NATIONAL UNIVERSITY OF SCIENCES & TECHNOLOGY

Instrumentation and Measurements (EE-383)

Assignment # 1

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***Question**: Identify digital (05) and analog (05) sensors which could be interfaced with micro-controller. Write main features of the sensors, along with block diagram/picture and pin configuration for each. Moreover make a table to list all the parameters i.e., range, accuracy, precision, min, max, average values etc. Make use of datasheets to get the information.*

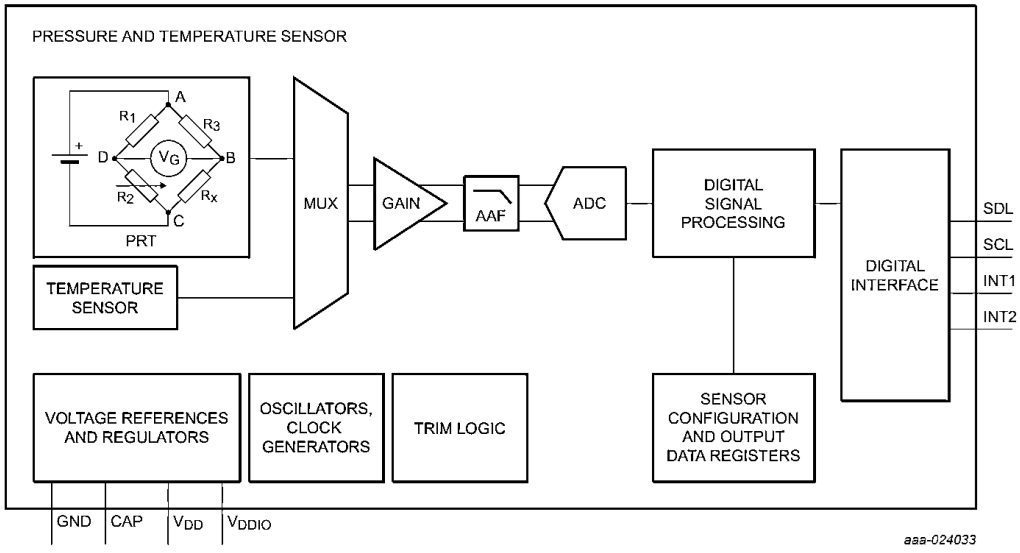
1 Digital Sensors

1.1 Compact Absolute Pressure Sensor - MPL3115A2

A. Main Features

- *Programmable interrupts*
- *Autonomous data acquisition*
- *Embedded 32-sample FIFO*
- *Data logging up to 12 days using the FIFO*
- *One-second to nine-hour data acquisition rate*
- *I^2C digital output interface*
- *Fully compensated internally*
- *Direct reading*

B. Block Diagram



C. Pin Configuration

Pin	Description
V_{DD}	Power supply
CAP	External capacitor
GND	Ground
V_{DDIO}	Digital interface supply

INT2	Pressure interrupt 2
INT1	Pressure interrupt 1
SDL	I^2C Serial Data
SCL	I^2C Serial Clock

D. Parameter Table

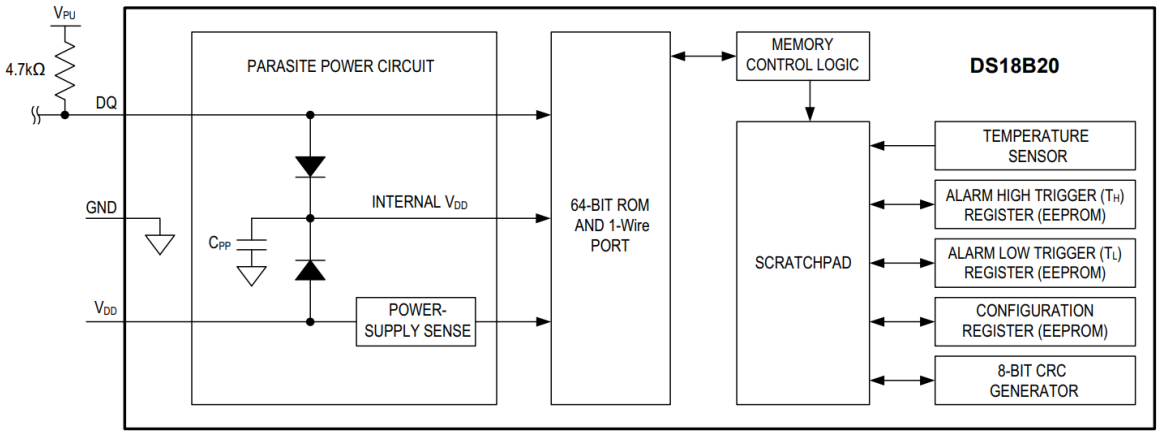
Parameters	**Values**
Calibrated range	70 - 150 kPa
Calibrated temperature output	-40 $°C$ to 85 $°C$
Operating range	50 - 150 kPa
Operating temperature	-40 $°C$ to 85 $°C$
Max pressure	500 kPa
Absolute accuracy	± 0.4 kPa

1.2 Programmable Resolution 1-Wire Digital Thermometer - DS18B20

A. Main Features

- *Unique 1-Wire Interface Requires*
- *Reduce Component Count with Integrated Temperature Sensor and EEPROM*
- *Parasitic Power Mode Requires Only 2 Pins for Operation*
- *Simplifies Distributed Temperature-Sensing Applications with Multidrop Capability*
- *Flexible User-Definable Nonvolatile (NV) Alarm Settings*

B. Block Diagram



C. Pin Configuration

Pin	**Description**
V_{DD}	Power supply
DQ	Data Input/Output
GND	Ground

D. Parameter Table

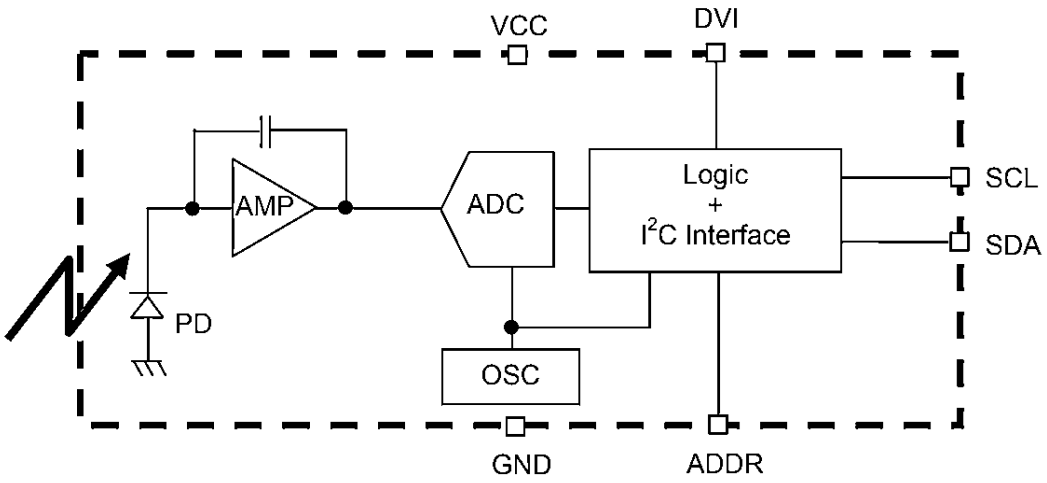
Parameters	Values
Thermometer error	± 2 °C
Accuracy	± 0.5 °C
Temperature resolution	9 to 12 bits
Operating temperature	-55 °C to 125 °C
DQ input current	± 0.4 kPa
Conversion time	< 750 ms

1.3 Ambient Light Sensor - BH1750

A. Main Features

- I^2C bus interface
- Spectral responsibility is approximately human eye response
- Illuminance to digital converter
- Supports continuous measurement mode
- Supports one-time measurement mode
- Low current by power down function

B. Block Diagram



C. Pin Configuration

Pin	Description
V_{CC}	Power supply
GND	Ground
SCL	SCL pin for I^2C communication
SDA (Data)	SDA pin for I^2C communication
ADD*	Selects address

D. Parameter Table

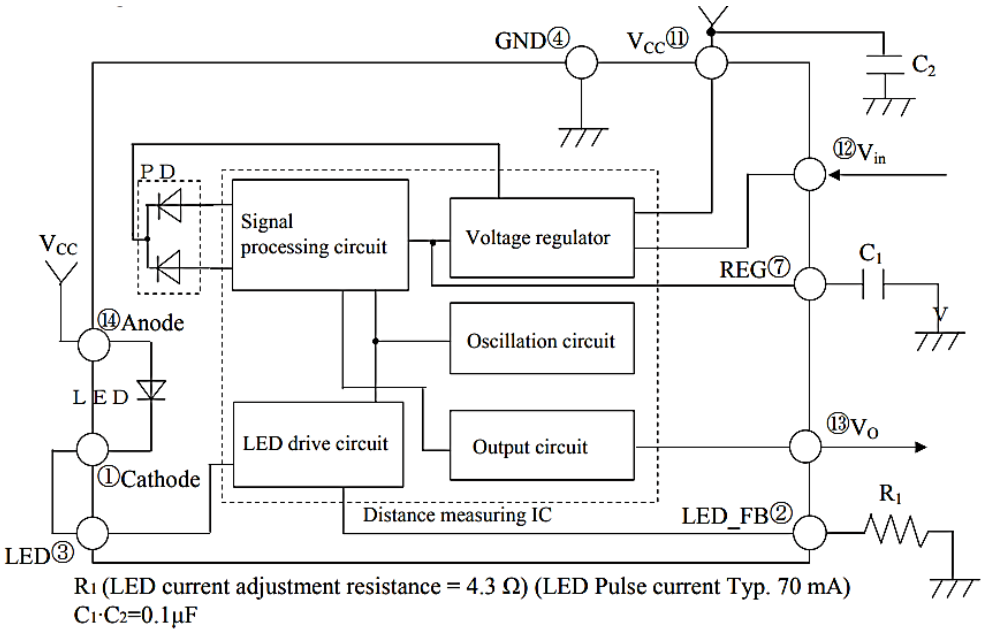
Parameters	Values
Resolution modes	High, H-2, Low
Accuracy	± 1.4% cd.
Operating temperature	-40 °C to 85 °C
Peak wave length	560 nm
Powerdown current	1 μA
Conversion Time	< 750 ms

1.4 Distance Measuring Sensor Unit - GP2Y0D810Z0F

A. Main Features

- Short distance type
- Sunlight tolerance
- Battery drive possible
- Low profile; weight without header pins: 1.3 g
- Add V_{IN} terminal, and an external transistor of V_{CC} line is unnecessary at operation

B. Block Diagram



C. Pin Configuration

Pin	Description
V_{CC}	Power supply
GND	Ground
D_O	Digital output

D. Parameter Table

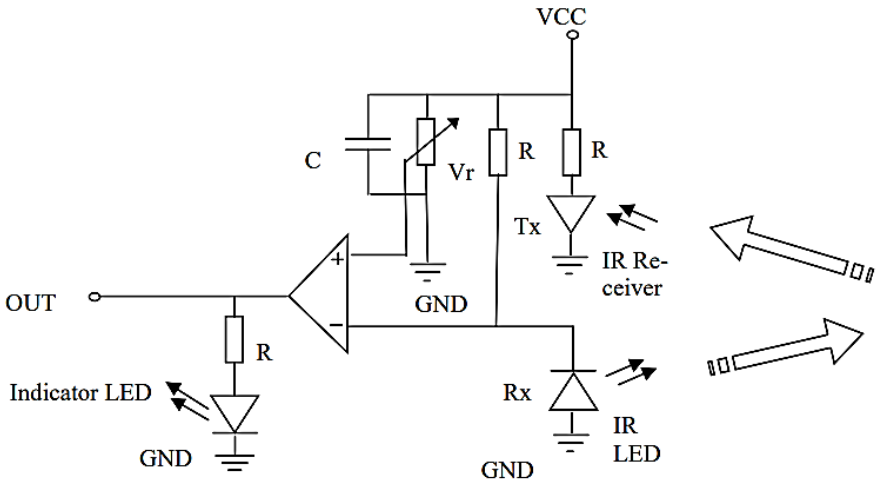
Parameters	Values
Operating temperature	-10 °C to 60 °C
Measuring duration	2.56 ms
Supply current	5 mA
Detecting distance	20 - 100 mm

1.5 Digital IR Sensor - TSOP38238

A. Main Features

- Adjustable Sensing range
- Built-in Ambient Light Sensor
- Mounting hole

B. Block Diagram



C. Pin Configuration

Pin	Description
V_{CC}	Power supply
GND	Ground
D_O	Digital output

D. Parameter Table

Parameters	Values
Operating temperature	-20 °C to 50 °C
Supply current	20 mA
Obstacle detection range	upto 20 cm

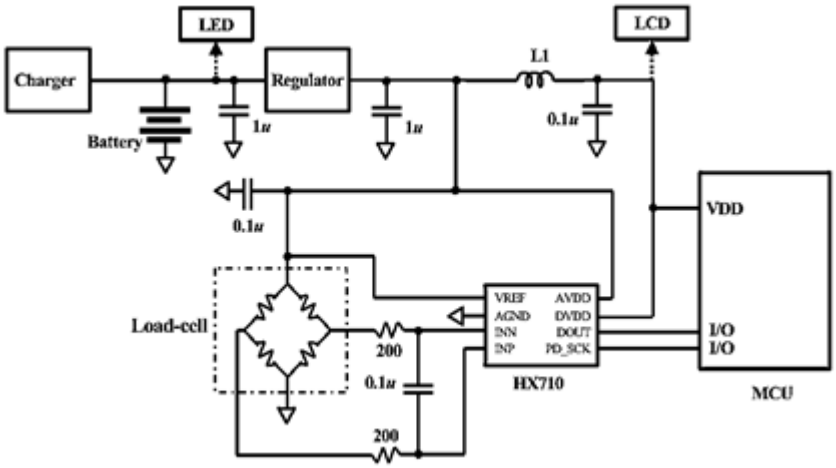
2 Analog Sensors

2.1 Analog Temperature Sensor - HX710A

A. Main Features

- On-chip temperature measurement
- On-chip power-on-reset
- On-chip oscillator requiring no external component
- DVDD and AVDD supply voltage difference measurement
- Simultaneous 50 and 60Hz supply rejection

B. Block Diagram



C. Pin Configuration

Pin	Description
V_{CC}	Power supply
GND	Ground
D_{OUT}	Analog output
SCK	Clock

D. Parameter Table

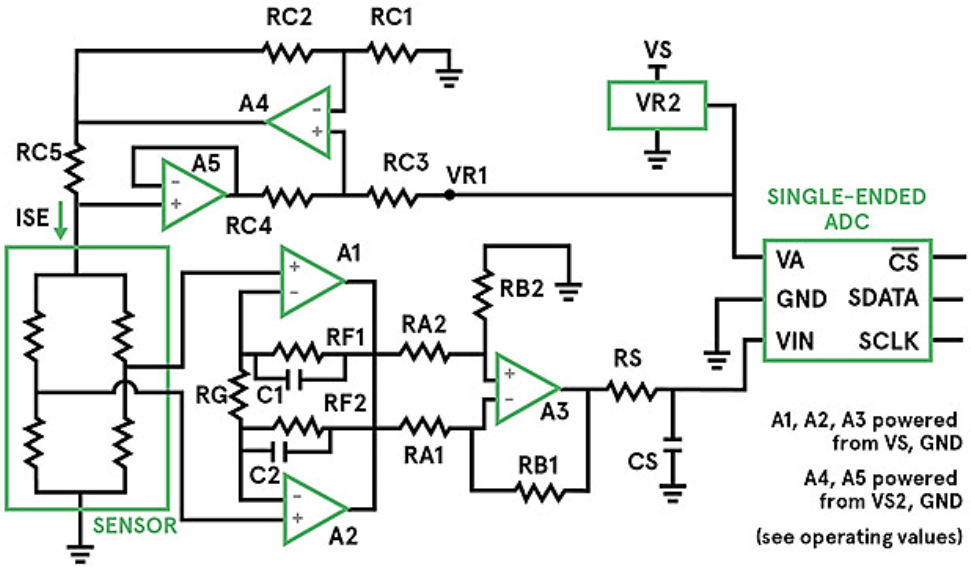
Parameters	Values
Operating temperature	-40 $°C$ to 85 $°C$
Supply current	1100 μA
Temperature drift	± 15 $nV/°C$
Output data rate	10/40 Hz
Power supply rejection	100 dB
Output settling time	400 ms

2.2 Analog Water Pressure Sensor – DFRobot Gravity

A. Main Features

- Support liquid level detection in special situation
- Support water pressure detection of tanks
- Support water pressure detection of outdoor environment

B. Block Diagram



C. Pin Configuration

Pin	Description
VS	Power supply
GND	Ground
CS	Chip select
SDATA	Serial analog data
SCLK	Clock

D. Parameter Table

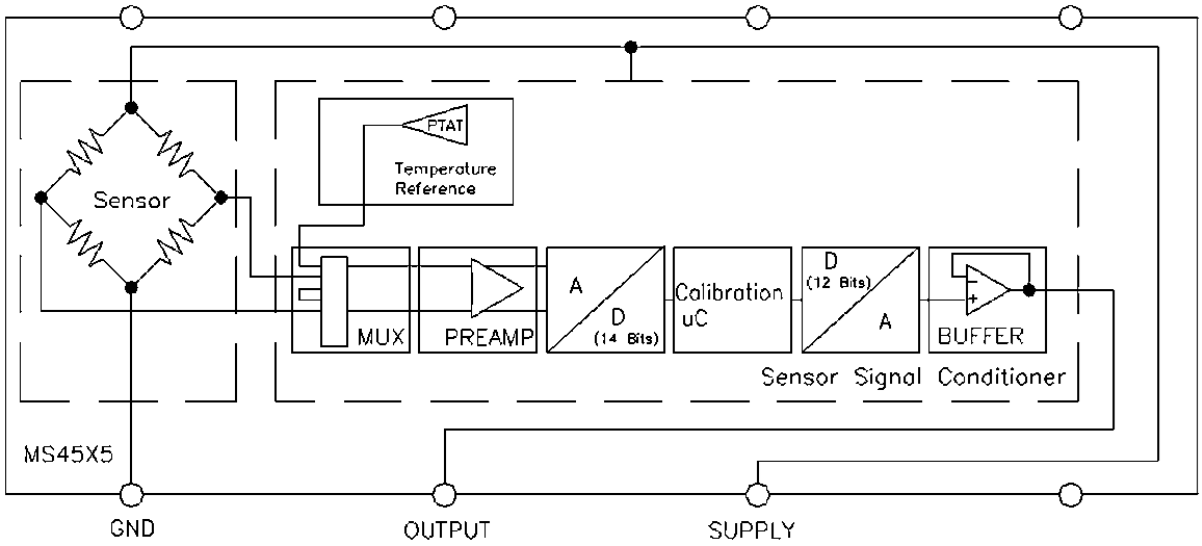
Parameters	Values
Operating temperature	-20 $°C$ to 85 $°C$
Quiescent current	2.8 mA
Temperature drift	± 15 $nV/°C$
Response time	<2 ms
Accuracy	0.5 %
Operating pressure	< 2 MPa

2.3 Pressure Transducer - MS4515

A. Main Features

- Inches H2O Pressure Ranges
- PCB Mountable
- High Level Analog Output
- Barbed Pressure Ports
- Hosts 1/8” barbed pressure ports

B. Block Diagram



C. Pin Configuration

Pin	Description
SUPPLY	Power supply
GND	Ground
OUTPUT	Analog output

D. Parameter Table

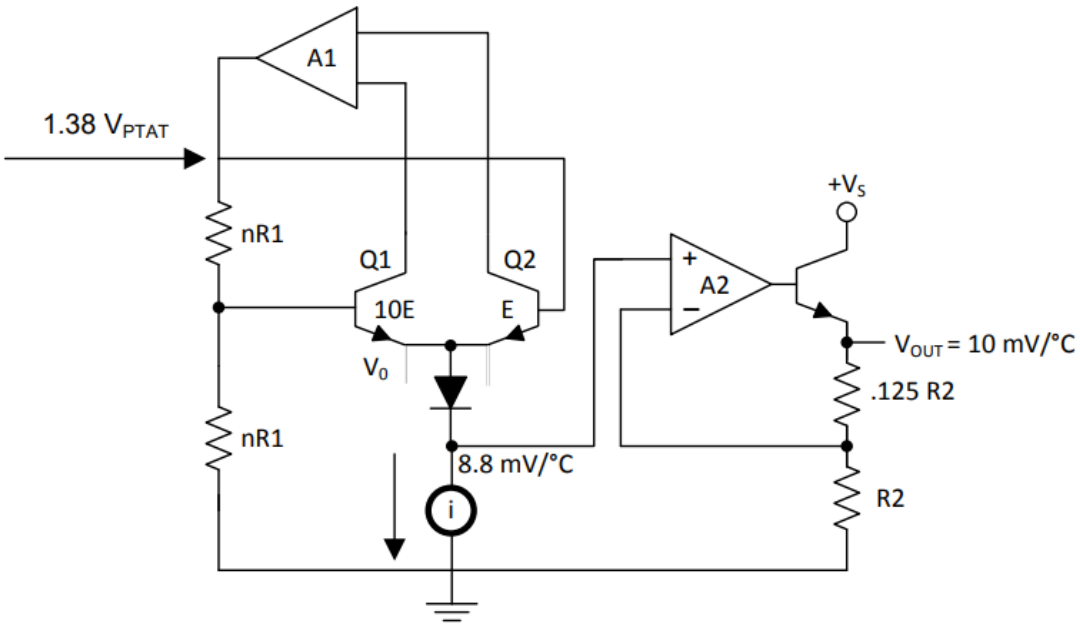
Parameters	Values
Operating temperature	-10 $°C$ to 85 $°C$
Supply current	3 mA
Creep time	6 ms
Response time	1 ms
Accuracy	0.5 %
Output voltage$_{max}$	4.75 V

2.4 Precision Centigrade Temperature Sensor - LM35

A. Main Features

- Calibrated Directly in Celsius
- Low-Cost Due to Wafer-Level Trimming
- Low-Impedance Output
- Low Self-Heating

B. Block Diagram



C. Pin Configuration

Pin	Description
V_S	Power supply
GND	Ground
OUTPUT	Analog output

D. Parameter Table

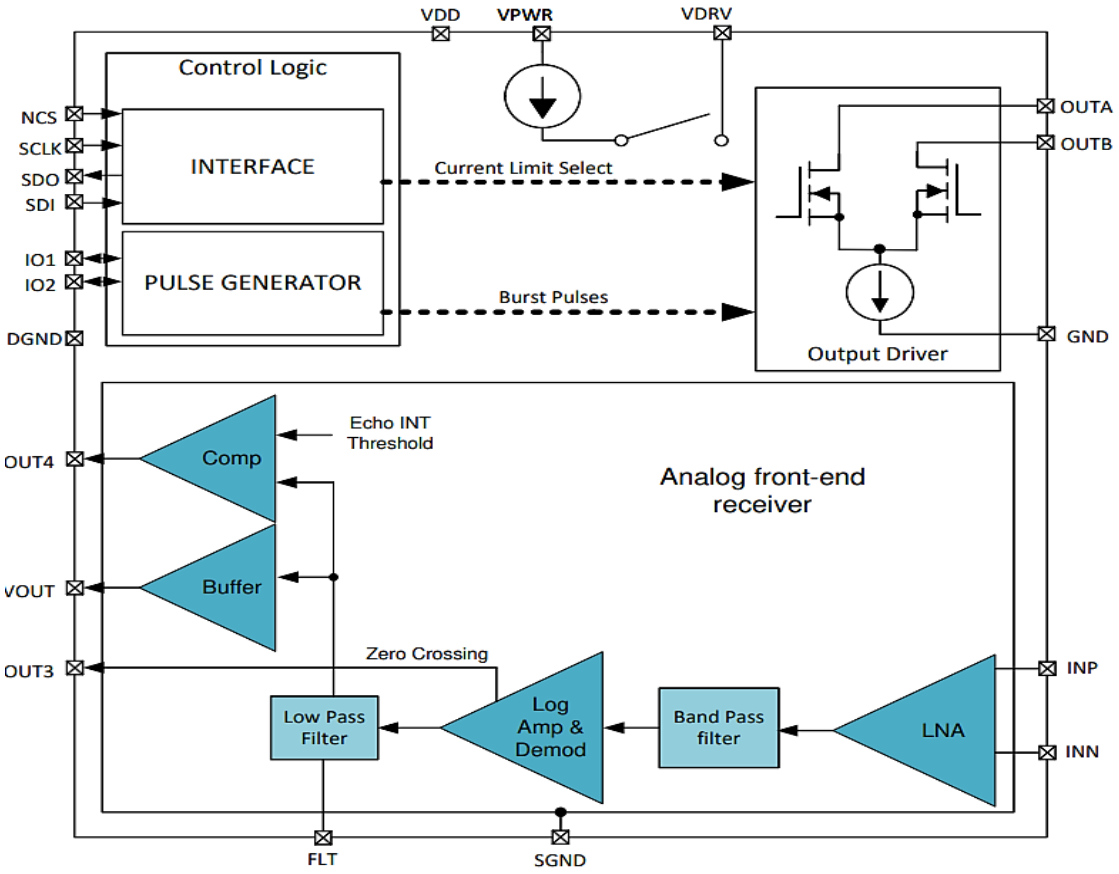
Parameters	Values
Operating temperature	-55 °C to 150 °C
Quiescent current	60 μA
Temperature rating	-55 °C to 150 °C
Nonlinearity	± 0.18 °C
Accuracy	± 0.4 °C

2.5 Transformer Drive Ultrasonic Sensor - TUSS4440

A. Main Features

- Integrated driver for transformer driven transducers and receiver stage with analog output
- Configurable drive stage
- Serial Peripheral Interface (SPI) for configuration by microcontroller
- 86-dB input dynamic range analog front-end

B. Block Diagram



C. Pin Configuration

Pin	Description
VPWR/VDD	Power supply
GND	Ground
INN	Negative transducer receive
INP	Positive transducer receive
SDI	SPI data input
SDO	SPI data output
OUT A/B	Transducer driver output

D. Parameter Table

Parameters	Values
Operating temperature	-40 °C to 105 °C
Maximum current rating	25 mA
Maximum output load capacitance	10 pF
Input hysteresis	100 mV
Supported transducer frequencies	40 - 400 kHz
Dynamic input range	86 dB

2.6 The true value of a voltage is 100 V. Values indicated by a measuring instrument are 104, 103, 105, 103 and 105 volts. Find the accuracy of the measurement and the precision of the instrument.

- Mean of readings $= \frac{104 + 103 + 105 + 103 + 105}{5}$

$= 104$

- Accuracy $= \left|\frac{\text{True} - \text{Mean}}{\text{True}}\right| \times 100\% = \boxed{4\%}$

- Absolute Deviations : Reading - Mean

	0	101
104	0	0
103	-1	1
105	1	1
103	-1	1
105	1	1

- Average Deviation $= \frac{1 + 1 + 1 + 1}{5}$

$= 0.8$

- Precision : $\pm$ A.D $= \boxed{\pm 0.8}$ V

2.14 Choose the correct answers:

(a) A 50 Ω resistor dissipates 2 W of power. The voltage across the resistor is

(i) 100 V
(ii) 25 V
(iii) 12.5 V
(iv) 10 V

$P = \frac{V^2}{R} \Rightarrow 2 = \frac{V^2}{50} \Rightarrow V = \boxed{10}$ V

(b) The errors committed by a person in the measurement are

(i) gross errors
(ii) random errors
(iii) instrumental errors
(iv) environmental errors

(c) A reading is recorded as 68.0 Ω. The reading has
- (i) three significant figures
- (ii) five significant figures
- (iii) four significant figures
- (iv) none of the above

(d) The degree of reproducibility among several independent measurements of the same value under reference conditions is known as
- (i) accuracy
- (ii) precision
- (iii) linearity
- (iv) calibration

(e) In an instrument the smallest measurable input is known as
- (i) threshold
- (ii) resolution
- (iii) dead zone

(f) The threshold of an instrument is normally defined
- (i) as the smallest measurable input change (non-zero value) which can be detected
- (ii) as the smallest measurable input which can be detected
- (iii) in terms of linearity of scale
- (iv) as a function of drift

(g) The term 'precision' used in instrumentation means
- (i) gradual departure of the measured value from the calibrated value.
- (ii) smallest increment in the measurand that can be detected by the instrument
- (iii) maximum distance or angle through which any part of a mechanical system may be moved in one direction without causing motion of the next part
- (iv) the ability of the instrument to give output readings close to each other, when the input is constant.

(h) A voltmeter connected across the 10 kΩ resistor in Fig. 2.20 reads 5 V. The voltmeter is rated at 1000 ohms/volt and has a full scale reading of 10 V.

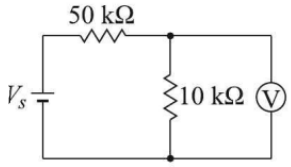


Fig. 2.20

The supply voltage V_s in volt is
- (i) 30
- (ii) 50
- (iii) 55
- (iv) 80

Voltmeter internal resistance $= 1000\ \frac{\Omega}{V} \cdot 10V$

$= 10k\Omega$

$R_L = (1/10k + 1/10k)^{-1} = 5k\Omega$

$V_L = V_s \frac{R_L}{R_L + 50k} \Rightarrow V_s = \boxed{55}\ V$

(i) Threshold of a measurement system is
- (i) the smallest change in input which can be detected
- (ii) a measure of linearity of the system
- (iii) the smallest input which can be detected
- (iv) a measure of precision of the system

(j) A common practice of reducing hysteresis error in the output for a given value of input is
- (i) to maintain a high rate of change of input
- (ii) to maintain a low rate of change of input
- (iii) to take observations either in the ascending or in the descending order
- (iv) to take observations both in the ascending and descending orders and then take average value of the output

(k) The power supplied by the voltage source in the circuit, shown in Fig. 2.21, is

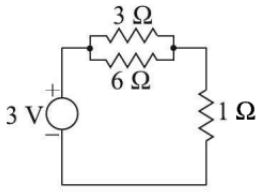


Fig. 2.21

- (i) 0 W
- (ii) 1.0 W
- (iii) 2.5 W
- (iv) 3.0 W

$R_{eq} = \left(\frac{1}{3} + \frac{1}{6}\right)^{-1} + 1 = 3\Omega$

$P = \frac{V^2}{R} = \frac{3^2}{3} = \boxed{3}\ W$

(l) The current I supplied by the dc voltage in the circuit, shown in Fig. 2.22, is

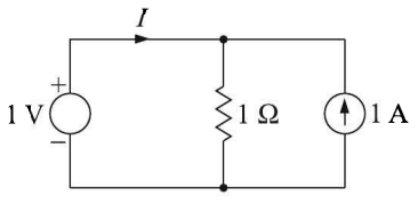


Fig. 2.22

(i) 0 A
(ii) 0.5 A
(iii) 1 A
(iv) 2 A

KCL at node above 1 Ω

$I + 1 = I_R$

$I = \boxed{0}$ A

$\therefore$ V across R = 1V

$\therefore I_R = V/R = 1$ A

2.16 An ammeter has a range of 0 to 30 A. The instrument gave the following readings:

Current flow (A)	0	5	10	15	20	25
Ammeter reading (A)	1	4	12	14	22	28

The nonlinearity of the instrument in terms of full scale reading (FSR) = ... % FSR

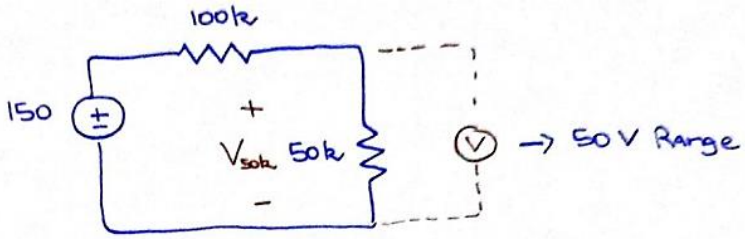
Non linearity = $\frac{\text{Max deviation}}{\text{F.S.R}}$ $\therefore I_{FSR} = 30$A

$= \frac{28 - 25}{30} \times 100\ \%$

% Non-linearity = $\boxed{10\ \%}$

2.18 A circuit arrangement consists of a dc voltage source of 150 V in series with two resistors of value 100 kΩ and 50 kΩ respectively. It is desired to measure the voltage across the 50 kΩ resistor. Two voltmeters are available for this measurement: Voltmeter 1 with a sensitivity of 1 kΩ/V and Voltmeter 2 with a sensitivity of 20 kΩ/V. Both meters are used on their 50 V range. Calculate

(a) The reading of each meter, and
(b) The error in each reading expressed as a percentage of the true value.



- True Value : $V_{50k} = 150 \times \frac{50k}{100k + 50k} = 50V$

→ R_i of Voltmeter 1 : $1k\Omega/V \cdot 50V = 50k\Omega$

→ R_i of Voltmeter 2 : $20k\Omega/V \cdot 50V = 1M\Omega$

- Voltmeter 1

$$R_L = (1/50k + 1/50k)^{-1} = 25k\Omega$$

$$V_{50k} = 150 \times \frac{25k}{100k + 25k} = \boxed{30\ V}$$

$$e_1 = \left|\frac{50 - 30}{50}\right| \times 100\% = \boxed{-40\%}$$

- Voltmeter 2

$$R_L = (1/50k + 1/1M)^{-1} = 47619k\Omega$$

$$V_{50k} = 150 \times \frac{47619}{100k + 47619} = \boxed{48.387\ V}$$

$$e_2 = \left|\frac{50 - 48.387}{50}\right| \times 100\% = \boxed{-3.22\%}$$