DOCUMENTATION

SPIDER_TASK1_EE

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Steps Followed for the circuit construction:

Step 1: All circuit components were added using the proteus component list.

Step 2: All the op-amps, resistors, and capacitors were connected suitably. They were all connected in such a manner so that they could do their desired operations, viz. differential, adder, proportional circuit, integrator circuit, and derivative circuit. The circuit diagram is attached for reference.

Step 3: The parameters kp, ki, and kd were set as given in the question by adjusting the values of the resistors and capacitors.

Step 4: The final output of the circuit was fed into the digital oscilloscope along with the original signal(set point) and the behavior was observed through the simulation.

Step 5: The final output and the original signal were again fed back into the input through a negative feedback mechanism so as to calculate the corresponding error signal.

Working of the Circuit:

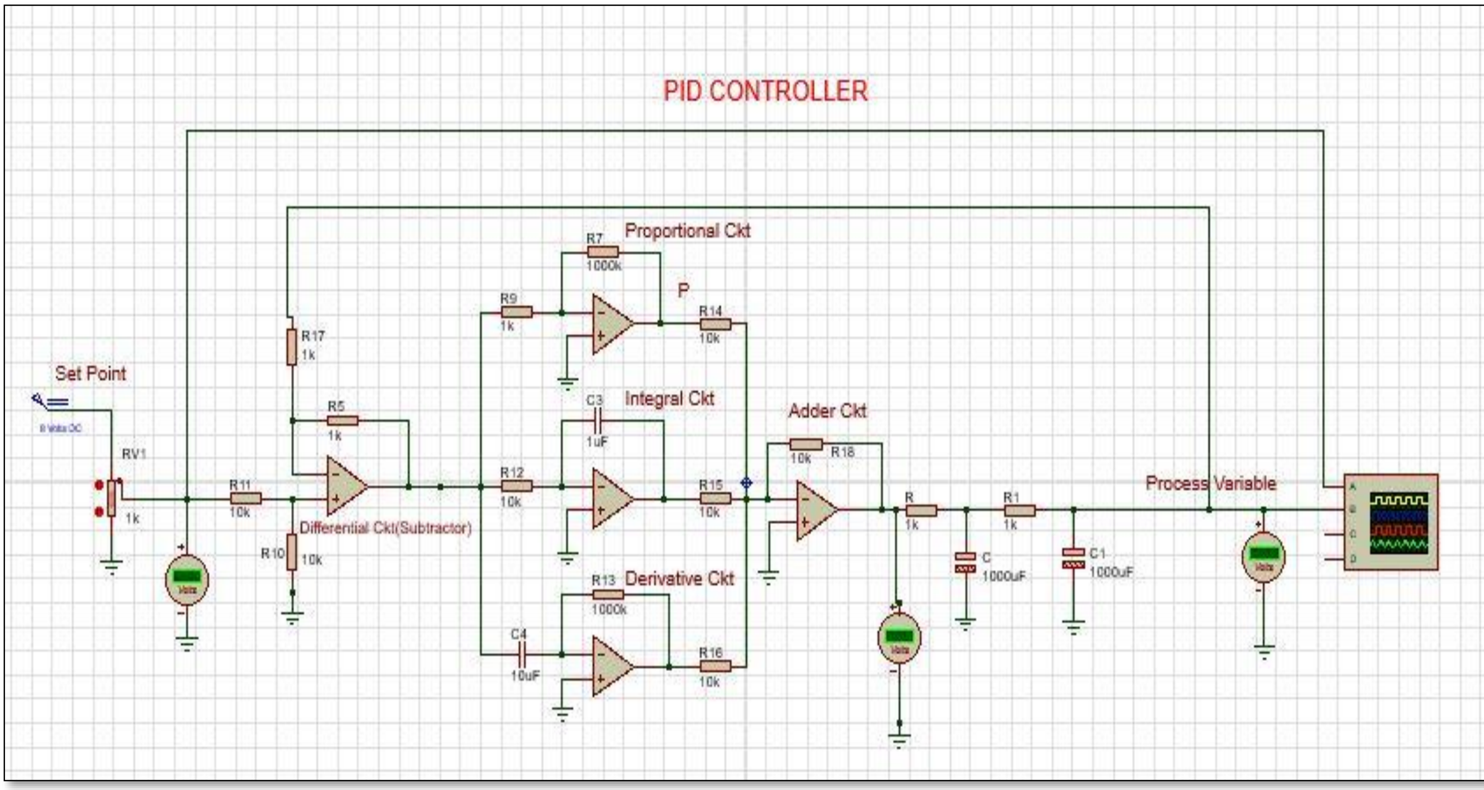
The circuit is constructed using op-amps, also known as operational amplifiers, resistors, and capacitors. The circuit uses a differential circuit(subtractor), an adder, a proportional circuit, an integral circuit, and a derivative circuit. The different circuits are implemented using suitable configurations of op amps resistors and capacitors. The separate diagrams for the individual circuits are given in the documentation ahead.

The subtractor circuit contains a single op-amp with two terminals, with one having the original signal as the input and the other having the output feedback signal as the input. The op-amp operates in **inverting amplifier mode,** in case of a subtractor, and thus calculates the difference between both the signals, which is the error signal and is further used as an input for the further circuits.

The error signal is fed as an input to the proportional, integrator, and derivative circuits. The op-amps configuration respectively calculates the proportional, integral, and derivative of the error signal, and the outputs from all three branches are taken through the output via three identical resistors and are used as an input for the adder circuit so that the complete PID Equation can be implemented. The adder, proportional, integrator, and derivative circuits all work in the **inverting amplifier mode.**

The final output is passed through a filter circuit to remove any noise from the signal output and finally, the filtered signal is fed into the oscilloscope and compared with the actual signal input to determine the accuracy of the controller.

CIRCUIT DIAGRAM

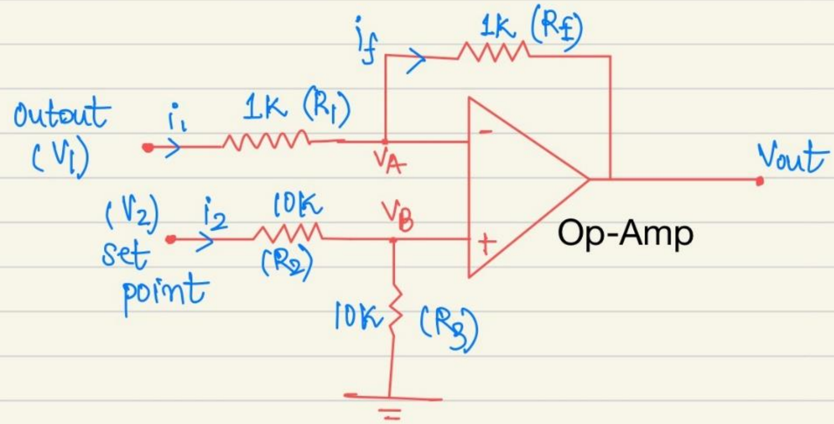


Components of the PID-circuit:

1. Differential or Subtractor Circuit
2. Proportional Circuit
3. Integrator Circuit
4. Derivative Circuit
5. **5.** Adder Circuit

Working of different components of the circuit:

Subtractor Circuit



Now, we assume, the point V_A to be virtually grounded with $V_A = 0V$.

Also, now we first consider, $V_2 = 0$. Then,

so, $i_1 = i_f$

$$\Rightarrow \frac{V_1 - V_A}{R_1} = \frac{V_A - V_{out}}{R_f}$$

$$\Rightarrow \frac{V_1}{R_1} = \frac{-V_{out}}{R_f}$$

$$\therefore \boxed{V_{out} = -\left(\frac{R_f}{R_1}\right) V_1.} = -\left(\frac{10^3}{10^3}\right) V_1 = -V_1$$

Now, consider, $V_1 = 0$. Then, A/Q

$$\frac{V_2 - V_B}{R_2} = \frac{V_B - 0}{R_3}$$

$$\Rightarrow \boxed{\frac{V_2 - V_B}{R_2} = \frac{V_B}{R_3}}$$

On solving,

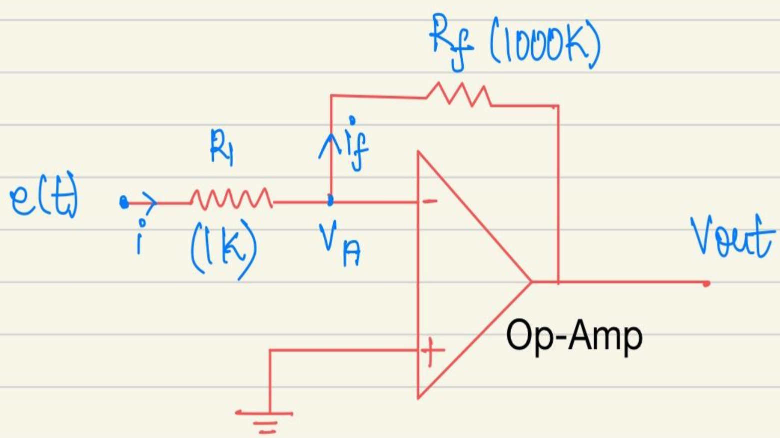
$$V_B = \left(\frac{R_3}{R_3 + R_2}\right) V_2. = \left(\frac{10}{10+10}\right) V_2 = \frac{V_2}{2}.$$

Then, $\boxed{V_{out} = \left(1 + \frac{R_f}{R_1}\right) V_B} = \left(1 + \frac{10^3}{10^3}\right)\left(\frac{V_2}{2}\right) = V_2.$

So, $\boxed{V_{net} = V_2 - V_1}$

Thus, $\boxed{\begin{aligned} V_{out} &= \text{Set Point} - \text{process Variable} \\ &= \text{error signal } (e(t)). \end{aligned}}$

Proportional Circuit



Now, V_A can be considered as a virtual grounded point, i.e $V_A = 0V$.

clearly $\boxed{i = i_f}$

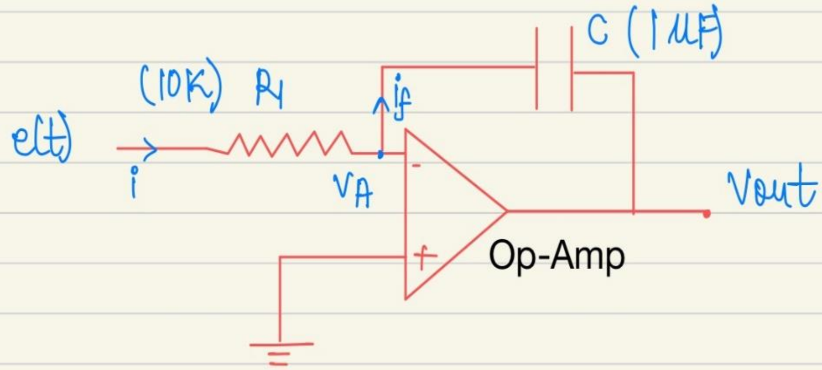
$$\Rightarrow \frac{e(t) - V_A}{R_1} = \frac{V_A - V_{out}}{R_f}$$

$$\Rightarrow \frac{e(t) - 0}{R_1} = \frac{0 - V_{out}}{R_f}$$

$$\Rightarrow \boxed{V_{out} = -\left(\frac{R_f}{R_1}\right) e(t). = -K_d\, e(t)}$$

$$\therefore \boxed{V_{out} = -\frac{1000K}{1K} e(t) = -1000\, e(t).}$$

Integrator Circuit



Now, again the point A can be considered as a virtually grounded point, i.e $V_A = 0V$

Also, $\boxed{i = i_f}$

$$\Rightarrow \frac{e(t) - V_A}{R_1} = \frac{dQ}{dt}$$

$$\Rightarrow \frac{e(t)}{R_1} = \frac{d}{dt}(CV) = C \cdot \frac{dV}{dt}$$

$$\Rightarrow \frac{e(t)}{R_1} = C \cdot \frac{d}{dt}(V_A - V_{out})$$

$$\Rightarrow \frac{e(t)}{R_1} = C \cdot \left(-\frac{dV_{out}}{dt}\right)$$

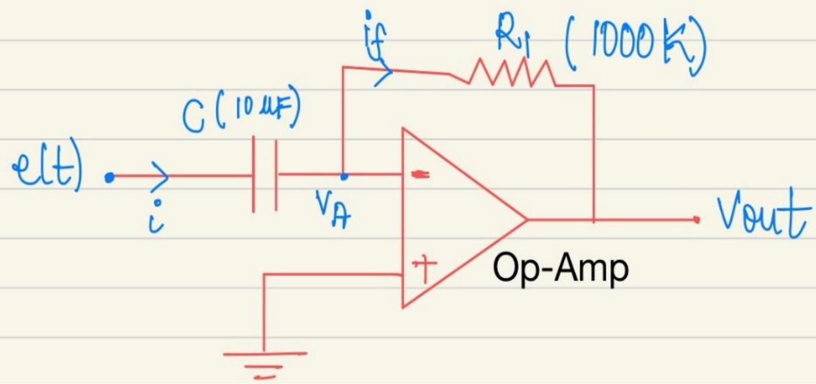
$$\Rightarrow -\frac{1}{R_1 C} e(t) = \frac{dV_{out}}{dt}$$

$$\Rightarrow \int dV_{out} = \int -\frac{e(t)}{R_1 C} \, dt$$

$$\Rightarrow \boxed{V_{out} = -\frac{1}{R_1 C} \int e(t)dt = -K_i \int e(t)dt}$$

$$\Rightarrow \boxed{V_{out} = -\frac{1}{10 \times 10^3 \times 10^{-6}} \int e(t)dt = -100 \int e(t)dt}$$

Derivative Circuit



Again we consider the point A, to be virtually grounded i.e $V_A = 0V$.

So, we have:

$$\boxed{i = i_f}$$

$$\Rightarrow \frac{dQ}{dt} = \frac{V_A - V_{out}}{R_f}$$

$$\Rightarrow \frac{d(CV_c)}{dt} = -\frac{V_{out}}{R_f}$$

$$\Rightarrow C \cdot \frac{d}{dt}\left(e(t) - V_A\right) = -\frac{V_{out}}{R_f}$$

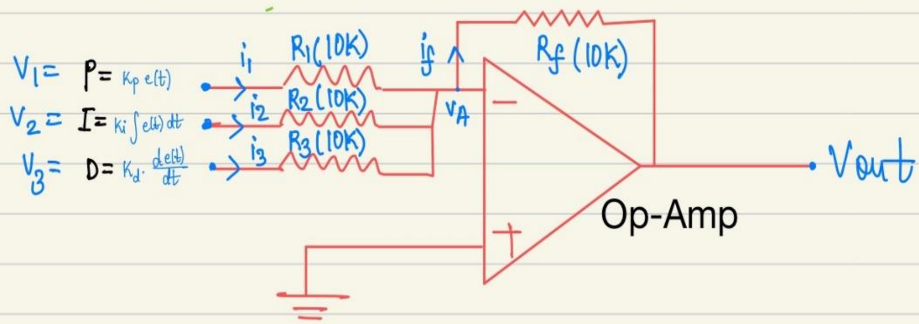
$$\Rightarrow C \cdot \frac{de(t)}{dt} = -\frac{V_{out}}{R_f}$$

$$\Rightarrow \boxed{V_{out} = -R_f C \cdot \frac{de(t)}{dt} = -K_d \frac{de(t)}{dt}}$$

$$\Rightarrow \boxed{V_{out} = -1000 \times 10^3 \times 10 \times 10^{-6} \cdot \frac{de(t)}{dt} = -10 \frac{de(t)}{dt}}$$

Note: The negative sign denotes that the output is inverted with respect to the input signal (e(t)).

Adder Circuit



Now, we consider point A, to be virtually grounded i.e $V_A = 0V$. So,

By KCL we have:

$$\boxed{i_1 + i_2 + i_3 = i_f}$$

$$\Rightarrow \frac{V_1 - V_A}{R_1} + \frac{V_2 - V_A}{R_2} + \frac{V_3 - V_A}{R_3} = \frac{V_A - V_{out}}{R_f}$$

$$\Rightarrow \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} = \frac{-V_{out}}{R_f}$$

$$\Rightarrow \boxed{V_{out} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right).}$$

Now, we substitute values of R_f, R_1, R_2, R_3, V_1, V_2 and V_3.

So,

$$V_{out} = -10\times10^3\left(\frac{-K_p\,e(t)}{10\times10^3} + \frac{-K_i\int e(t)\,dt}{10\times10^3} + \frac{-K_d\cdot\frac{de(t)}{dt}}{10\times10^3}\right)$$

$$\therefore \boxed{V_{out} = K_p\,e(t) + K_i\int e(t)\,dt + K_d\cdot\frac{de(t)}{dt}.}$$

which is the required PID equation, with

$$\boxed{K_p = 1000 \qquad K_i = 100 \quad \text{and} \quad K_D = 10}$$

$K_p = R_f / R_1$

$K_i = 1 / R_1 C$

$K_d = R_f C$

Note: All the formulas and equations used while designing the circuit and the PID controller are enclosed in the above sheets in GREEN BOXES.

So, the subtractor circuit finds the difference between the input signals fed into both the terminals of the op-amp subtractor circuit and thus helps in finding the error signal, which is nothing but the difference between the two.

This error signal output from the subtractor circuit is input for the proportional, integral, and derivative circuits. All three circuits perform their functions, and the process is mentioned above in the sheets under their respective sections.

Finally, the output from all three circuits is fed into the inverting terminal of the adder circuit, which is then used to add all three outputs to generate the final output using the suitable values of resistors. The desired output is the final PID Equation.