in mV).

Q.4 Calculate the time base error Δf_{tb} (in Hz) in an electronic counter for the measurement of frequency of a 12 MHz signal, if the crystal oscillator's frequency is 100 MHz and its accuracy is specified to be 20 ppb.

Q.5 The chart speed of a recording instrument is 2 cm/s. What is the distance d_{cycle} (in mm) to which one cycle of a 5 Hz signal would extend on the chart?

Next 5 questions: (5 questions x 3 marks = 15 marks)

Q.6 An amplifier is fed an input signal with frequency components f_1 = 31.8 kHz and f_2 =32.2 kHz and analyzed for the Intermodulation components $(mf_1 \pm nf_2)$ in the output. Write the values of the third order Intermodulation components $f_{IM,3,1}$ and $f_{IM,3,2}$ (in kHz) whose frequencies are close to those present in the input signal.

Q.7 A high impedance probe with a 10 MΩ resistance and 5 pF capacitance is connected to an oscilloscope with an input resistance of 1 MΩ. When the probe is connected, the effective capacitance decreased to 4.5 pF. What is the input capacitance C_{in} (in pF) of the oscilloscope?

Q.8 The reference frequency f_{ref} applied to an 8-bit Direct Digital Synthesis (DDS) chip is 10 MHz. What are (i) the Frequency resolution f_{res} (in Hz) and (ii) the Phase resolution ϕ_{res} (in rad)?

Q.9 In a laboratory, the mass of an object is measured using a beam balance whose tolerance is ±0.1 g, which in turn is calibrated using a physical balance of tolerance ±0.02 g, all specified with a 2 sigma confidence interval. (i) What is the Test Accuracy Ratio (TAR) in the measurements? (ii) What is the probability (in %) that the reading will lie within the specified tolerance limits.

Q.10 Calculate the output noise voltage V_0 due to shield voltage V_s as shown in Fig. Q10, if shield voltage is 1V at 1.5MHz, cable shield to conductor capacitance is 200 pF, the signal source impedance is 1000 Ω and the load resistance is 10 kΩ.

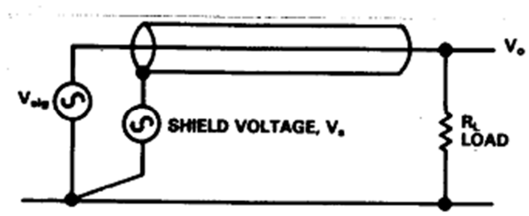

Fig. Q10. Shield at potential V_s

--×--

Part B (45 marks, 120 minutes)

Instructions:

- **Write all the steps clearly and give explanations for complete credit.**
- **Overwritten answers and answers written with a pencil will not be rechecked.**
- **Make suitable assumptions wherever necessary and mention them clearly.**

Question 1:

(a) Ayrton Shunt arrangement, (Fig. B.1.1) is designed to achieve DC current measurement ranges of 0-10 mA, 0-100 mA and 0-1 A with a PMMC mechanism that has an internal resistance of 50 Ω with a full scale deflection current of 1 mA. Find resistances R_1, R_2 and R_3. [4 M]

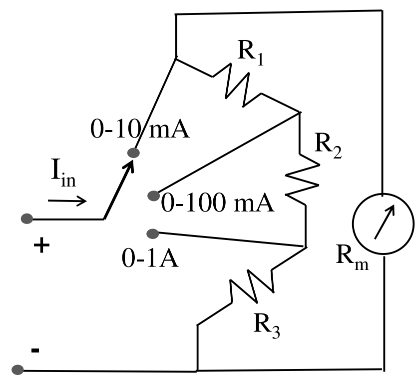

Fig. B1.1 Ayrton Shunt

(b) A Wheatstone's bridge is powered by a DC current source I_S (Fig. B1.2). The arm resistances R_1, R_2, R_3 and R_4 are equal and at the balanced condition equal to R_0. During an experiment, their values were found to undergo a fractional change given by -α, +2α, +α and -2α respectively, where α<<1. The Galvanometer, whose resistance is R_G, carries a current I_G due to bridge imbalance.

→Obtain expressions for Thevenin voltage V_{TH} across c,d and I_G. as function of α, I_S, R_0, R_G.

→ If R_0 =1 kΩ and R_G =50 Ω, ,I_S= 2 mA, calculate V_{TH} and I_G for α = 0.5%. [5 M]

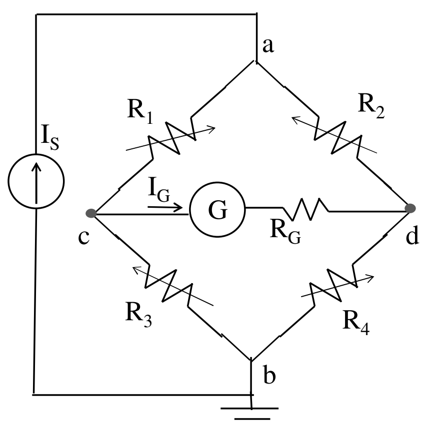

Fig. B1.2 Wheatstone's Bridge

(c) Design a decade-programmable Fast Switching Direct Analog Synthesizer to generate 15.7 MHz from a reference of 10 MHz. The Synthesizer consists of identical modules, one to program each significant digit in the output frequency. Each module contains a mixer, an oscillator that produces one of 10 possible frequencies, band-pass filter and a ÷ 10 divider. [3 M]

Question 2:

An LCR bridge uses a sinusoidal current source I_s of 1 mA peak current at 1 kHz to power a standard resistor R_{std} and an unknown component Z_x both connected in series. The instantaneous differential voltages across R_{std} and Z_x given by e_{std} and e_x are fed to Channel-1 and Channel-2 respectively of a dual trace oscilloscope. Their time trace is shown in Fig. B.2. The grid spacing along the Time and Voltage axes are 125 μs and 250 mV respectively.

(a) If the unknown component Z_x is modelled as a series combination of a resistor R_x and a capacitor, C_x, find the component values R_{std}, R_x and C_x. [4 M]

(b) Sketch the X-Y plot (Lissajous figure) wherein Channel-1 and Channel-2 are configured as X- and Y- channels respectively. [3 M]

(c) The impedance Z_x is now modelled at the same excitation frequency as an equivalent parallel combination of a resistor R_P and a capacitor C_P. Obtain the expressions for R_P and C_P as a function of R_x, C_x and a dimensionless parameter $\alpha = R_x C_x \omega$. Calculate α, R_P and C_P. [5 M]

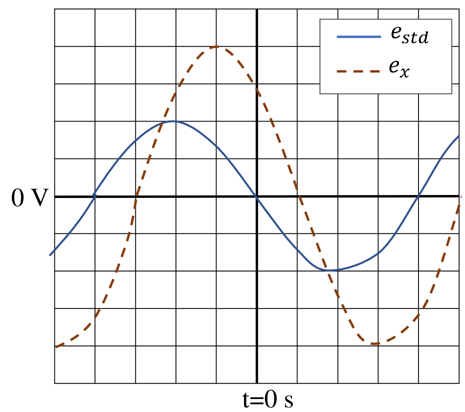

Fig. B.2 Time trace of signals e_{std} and e_x

Question 3:

(a) In a counter, the input channel noise is 200 µV, and the input signal has 1 mV rms noise through the specified bandwidth. Slew rates corresponding to the rising and falling edges are 300 mV/µs and 400 mV/µs respectively. The ±1 count error and the least significant digit (LSD) in the display are both 0.001 Hz. The frequency of input signal is 2 MHz. Find the overall frequency resolution in Hz and in number of LSD. [3 M]

(b) Calculate the maximum time base error in frequency for the input signal in (a), assuming that the counter has not been calibrated for a year. Aging rate: $< 2 \times 10^{-7}$ per month, Temperature variation: $< 3 \times 10^{-6}$ (0 °C to 50 °C) and Line voltage effect: $< 1 \times 10^{-7}$ for 10% variation. [3 M]

(c) Define Total Harmonic Distortion (THD) of a sinusoidal signal. Sketch the block diagram of the Distortion Analyzer that characterizes the THD of a signal. Describe in brief the functionality of each block. [3 M]

Question 4:

a) Describe the three phases of a product's life cycle, through the "bathtub curve" of the product's reliability. [3 M]

b) What is skin depth? What measures will you take to reduce magnetic field effect on the receiving circuit? [4 M]

c) Explain ingress protection code for the enclosures. [5 M]

--×--