Unit 47 Analog computers

- In analog computers, quantities or variables are represented by voltages.
- Computations are carried out by passing the voltage signals through adders, inverters, differentiators and integrators and other functional amplifiers.
- The results of individual computations are combined by using adders.

We have already met most of the circuit blocks which are used in analog computers. These are DC amplifiers, adders, differentiators, integrators and logarithmic amplifiers.

There are some other circuit blocks which are used in analog computers but which we have not examined. These are multipliers, dividers and square root extractors all of which are readily available as standard ICs for which data sheets are available. We will leave these for other courses.

In analog computers, voltages are used to represent physical real world quantities and the circuit blocks are used to carry out computations on these voltages. In contrast, in digital computers, numbers are used to represent physical real world quantities and the numbers are then manipulated digitally in accordance with a program. In analog computing, the circuit can be considered to be the program, which means that any revision of the program requires a circuit redesign.

Analog computers are often used because of the low cost of op-amps, the robustness of analog control systems and because many real world sensors have voltage outputs which are directly compatible with the inputs of analog computing systems.

We have already seen an example of analog computing in Example 42.1 which showed how a number of voltage inputs could be scaled and added.

47.1 Example

47.1 Design a circuit which implements the following function of the input voltage, V_{in}.

$$V_{out} = 3.3V_{in} + 2.2\frac{dV_{in}}{dt}$$

This function represents a controller having gain 3.3 and derivative or rate action of $2.2\frac{dV_{in}}{dt}$ which could be used as the amplifier in a process control loop such as is shown in Figure 41.2. This computer or controller acts so as to correct any error or difference between, say, the set point temperature and the measured process temperature and also to add in extra corrective action proportional to the trend or derivative of the process output. This derivative action gives more rapid correction of process deviations from the set point because it can be considered to correct for the error which will occur if the present trend continues. A good analogy is that in hitting a ball in tennis, you aim at where the ball will be, not at where the ball is. You include a correction for the rate of change of position of the ball.

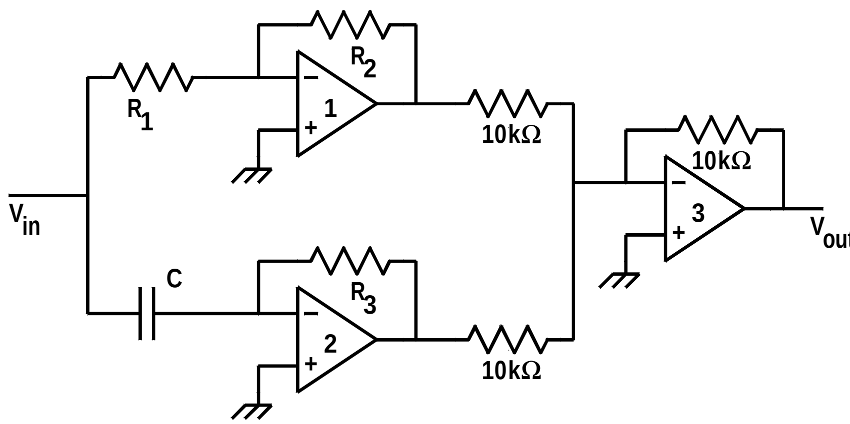

Figure 47.1: PD or proportional plus derivative action controller.

A suitable circuit for this application is shown in Figure 47.1. In this circuit, op-amp 1 gives the gain of $3.3V_{in}$ and so $\frac{R_2}{R_1} = 3.3$. If we arbitrarily choose $R_1 = 10\,\mathrm{k}\Omega$ then $R_2 = 33\,\mathrm{k}\Omega$.
Op-amp 2 gives the derivative action, $2.2\frac{dV_{in}}{dt}$, so we have $R_3C = 2.2$. We choose $C = 1\,\mu\mathrm{F}$ and then get $R_3 = 2.2\,\mathrm{M}\Omega$.
The two signals are then added in the inverting adder using op-amp 3. There are two stages of inversion, so the sign of the output signal is correct.

47.2 Problems

47.1 Design a circuit which has an output which is given by:

$$V_{out} = 23V_1 - 12V_2 + 8V_3$$

where V_1, V_2 and V_3 are inputs to the circuit. What is the minimum number of op-amps required?

47.2 Derive the mathematical expression which gives the output of the circuit, shown in Figure 47.2, in terms of the single input V_{in}.

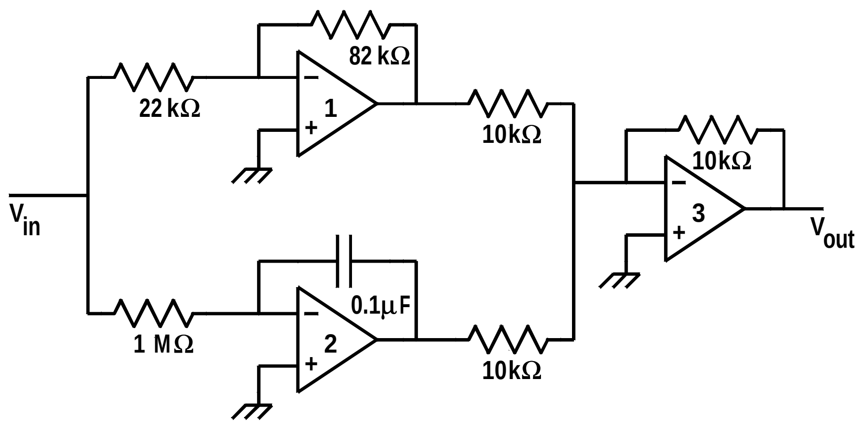

Figure 47.2: Problem 47.2.

47.3 A circuit has three inputs, V_1, V_2 and V_3. Design a circuit which will give an output which is described by:

$$V_{out} = 1.9V_1 - 2.8V_2 + 8.2V_3 + 0.6\frac{dV_1}{dt} - 3.6\int V_2 dt$$

47.4 The circuit shown in Figure 47.3 is used to move the scanning tip up and down as it scans the surface in the scanning tunnelling microscope manufactured by Burleigh Instruments. The input signal is the tip tunnelling current. The output signal drives the tip in the z direction. Explain the function of each of the circuit blocks.

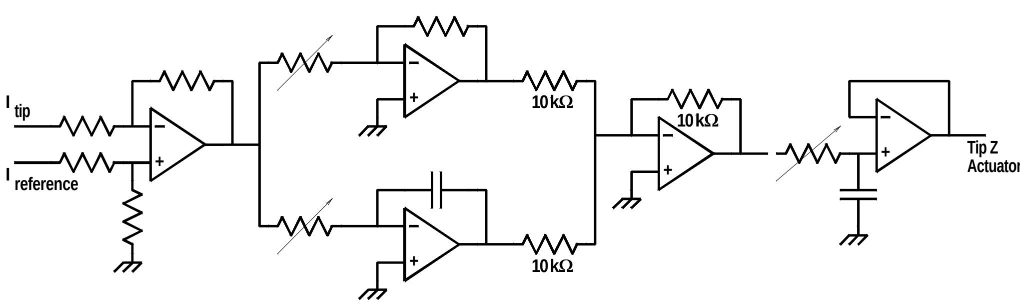

Figure 47.3: STM scanning tip height servo control circuit.