Pearson BTEC Level 4 Higher Nationals in Engineering (RQF)

Unit 22: Electronic Circuits and Devices

Unit Workbook 2

in a series of 4 for this unit

Learning Outcome 2

Feedback

2.1 Different Feedback Systems

Systems can operate under an open or closed loop system, the difference between the two is what is happens to the data after the transfer functions take place. We consider all actions and processes as a function of time. We must also consider positive and negative feedback systems, and the effects this can have on an amplifiers performance.

2.1.1 Open Loop

An open loop system does not use the collected data to feed back into the system and will just display the current status for manual intervention to fix any problems. The control action is not performed automatically by a processing unit within the system. Let's say we are using a cheap fan to cool something down, we press a button which give a varying fan speed, the button completes the circuit and starts the motor. We model systems with a block diagram. When drawing the block diagram for an open loop system, we have a linear path between the input and the output, with transfer function blocks in between. A block diagram for a fan can be found in Fig.2.1 below.

The main characteristics of an open loop system can be simplified to:

- desired and real values are not compared,
- no self-control or regulation,
- input is a fixed operating position for the controller,
- external disturbances do not result in a direct output change unless manual alteration takes place.

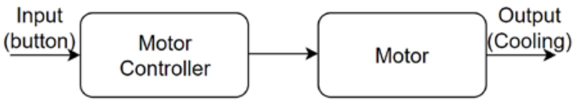

Fig.2.1: An open loop block diagram of a fan

2.1.2 Closed Loop

A closed loop system will collect data while it runs and will feedback into the system to correct to compensate for any disturbances without any external intervention. A closed loop system basically has its own element of control. Let's say our fan is now monitoring the temperature of the item we are cooling; the input is no longer the manual operator pressing the button, it is the desired temperature of the item. Fig.2.2 shows the block diagram for the closed loop fan.

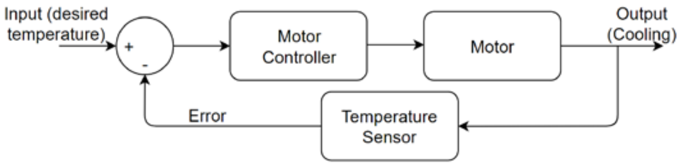

Fig.2.2: Closed loop diagram of a fan

Again, this is still a very basic system. Block diagrams can be huge pieces of work, with sensors analysing anything and everything. We can look at the block diagram for a car's power transmission in Fig.2.3, when the driver presses the pedal down to the floor as quickly as possible, the microprocessor that actually controls the throttle does not allow this, as it could damage the engine. Instead the throttle slowly opens for a more controlled and efficient acceleration.

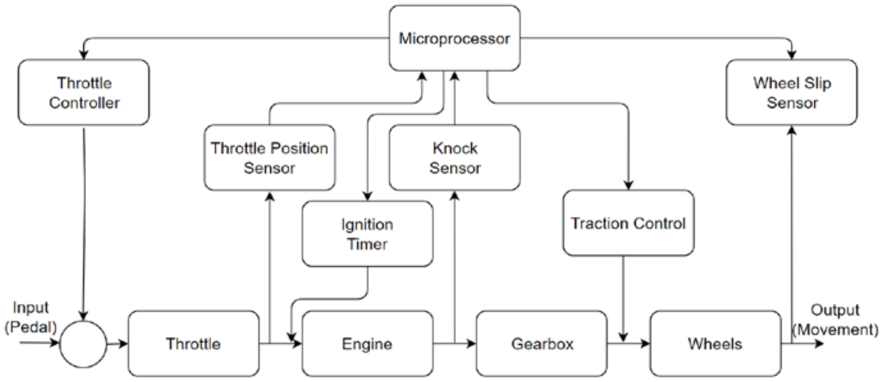

Fig.2.3: Power transmission block diagram

Of course, we can still go deeper, since there are about 60 different warning lights that a car could have, but the size of the block diagram for this would be difficult to read and doesn't really add to your knowledge. But some of the factors we could consider are:

- Environmental sensors such as:
  - Moisture for windscreen wipers
  - Light sensors for lights
- Brakes can incorporate different systems for feedback including:
  - Brake lights
  - Anti-lock brakes
  - The car could also incorporate an air-brake
- We also haven't monitored the condition of the engine yet:
  - Oil Levels
  - Temperature
  - Fuel Levels
  - Fuel consumption
  - Remaining range of the car before refuelling
- Monitoring the condition of the catalytic converter
- There's also the passengers to consider:
  - Monitoring different aspects for cruise control
  - Climate control
  - Alerts for potential problems with the car
  - Airbags
  - Open Bonnet/Doors/Boot
  - A seatbelt is not fastened
- High performance road cars also have different performance settings that will adjust:
  - Suspension (ride height and firmness)
  - Aerodynamics

2.1.3 Summing Point

If we look back at Fig.2.2 for a closed loop system, we can see the merging point of the feedback, or the "summing point". This point can define whether or not the feedback is positive or negative, which will be discussed in further detail later in the chapter. Fig.2.4 shows a block diagram summing point for positive and negative feedback.

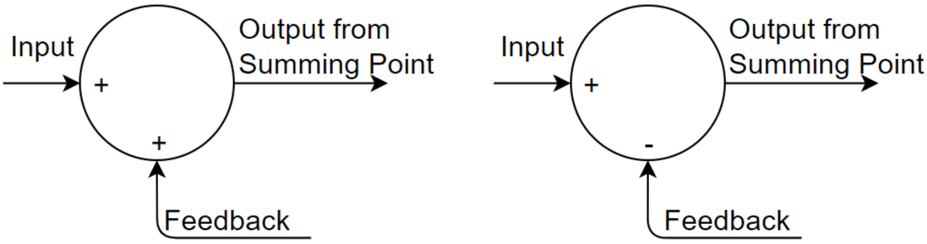

Fig.2.4: Summing point diagram for positive feedback (left) and negative feedback (right)

2.1.4 Positive Feedback

Positive feedback is a system where the feedback values are added to the input value, which will mean that if the feedback has a positive value, the gain will be greater than if it was than without feedback. Components such as amplifiers tend to be positive feedback systems. However, saturating the signal is important, as if the gain is too high then the system will begin to oscillate, and will no longer need the input signal.

We can apply this to an Op-Amp, consider the Op-Amp circuit in Fig.2.5. The voltage gain $\mathrm{A_V}$ will be calculated with Eq.2.1. $\mathrm{V_{OUT}}$ is slowly fed back into $\mathrm{V_{IN}}$ and will begin to increase the gain, until it is saturated by the voltage supply rail ($+\mathrm{V_{CC}}$). In essence, positive gets more positive.

$$\mathrm{A_V} = \frac{\mathrm{V_{OUT}}}{\mathrm{V_{IN}}} = \frac{\mathrm{R_2}}{\mathrm{R_1}} \qquad \text{(Eq.2.1)}$$

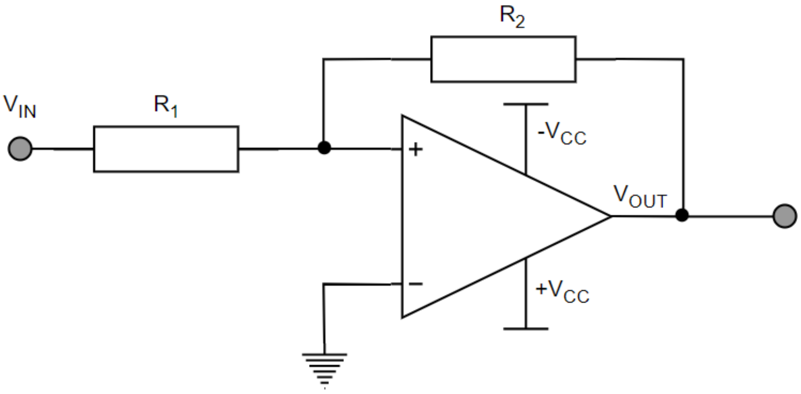

Fig.2.5: Positive feedback amplifier

Let's say that the input that is given has a negative value ($V_{IN} < 0$), this will be fed back into the create a negative gain and it will slowly become more negative as the loop continues, until it is saturated by the negative supply rail ($-V_{CC}$). In this case, negative gets more negative. Positive feedback systems are most commonly used to create oscillators and timing circuits, due to the instability concerning its gain. A positive feedback controller output can be seen in Fig.2.6.

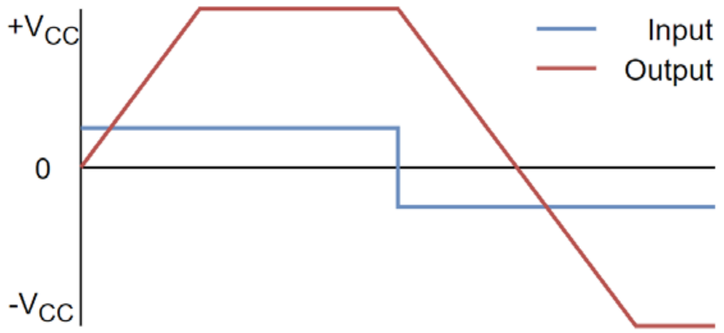

Fig.2.6: Positive feedback controller reading

2.1.5 Negative Feedback Systems

Negative feedback systems are reactive systems that uses the feedback "error", comparing the input with the feedback value. The system will generate a small amount of noise, as it is unlikely that the system will remain constant throughout the entire operation, and so the signal output will hover around the desired value as it hones in. An Op-Amp diagram of a negative feedback system is shown in Fig.2.6.

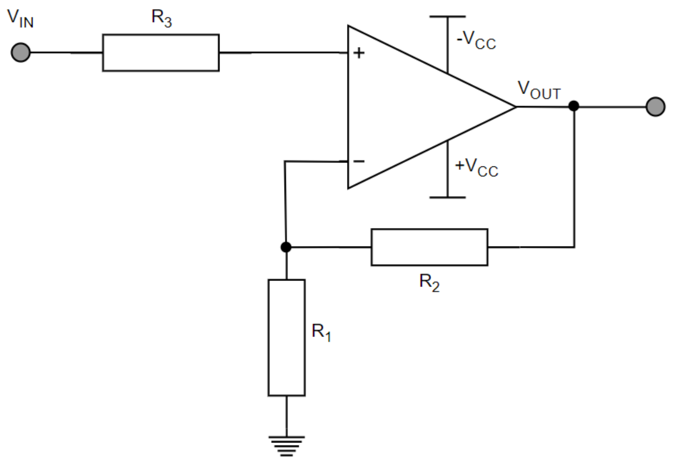

Fig.2.5: Negative Feedback Op-Amp system

Other examples of negative feedback controllers include Proportional Integral Derivative controllers (PIDs), and negative feedback systems can be used in heating and air conditioning, throttle control, charging control.

Negative feedback systems become more stable over time, as the value slowly corrects itself, but only if they are well tuned, otherwise the system will not be able to stabilise itself the gain is too high and will also oscillate. A low gain is also problematic as the control response could be too slow to sort any problems that may exist. Consider a server room for a company, server rooms generate a substantial amount of heat if there is high traffic, so if the room gets too hot, the sensitive components will be damaged, or even start a fire. The temperature of a server room is closely monitored, and the climate is controlled. If the gain of the feedback system is too high, then the system will constantly bounce up and down to try and compensate, and the system will have no effect. If the gain is too low, then the system takes too long to respond appropriately, hence why the gain needs to be accurately controlled to optimise the performance of the system.

Ideally, in this configuration, both $\mathrm{R_{IN}}$ and $\mathrm{R_{OUT}}$ would be very small. Fig.2.8 shows a Shunt – Shunt configuration. It is assumed that the feedback current is negligible in this configuration.

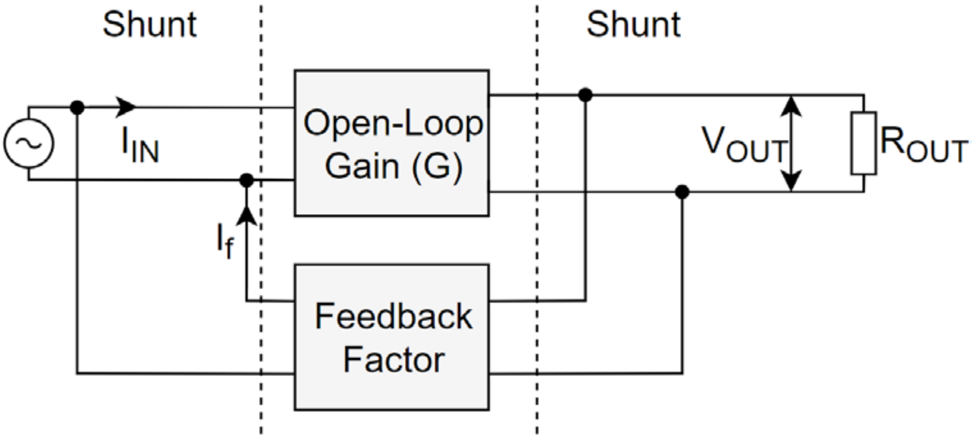

Fig.2.8: Shunt – Shunt feedback

2.2.3 Series – Series

Series – Series feedback uses the input voltage and output current to calculate the open-loop gain of the system. While the output current is used to calculate the gain, it is actually a case of the current is measured, and this measurement is converted into a voltage signal and fed into the feedback loop. The gain for this system $\mathrm{G_m}$ is calculated using Eq.2.4.

$$\mathrm{G_m} = \frac{\mathrm{I_{OUT}}}{\mathrm{V_{IN}}} \qquad \text{(Eq.2.4)}$$

In this system, it is assumed that the voltage drop across $\mathrm{R_f}$ is negligible, and the configuration of the system is shown in Fig.2.9.

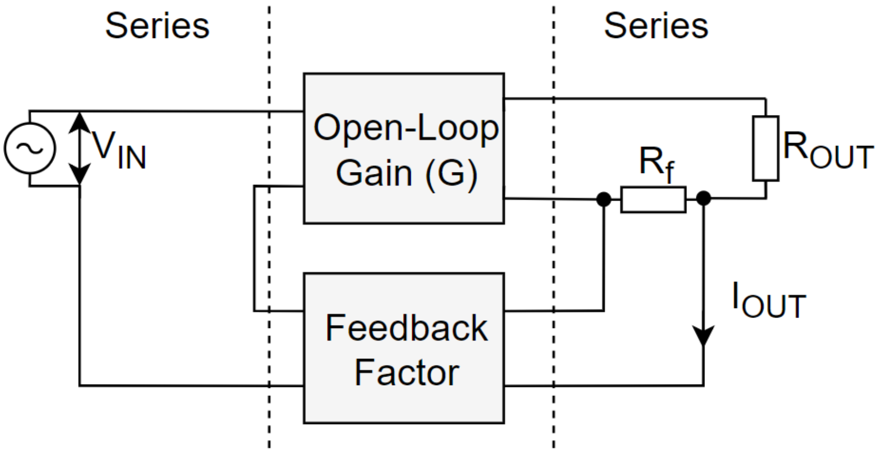

Fig.2.9: Series – Series feedback

2.2.4 Shunt – Series

The final configuration is current input – current output. The signal is fed back in parallel with the input, and it the currents are added together. The voltage gain of the system is normally unaffected in this system, there will however, be a current gain, which is calculated using Eq.2.5. Ideally, there would be a large $\mathrm{R_{OUT}}$ and a small $\mathrm{R_{IN}}$.

$$A_I = \frac{I_{OUT}}{I_{IN}} \qquad \text{(Eq.2.5)}$$

The Shunt – Series feedback system will look as described in Fig.2.10 below. It is assumed that the voltage drop across R_f is negligible.

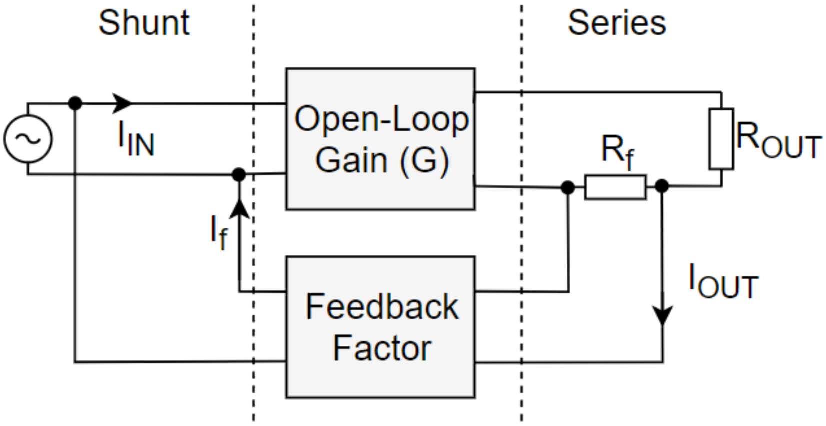

Fig.2.10: Shunt – Series feedback system