Reg. No.									

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

V SEMESTER B.TECH (ELECTRICAL & ELECTRONICS ENGINEERING)
ONLINE EXAMINATIONS, JANUARY - FEBRUARY 2021

MEASUREMENTS AND INSTRUMENTATION [ELE 3153]
REVISED CREDIT SYSTEM

Time: 3 Hours **Date: 02 February 2021** **Max. Marks: 50**

Instructions to Candidates:
- Answer **ALL** the questions.
- Missing data may be suitably assumed.

1A. Four ammeters M1, M2, M3 and M4 with the following specifications are available for measurements in a laboratory setup:

Instrument	Type	Full scale value (A)	Accuracy % of FS
M1	$3\frac{1}{2}$ digit dual slope	20	± 0.10
M2	PMMC	10	± 0.20
M3	Electrodynamometer	5	± 0.50
M4	Moving iron	1	± 1.00

A current of 1 A is to be measured. Through appropriate calculations, justify which instrument has the least error. ***(03)***

1B. A no-load test was performed on a three-phase induction motor. Two-wattmeter method was used to measure the 3-phase input power. The wattmeters have an electrodynamometer type of construction. The results of the conducted test are as follows: V = 400 V ± 1%, I = 3.25 A ± 1%, W_1 = – 600 W ± 2% and W_2 = 850 W ± 1%.

Power factor is calculated using these measurements. Accordingly, calculate the power factor in the worst case error scenario. ***(03)***

1C. During the measurement of resistance, it was found that the current flowing through a resistor of 0.105 Ω was 30.4 A. It was later discovered that the ammeter reading was low by 1.2 % and the marked resistance was high by 0.3 %. Find the true power as a percentage of the power that was originally calculated. ***(04)***

2A. Find an expression for the deflecting toque of a moving-iron ammeter in terms of the current and its inductance. Given that the controlling torque per degree is 4×10^{-7} N-m, find the current to give a deflection of 30°. Given data:

Deflection (degrees)	20	30	40	50	60	70	80	90
Inductance (µH)	335	345	355.5	366.5	376.5	385	391.3	396

(03)

2B. A new car is equipped with a tyre pressure monitoring system (TPMS) that uses piezoelectric transducers installed inside the 4 tyres. The dimension of each transducer is 6 mm × 6 mm × 1.3 mm. The charge sensitivity and the dielectric constant of the transducer are given as 160 pC/N and 1250×10^{-11} F/m respectively. If each transducer is subjected to a force of 6 N, calculate the voltage generated in it and the deflection caused to its surface. The Young's modulus of elasticity of the material is given as 12×10^{6} N/m^2. ***(03)***

2C. The parallel resistance-capacitance bridge shown in **Fig. Q2C** has C_1 = 0.1 µF and R_3 = 10 kΩ. The bridge is balanced at a supply frequency of 100 Hz for R_1 = 375 kΩ, R_3 = 10 kΩ and R_4 = 14.7 kΩ.

Determine the dissipation factor $\left(D = \frac{1}{\omega C_p R_p}\right)$ of the parallel combination of C_p and R_p.

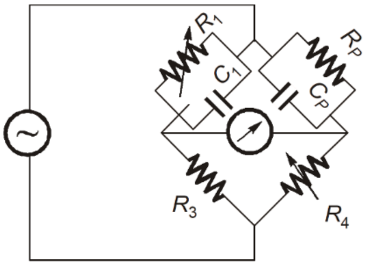

Fig. Q2C ***(04)***

3A. The schematic of a tentative capacitive based displacement measurement system is as shown below in **Fig. Q3A**. Consider the reference input to the measurement system as well as the subsequent A/D converter (12 bit) to be the same DC input.

The maximum value of observed capacitive change is ±5%.

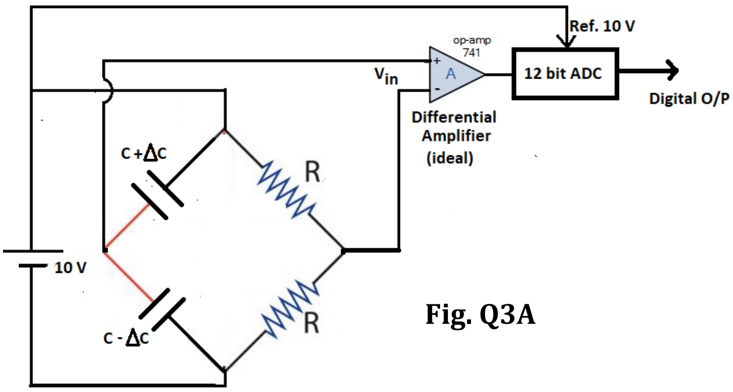

Fig. Q3A

- Through appropriate analysis, compute the required gain of the differential amplifier such that the full range of the A/D converter is used effectively for further specifications of an application.
- Design a suitable 3 – OPAMP based instrumentation amplifier to replace the differential amplifier in the schematic which will still provide the same value of the gain determined earlier.

(Passive component values may be selected from the below given tables)

Standard Resistor Values (±5%)

1.0	10	100	1.0K	10K	100K	1.0M
1.1	11	110	1.1K	11K	110K	1.1M
1.2	12	120	1.2K	12K	120K	1.2M
1.3	13	130	1.3K	13K	130K	1.3M
1.5	15	150	1.5K	15K	150K	1.5M
1.6	16	160	1.6K	16K	160K	1.6M
1.8	18	180	1.8K	18K	180K	1.8M
2.0	20	200	2.0K	20K	200K	2.0M
2.2	22	220	2.2K	22K	220K	2.2M
2.4	24	240	2.4K	24K	240K	2.4M
2.7	27	270	2.7K	27K	270K	2.7M
3.0	30	300	3.0K	30K	300K	3.0M
3.3	33	330	3.3K	33K	330K	3.3M
3.6	36	360	3.6K	36K	360K	3.6M
3.9	39	390	3.9K	39K	390K	3.9M
4.3	43	430	4.3K	43K	430K	4.3M
4.7	47	470	4.7K	47K	470K	4.7M
5.1	51	510	5.1K	51K	510K	5.1M
5.6	56	560	5.6K	56K	560K	5.6M
6.2	62	620	6.2K	62K	620K	6.2M
6.8	68	680	6.8K	68K	680K	6.8M
7.5	75	750	7.5K	75K	750K	7.5M
8.2	82	820	8.2K	82K	820K	8.2M
9.1	91	910	9.1K	91K	910K	9.1M

Standard Capacitor Values (±10%)

10pF	100pF	1000pF	.010µF	.10µF	1.0µF	10µF
12pF	120pF	1200pF	.012µF	.12µF	1.2µF	
15pF	150pF	1500pF	.015µF	.15µF	1.5µF	
18pF	180pF	1800pF	.018µF	.18µF	1.8µF	
22pF	220pF	2200pF	.022µF	.22µF	2.2µF	22µF
27pF	270pF	2700pF	.027µF	.27µF	2.7µF	
33pF	330pF	3300pF	.033µF	.33µF	3.3µF	33µF
39pF	390pF	3900pF	.039µF	.39µF	3.9µF	
47pF	470pF	4700pF	.047µF	.47µF	4.7µF	47uF
56pF	560pF	5600pF	.056µF	.56µF	5.6µF	
68pF	680pF	6800pF	.068µF	.68µF	6.8µF	
82pF	820pF	8200pF	.082µF	.82µF	8.2µF	

(06)

3B. The same previous design of the active measurement system developed as shown in **Fig. Q3A**, will be applied to determine the thickness of paper sheets used in canvas drawings. The analytical relation between the capacitance (C) and the thickness of the paper (t) is found to be $C = 2 \times [1 - \sin(at)] \times 10^{-9}\ F$, where $a = 1432.5$ is a constant. The expected value of the thickness of the paper sheet is 1 mm. Through appropriate analysis, determine the signal levels from the active measurement system during the absence as well as the presence of the paper sheet. Further, compute the equivalent digital output from the 12 - bit A/D converter for each of the cases. ***(04)***

4A. Linear variable differential transformer (LVDT) is used in a cantilever system (beam length is 1 meter) to measure the free tip deflection caused by a water jet as it strikes the tip as shown in the overall application schematic of **Fig. Q4A**. The free tip deflection is characterized mathematically by the following equation $y\,(x) = 0.001 \times F \times x^2\left(1 - {}^{x}/_{3}\right)$meters, where:

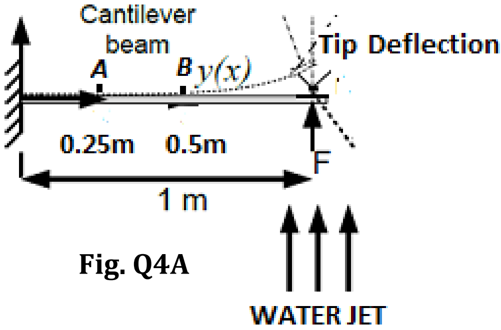

Fig. Q4A

F is the force applied on the free tip due to the water jet striking it and x is the distance (in meters) from the fixed end.

- Determine the possible change in deflection of the free tip with respect to change in distance (from the fixed end) for an applied force of 1N at the free tip.
- Determine the ratio of the measurement outputs if two LVDTs are placed at 0.25 m (point A) and 0.5 m (point B) from the fixed end of the cantilever system. ***(03)***

4B. Shock sensors are widely used in detecting abnormal vibrations in industrial motors. They behave like piezoelectric sensors. In the application here, the motor runs at variable speeds and the maximum shock sensed is 50G. The electric signals from the shock sensor is fed to a charge amplifier configured in its charge mode. The charge source is defined to be $0.35 pC/G$, while the shunt resistor and capacitor were defined to be $10 G\Omega$ and $390 pF$ respectively. The cable length used here was 1 meter. The insulation material used in the cable is Polytetrafluoroethylene (PTFE) whose dielectric constant is 2.1 and the cable capacitance is $100 pF$. The analog platform is designed in such a manner that for zero input, the voltage output too should be zero. The resonant frequency of the shock sensor is $28 kHz$. Design the analog signal conditioning platform (amplifier along with the active filters) such that voltage output for a fixed pass band of 160 Hz – 2 kHz is obtained.

Standard Resistor Values (±5%)						
1.0	10	100	1.0K	10K	100K	1.0M
1.1	11	110	1.1K	11K	110K	1.1M
1.2	12	120	1.2K	12K	120K	1.2M
1.3	13	130	1.3K	13K	130K	1.3M
1.5	15	150	1.5K	15K	150K	1.5M
1.6	16	160	1.6K	16K	160K	1.6M
1.8	18	180	1.8K	18K	180K	1.8M
2.0	20	200	2.0K	20K	200K	2.0M
2.2	22	220	2.2K	22K	220K	2.2M
2.4	24	240	2.4K	24K	240K	2.4M
2.7	27	270	2.7K	27K	270K	2.7M
3.0	30	300	3.0K	30K	300K	3.0M
3.3	33	330	3.3K	33K	330K	3.3M
3.6	36	360	3.6K	36K	360K	3.6M
3.9	39	390	3.9K	39K	390K	3.9M
4.3	43	430	4.3K	43K	430K	4.3M
4.7	47	470	4.7K	47K	470K	4.7M
5.1	51	510	5.1K	51K	510K	5.1M
5.6	56	560	5.6K	56K	560K	5.6M
6.2	62	620	6.2K	62K	620K	6.2M
6.8	68	680	6.8K	68K	680K	6.8M
7.5	75	750	7.5K	75K	750K	7.5M
8.2	82	820	8.2K	82K	820K	8.2M
9.1	91	910	9.1K	91K	910K	9.1M

Standard Capacitor Values (±10%)						
10pF	100pF	1000pF	.010µF	.10µF	1.0µF	10µF
12pF	120pF	1200pF	.012µF	.12µF	1.2µF	
15pF	150pF	1500pF	.015µF	.15µF	1.5µF	
18pF	180pF	1800pF	.018µF	.18µF	1.8µF	
22pF	220pF	2200pF	.022µF	.22µF	2.2µF	22µF
27pF	270pF	2700pF	.027µF	.27µF	2.7µF	
33pF	330pF	3300pF	.033µF	.33µF	3.3µF	33µF
39pF	390pF	3900pF	.039µF	.39µF	3.9µF	
47pF	470pF	4700pF	.047µF	.47µF	4.7µF	47uF
56pF	560pF	5600pF	.056µF	.56µF	5.6µF	
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82pF	820pF	8200pF	.082µF	.82µF	8.2µF	

(03)

4C. As part of a project execution, it is mandatory to determine the sensitivities of two bridge circuit designs shown in **Fig. Q4C** which may be possibly used in the transducer circuit.

- Determine the sensitivity of design A for small variations in $x; x < 0.1$
- Derive the linear relation of the output voltage with respect to x for large values of x.
- Through appropriate analysis, comment on the sensitivity as well as linear relationship of the measurement system when design B is used in place of design A.
- Finally, from the conducted analysis above, justify through appropriate reasoning, on the design you would choose to be integrated in the transducer.

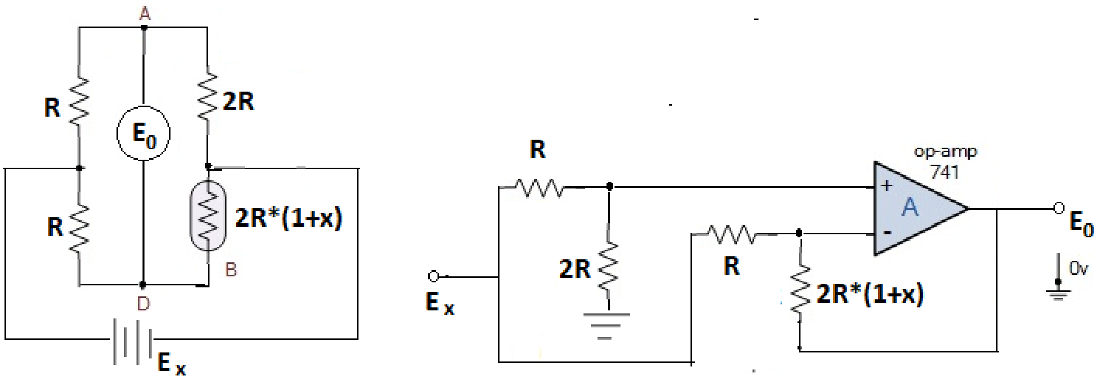

Fig. Q4C

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5A. The block schematic shown in **Fig. Q5A** below is that of speed control of a small DC motor for the regulated flying objective of a Quadcopter. According to the transduced signal from the encoder, the control algorithm written in the microcontroller generates the required digital train of pulses which needs to be converted to their analogue equivalent so as to drive the control circuits which in turn regulate the speed of the motor. With appropriate justification, mention which of the following two D/A converters is preferred for this application:

- Binary weighted D/A converter and
- R-2R Ladder D/A converter

With a neat sketch, explain the working of a 4 – bit R-2R D/A converter for an input pulse train of 0101. Consider the reference voltage to be 10 V while $R = 10k\Omega$. Through appropriate calculations, determine the values of the following parameters:

- Current flowing into the analogue ground
- Developed output voltage.

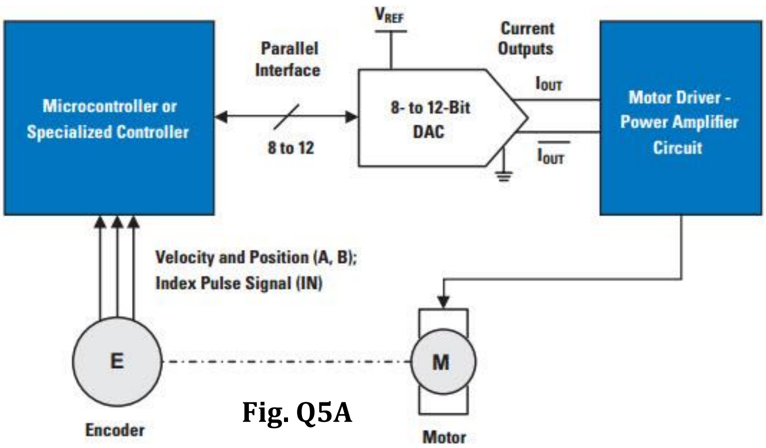

Fig. Q5A

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5B. With the help of neat block diagram explain in detail, the working of a digital energy meter. Consider a 3200 impulses/kWh rated electronic energy meter (EEM) to be installed at your home where the supply is single phase ($230\ V_{rms}, 50\ Hz$). The loads considered at home are:

Serial number	**Load**	**Rating (per unit)**	**Number of units**
1	Electric bulbs	100 W	5
2	Fan	80 W	3
3	Laptop	50 W	1
4	Electric Iron	1000 W	1
5	Air Conditioner (1 HP)	1000 W	1
6	Music System	40 W	1

During morning hours in a typical summer day (temperature around 30^0C with humidity around 80%RH), before going to work, for about 30 minutes (08:30 AM – 09:00 AM), three electric bulbs, one fan and the rest of the above mentioned loads were switched ON. From the fundamentals, perform the required analysis to monitor the EEM and determine the corresponding pulse rate of the EEM for the above mentioned time interval. Accordingly, calculate the current drawn from the supply during this time interval. ***(06)***