locktronics

Simplifying Electricity

EASA - Electronic Fundamentals 4

LK7430

MATRIX

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LVDT

Electronic fundamentals 4

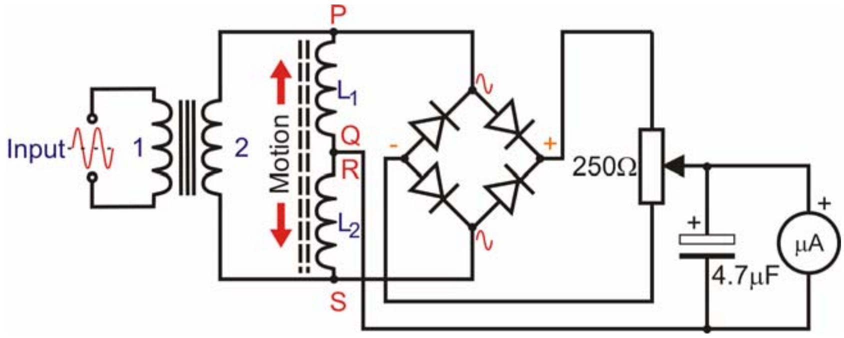
Linear variable differential transformers (LVDT) are widely used to sense position, for example of aircraft control surfaces, such as ailerons, elevators or rudders.)

They produce an output signal containing information about direction and distance.

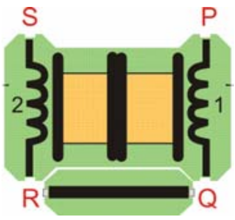
In this worksheet you will investigate the principle of a simple LVDT arrangement based on two inductively coupled coils.

Over to you:

- Build the circuit shown opposite.



- The two coupled coils should be connected as shown in the second diagram. Ensure that the ferrite core in the exact centre of the two coil assembly.



- Set the 'pot' to mid-position.
- Connect the input to a signal generator, set to give an output of between 10V and 20V peak-to-peak at a frequency of 2kHz.
- Set meter to the 100µA DC range.
- Adjust the variable resistor until the reading on the meter is zero.
- Slowly move the ferrite core first in one direction and then in the other.
  Watch what happens to meter reading as you do so.
  You may have to change the meter polarity for one of the two directions.
- Measure and record the current for various values of core position.

Core displacement in mm	-20	-15	-10	-5	0	+5	+10	+15	+20
Current in µA									

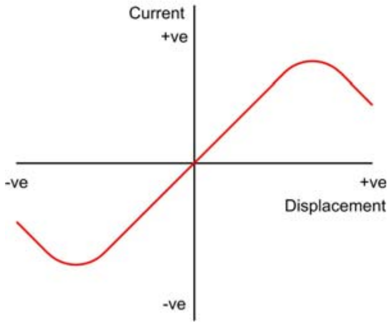
Worksheet 1

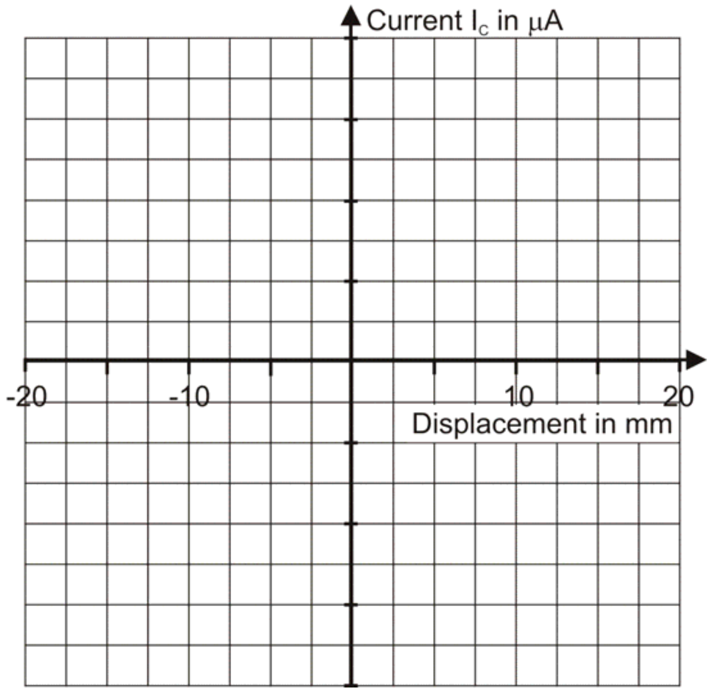
LVDT

Electronic fundamentals 4

So what?

- Plot a graph to show how current varies with displacement. An example is shown below.



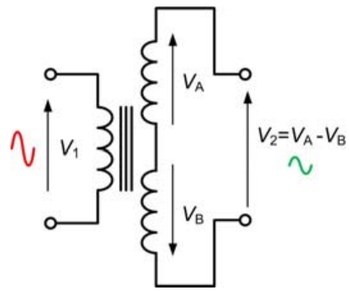


The LVDT is a miniature transformer with one primary and two secondary windings. The primary is centred between identical secondary coils.

The coil assembly is usually stationary. A ferrite or soft-iron core, attached to the sensor/actuator, moves inside the coils, as the sensor/actuator moves. Ideally, there is no physical contact between core and coil, and so no mechanical wear takes place.

The LVDT requires an AC input, of a few volts amplitude with a frequency usually of a few kilohertz. This generates an alternating magnetic field, which is intensified in the core. This, in turn, induces an alternating voltage in the secondary coils. The greater the overlap of the core and the secondary coil, the greater the voltage induced.

The two secondary coils are connected in series in such a way that the induced voltages oppose each other. Thus the output voltage, V_2, is zero when $V_A = V_B$. The phase of the output voltage indicates the direction in which the core has moved and the amplitude indicates how far it has moved. This AC output voltage is converted to a DC voltage by a rectifier circuit, and smoothing. The DC output can be sensed in a number of ways, the simplest being by a DC centre-zero meter.



For your records:

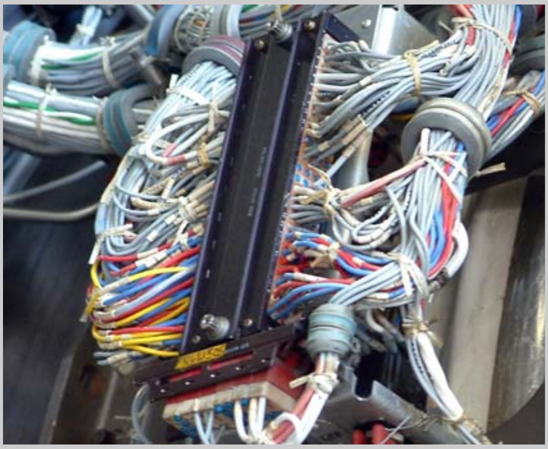
- Explain, in your own words, how the circuit works.
- Does the LVDT produce a linear output and if so, over what range is it linear?
- How could the LVDT be improved? What would make it more sensitive?
- Suggest how the LVDT could be used in a position control system. What additional components and devices would be needed?

Worksheet 2

Capacitance bridge

Electronic fundamentals 4

A wide variety of transducers are used to provide input signals to the control and servo systems used on a large aircraft.

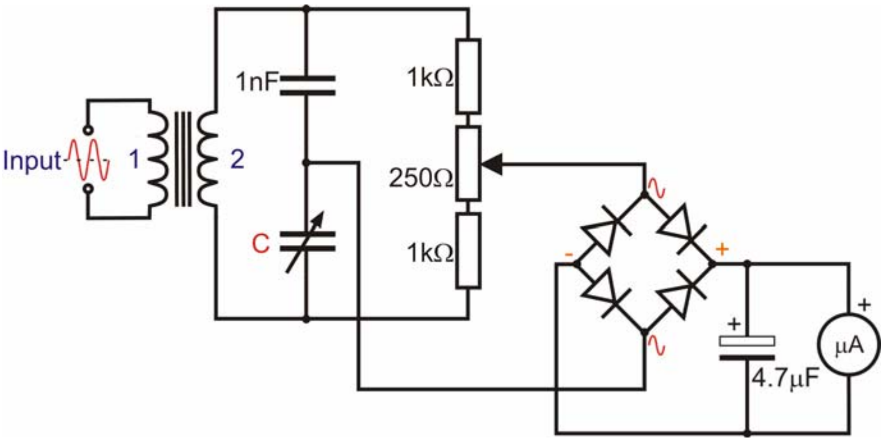


Some sensors are inductive (as in the case of the LVDT) whilst others are resistive or use semiconductor sensing elements.

Capacitive transducers are widely used for fuel level sensing.

In this worksheet you will investigate the principle of operation of a capacitive sensor connected in a simple AC bridge circuit.

Over to you:



- Build the circuit shown opposite. The variable capacitor, C, should be capable of adjustment over the range 100pF to 10nF.
- Connect the input to a signal generator, set to give an output of between 10V and 20V peak-to-peak at a frequency of 2kHz.
- Set the meter to the 100µA DC range.
- Set the variable capacitor to 1nF, (1000pF,) and carefully adjust the variable resistor for zero indication on the meter. At this point the bridge will be in the balanced condition.
- Slowly increase the variable capacitance and then reduce it. Note the indications on the meter. You may have to change the meter polarity in one of the two directions.
- Measure and record the meter current for various different values of variable capacitance over the range 600pF to 1.4nF (1400pF).

Capacitance in pF	600	700	800	900	1000	1100	1200	1300	1400
Current in µA									

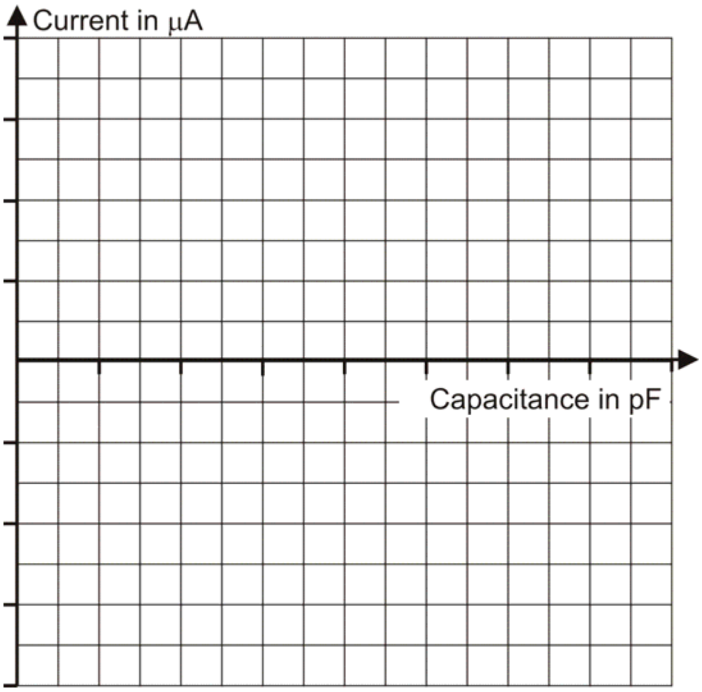
Worksheet 2

Capacitance bridge

Electronic fundamentals 4

So what?

- Plot a graph showing how the output current varies with capacitance.



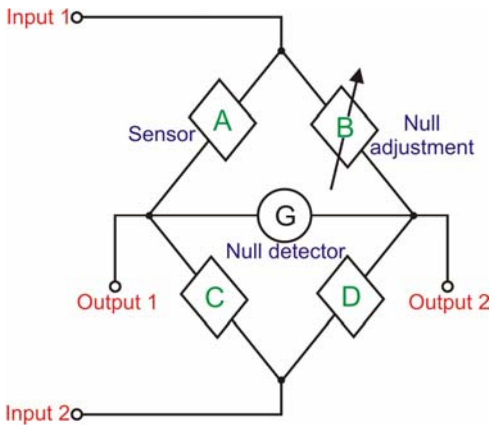
Bridge circuits:
are common circuit sub-systems, seen in a variety of forms.

The diagram shows the principle. Four devices, A, B, C and D, are arranged as two voltage dividers. One comprises A and C, the other B and D. They are 'bridged' by a sensing device, in this case a galvanometer G - a sensitive ammeter. Equally, an output can be taken from the mid-points of the voltage dividers.

When the bridge is 'balanced', i.e. the galvanometer reads zero:

A/C = B/D

The input can be either a DC or an AC power supply. The devices A to D can be resistors, capacitors, inductors or combinations of these.



When the input is AC, and inductors or capacitors are involved, phase as well as magnitude must be taken into account. When magnitudes alone 'balance' there may still be a residual voltage across the null detection device.

Advantages of the bridge circuit include:

- the power supply voltage is irrelevant, as it is the same for both 'legs';
- the calibration of the galvanometer is irrelevant. All it has to do is detect current, not measure it.

For your records:

- Explain, in your own words, how the circuit works.
- Does the bridge produce a linear output and if so, over what range is it linear?
- How could the AC bridge be improved? What would make it more sensitive?
- Suggest how the capacitive sensor could be used in a fuel indicating system. What additional components and devices would be needed?

Worksheet 3
Motor controller

Electronic fundamentals 4

Motors are widely used as output transducers in aircraft control systems, and so are motor controllers.

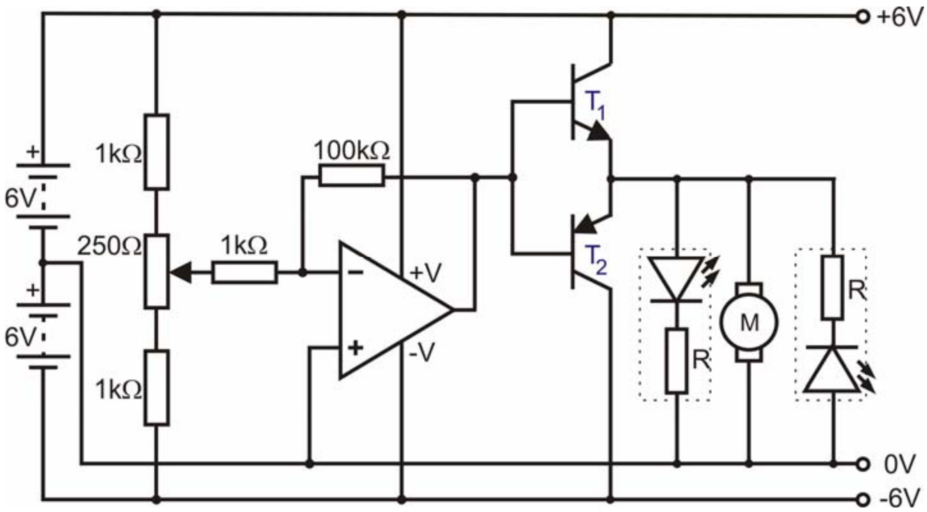
These control both speed and direction of rotation. This can be achieved using a motor controller based on nothing more than a pair of transistors and an operational amplifier.

In this worksheet you will investigate the operation of a simple 'open loop' motor controller, meaning that it uses no feedback.

w3a

Over to you:

- Build the circuit shown opposite.
- Use two DC power supplies, set to 6V, plugged into the dual-rail power supply carrier, to supply the +6V / 0V / -6V power rails.



w3b

- Two light emitting diodes, connected in 'anti-parallel', indicate the polarity of the output voltage supplied to the motor, and so also the direction of rotation of the motor - either clockwise or anti-clockwise.
- Set the 'pot' to produce an output of 0V. (The motor should not be running.)
- Vary the setting of the 'pot', first in one direction and then in the other and notice the effect on the motor and the two LED indicators.

Worksheet 3

Motor controller

Electronic fundamentals 4

So what?

- The op-amp is set up as an inverting amplifier, with a voltage gain of 100x. Its input impedance s around 1kΩ - i.e. relatively small, and so it affects the voltage taken from the sensing unit, the ‘pot’.
- Transistors T_1 and T_2 form a push-pull follower, investigated in an earlier module. They copy the input voltage to the output and are capable of delivering sufficient current to drive the motor.
- The power supply is set up to create, ostensibly, a +6V / 0V / -6V split power supply. The op-amp and output stage are referred to 0V. The output of the transistors can swing above and below this system reference voltage.
- There is no feedback loop to inform the system just how fast the motor is turning, or if it is turning at all, or even if there is a motor attached! This limitation will be addressed in the next worksheet.
- This kind of controller is not energy-efficient, for two reasons. The ‘pot’ and balancing 1kΩ resistors have current flowing through them at all times, and so dissipate energy. The transistors ‘follow’ the input voltage. When the output of T_1 is +2V, the rest of the +6V supply, i.e. 4V, is dropped across the transistor. The transistor can be delivering substantial current to the motor, and so is dissipating significant energy itself.

For your records:

- Explain, in your own words, how the circuit works.
- Over what approximate range of adjustment of the variable resistor does the motor remain stationary?
- Does the motor move in both directions? How do you know this?
- Does the variable resistor provide effective control of the speed? Is it possible to adjust the speed so that the motor runs slowly and consistently at the same speed?
- How could the motor controller be improved? What would make it provide smoother control of speed?
- Suggest how the motor controller could be used in a practical aircraft application. What additional components and devices would be needed?

Worksheet 4

Feedback control system

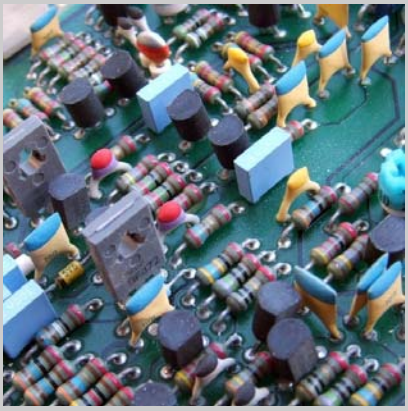
Electronic fundamentals 4

Earlier, you saw the limitations of ‘open loop’ motor control.

There is no automatic comparison of the actual output value with the desired value, and no compensation for any differences.

Modern aircraft systems use ‘closed loop’ control systems, in which negative feedback is used to regulate the system. In most cases this is fully automatic. The only human intervention is setting the desired output value.

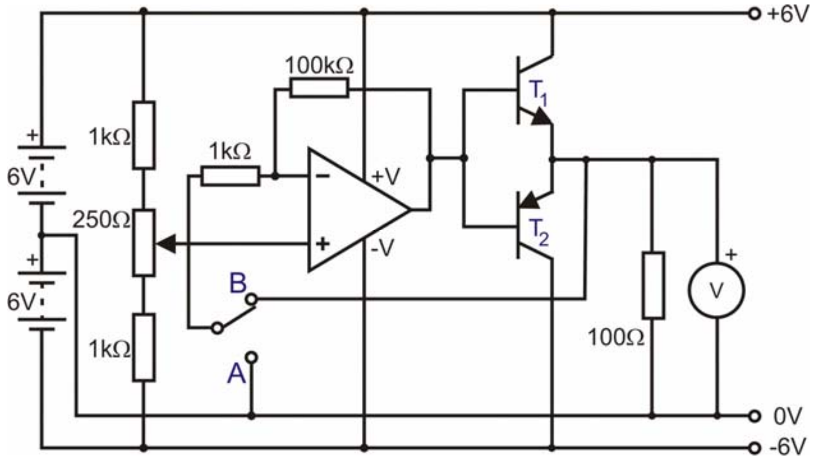
In this worksheet you investigate the behaviour of a system with and without this feedback.



w4a

Over to you:

- Build the circuit shown opposite.
- Again, use two DC power supplies, set to 6V, plugged into the dual-rail carrier, to supply the +6V / 0V / -6V power rails.
- A 100Ω resistor acts as a ‘load’. The voltage developed across it is measured using the meter set to the 20 V DC range.



w4b

- The link at the input can be set to either position A or B. In position A, no feedback is provided and so the control system operates in open-loop mode. In position B negative feedback is provided and the system operates in closed-loop mode.
- Set the link to position A .Turn the ‘pot’, first in one direction and then in the other and notice the effect on the DC output voltage. Record the range of output voltage produced,
- Now do the same with the link set to position B.
- Finally, repeat these steps with the 100Ω load removed. Once again, record the range of output voltage for both open-loop and closed-loop operation.

Open-loop operation	100Ω load	No load
Max. output voltage		
Min. output voltage		

Closed-loop operation	100Ω load	No load
Max. output voltage		
Min. output voltage		

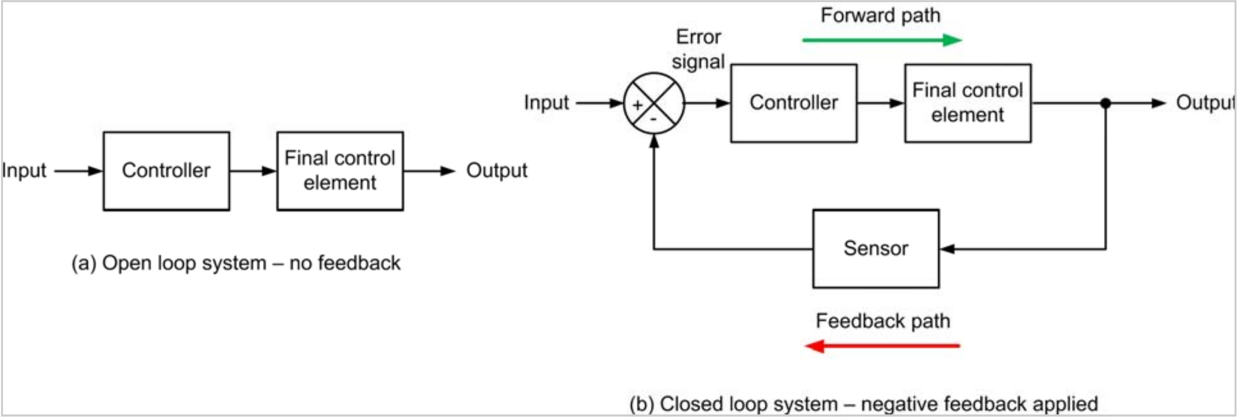
Worksheet 4

Feedback control system

Electronic fundamentals 4

So what?

The diagram shows the difference between open-loop and closed-loop control systems:



This difference can be illustrated by reference to the ‘cabin’ heating system inside a car.

In an open-loop control system, the driver turns the temperature control to a likely position, and waits. If the cabin is too hot, the driver turns the temperature control down. If too cold, the driver, turns it up. The actual temperature inside the car depends on the outside temperature, and on the temperature of the water circulating in the heater. It is up to the driver to make appropriate adjustment to take account of these.

In a closed-loop control system, the driver sets the desired temperature. A temperature sensor in the cabin feeds back information on the current temperature to the heating system. When the actual temperature is below the set temperature, the heating system warms up the cabin. When the temperature is above the set value, the heating system turns off, or even cools down the cabin . The only intervention by the driver is to set the desired temperature.

For your records:

- Explain, in your own words, how the circuit works.
- Comment on the results obtained for both open-loop and closed-loop operation of the system. Which configuration provided the smoothest control of the output?
- Which configuration produced the greatest output change and which produced the least? Why was this?
- Which configuration maintained an output that was more constant with and without the load connected? Why was this?