EE 204 - Analog Circuits
Lecture 21

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Contents

1 Overview

In the previous lecture, we discussed the Proportional Temperature Controller in detail and its drawback which produces errors in the circuit.

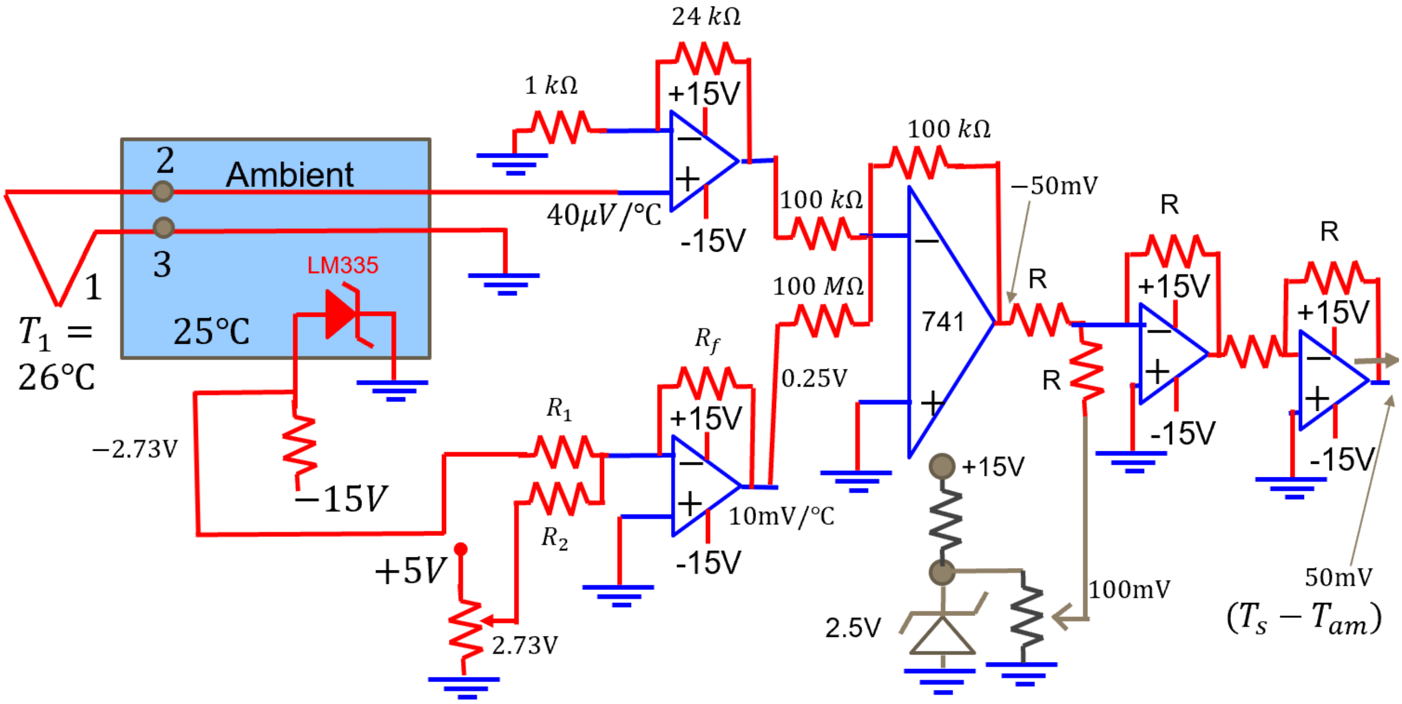
In this lecture, we attempt to mnodify the circuit such that we can remove the errors to the best extent possible. Later, we also see the equivalent electrical circuit of one such modified controller.

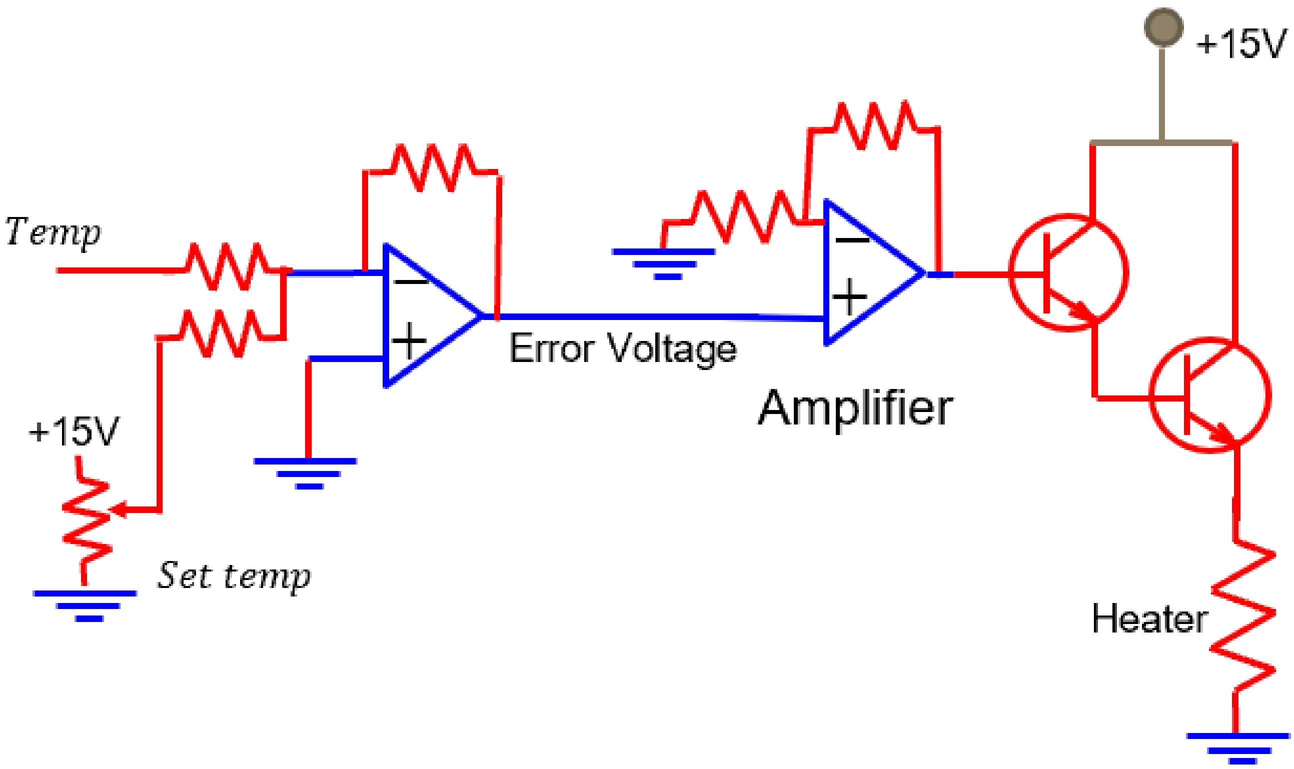
We first go over the Proportional Temperature Controller and review the error-inducing reasons and then present modifications in the circuit to counter the errors.

2 Proportional Temperature Controller

Proportional Temperature Controllers use proportional regulation to maintain a constant temperature with no swing in the control temperature.

For a proportional temperature controller, Heater voltage is proportional to the error, where the error is defined as the set temperature minus the actual temperature.



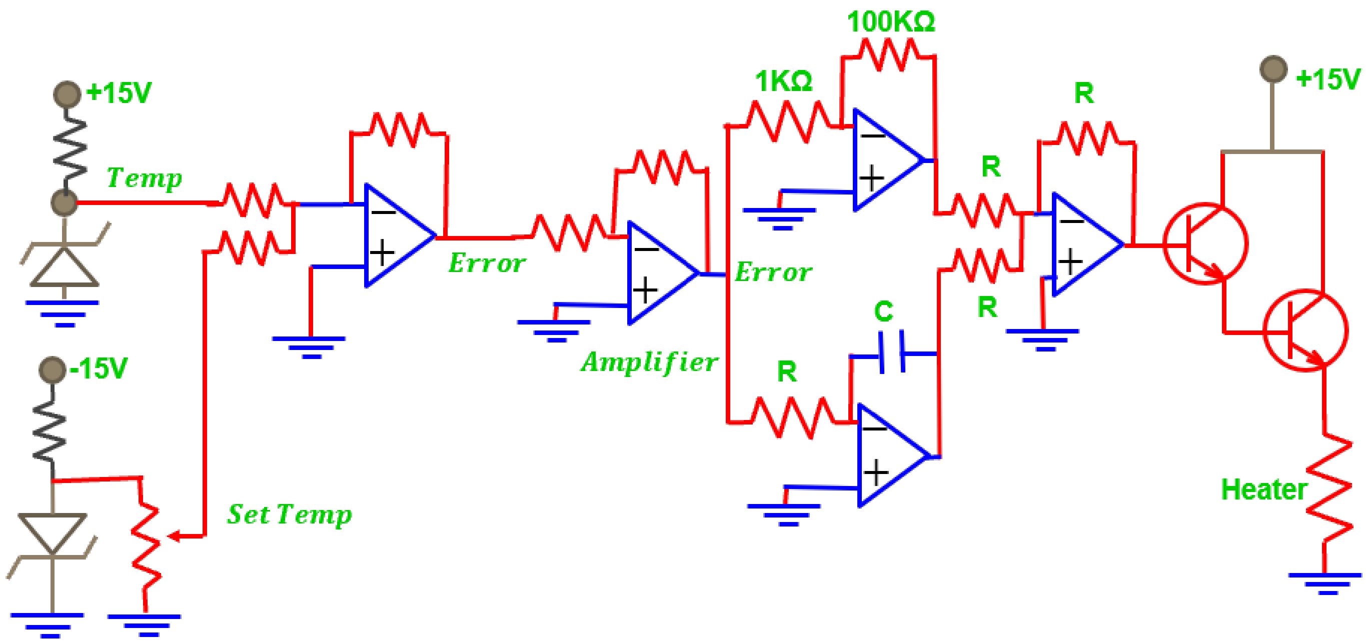


2.1 Problems of this temperature controller

- **Set Temperature $\neq$ Actual Temperature** $\coloneqq$ There is a difference between the set temperature and the actual temperature due to base-emitter losses in the Darlington Pair.
- **Error Voltage $\times$ Gain = Heater Voltage** $\coloneqq$ The principal of Proportional controller is based on the proportional relation between the error voltage and the heater voltage, and hence the gain should be set properly so as the values remain in the desired range and also manages to achieve the desired objective.

3 Proportional-Integrator (PI) Controller

In this controller, we add an integrator to the already existing circuit so as to remove/minimise the error (i.e. the difference between the set point temperature and the actual temperature).



In this controller, the integral part accumulates the past errors. It continuously sums up the error values over time and then applies a correction based on this accumulated error. This helps eliminate any long-term steady-state errors and brings the system closer to the set-point temperature over time.

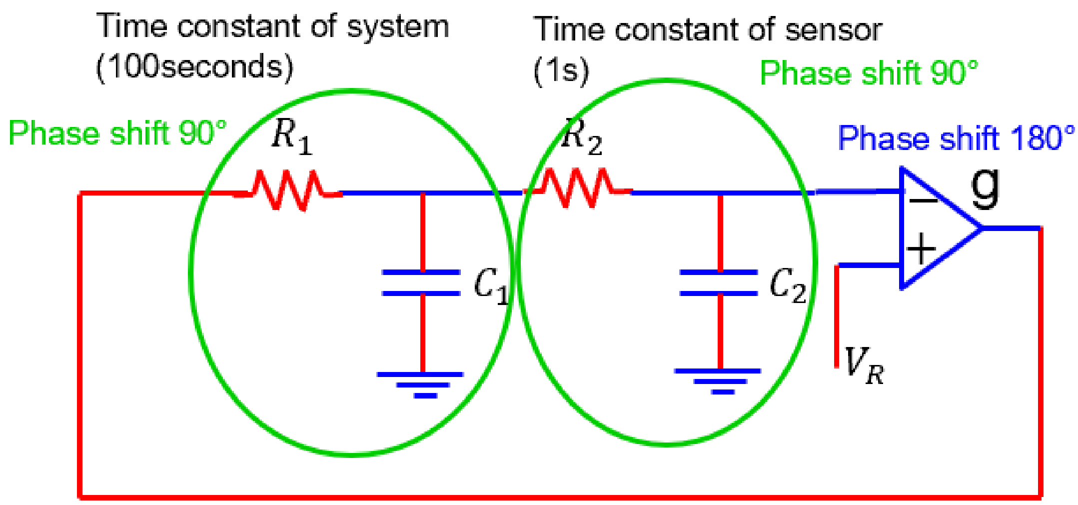
$$\boldsymbol{i \times t = C \times V}$$

$$\frac{\boldsymbol{Error\ voltage}}{\boldsymbol{R}} \times \boldsymbol{t = C \times V}$$

4 Control Theory Equivalence

We further attempt to draw an equivalent electrical circuit of PI controller which is used in control theory applications.

As shown, each capacitor causes a phase shift of $90°C$ and the inverting OpAmp at the end causes a phase shift of $180°C$ thus the complete circuit causes a phase shift of $360°C$, resulting in our original signal itself since we complete one full cycle of phase rotation.



5 PID Controller

PID Controller stands for Proportional-Integrator-Differentiator Controller. Just as we designed the PI controller above, we in addition to the existing PI circuit add a Differentiator in parallel to the PI combination.

The controller works by constantly comparing the desired temperature with the current temperature and then adjusting the heat output to keep the temperature as close to the desired setting as possible.

The PID controller looks like the following -