A LOCALLY DESIGNED ON-OFF TEMPERATURE CONTROLLER

by

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Introduction

A temperature controller is a small, yet a very important part of a system involving control of temperature. Take the case of an air-conditioned room, where we would always wish to limit the output of the air-conditioner so as to attain just the right or conducive temperature. During these times of high energy costs, we would not want that the air-conditioner's compressor unit will work over too hard to the point where the room temperature shall become undesirably cold, as this could mean wasted energy. Thus, to attain a desirable temperature inside the room, we may employ the use of a simple device to control the temperature. We normally use a thermostatic temperature controller for this type of application. There could be hundreds of instances wherein we would desire to control a certain system's temperature and thus, eventually we may have to use a more sophisticated means of controlling temperature.

Economics Involved in Designing and Fabricating a Temperature Controller Locally

There are two considerations why one would desire to design and fabricate his own or may simply buy a locally-assembled controller unit. These two categories are 1) initial cost and 2) cost of maintainance.

Imported temperature controllers could have a very high initial cost because of the following reasons:

1. Initial Cost – There is a number of factors which determine the cost of a temperature controller.

Control and measuring instruments normally require a great deal of adjustments after and during assembly and these are done by skilled technicians. As cost of labor is high abroad, this could add considerably to the cost of imported control and measuring systems.

Transportation costs are normally high these days and this would account for another added cost of imported measuring instruments.

The two previously mentioned incurred costs contribute a major part in the added initial costs of imported devices not mentioning other costs such as handling, storage, taxes and middle man profits (commissions). All of these taken together would come up to 50 to 60 per cent of the total initial cost. If we fabricate our own, the initial cost may be cut down by 40 to 50 per cent. This would mean that

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locally produced simple temperature controllers when produced in volume could be sold at half the price of imported units.

Producing these items is not a problem because the technology involved is simple enough and we already have it locally.

2. Ease of Maintenance can readily be achieved and equipment downtime controlled to a minimum since ninety-five (95%) per cent of the spare parts are available as off-the-shelves items in most electrical and electronics stores. This would also mean savings in indent costs of spare parts and likewise savings through minimal downtime.

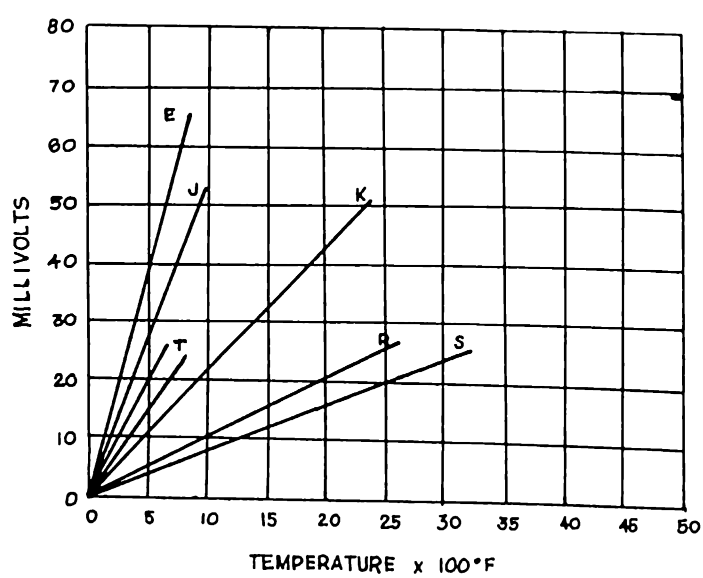
Temperature Sensors

Before control action can be achieved, a very important part of the system has to come into view and this is the sensing element. There are various kinds of sensors available in the market and they differ from each other on the basis of: principle of operation, range of usable measurement, and environmental applications.

From among the temperature sensing elements, the thermo-couple has a relatively vast range of operating temperatures taking into consideration its moderate price.

A graph showing the characteristics of thermocouples may be seen on Figure 1.

Fig. 1



ANSI SYMBOL

K - Chromel vs. Alumel

T - Copper vs. Constantan

E - Chromel vs. Constantan

J - Iron vs. Constantan

R - Platinum vs. Platinum 13% Rhodium

S - Platinum vs. Platinum 10% Rhodium

Table 1 may prove useful in the selection of thermocouples for various types of applications.

Table 1

Type	Temperature Working Range (°C)	Limits of Error °C	Environment
J	−270 to 760	1/2 to 1°C	Use recommended at reducing Atmospheres
K	−270 to 1372	1/2 to 1°C	Use in clean oxidizing atmospheres
E	−270 to 1000	±1% o-temp. 1/2°C	Mildly oxidizing or atmospheres
T	−270 to 1372	1/2°C	Mildly oxidizing and reducing atmospheres
R	0 to 1768	±1/4%; ±3/4°C	High resistance to oxidation and corrosion. May be contaminated by hydrogen and carbon vapor.
S	0 to 1768		

Principles of On-Off Control

Many processes require the use of an on-off temperature controller. In such a case, let us look into the details of the operation of a simple on-off control device.

There are a few things that the temperature controller must be able to do:

1. Measure and amplify the millivolts between the thermocouple terminals to a usable level.
2. Compensate variations of ambient temperature that may affect the whole temperature control system.
3. Provide a setpoint for temperature control within the measurement range.
4. Provide enough current or voltage to drive an external circuit that may be used to limit power being delivered to the heating system such as: solenoid valves, control valves, magnetic starters, etc.

Small D.C. Signal Level Measurement

Thermocouples are non-current generating sensors, thus loading effect must be minimized. To virtually eliminate loading the thermocouple sensing element, we may use a **Potentiometric** voltage measuring circuit.

Ambient Compensation

The output of a thermocouple is a function of the temperature difference between the hot and cold junction. The cold junction is referred to 0°C for all measurements. Since the cold junction of a thermocouple is normally at ambient temperature and does not necessarily become zero, an ambient error occurs. If the reference is now (for our case) above zero, which would mean that without ambient compensation, our measurements will be lower by approximately the value of the ambient temperature. Finding the solution for ambient error is very easy. The ambient temperature must be measured and this value added to that which measured by thermocouple.

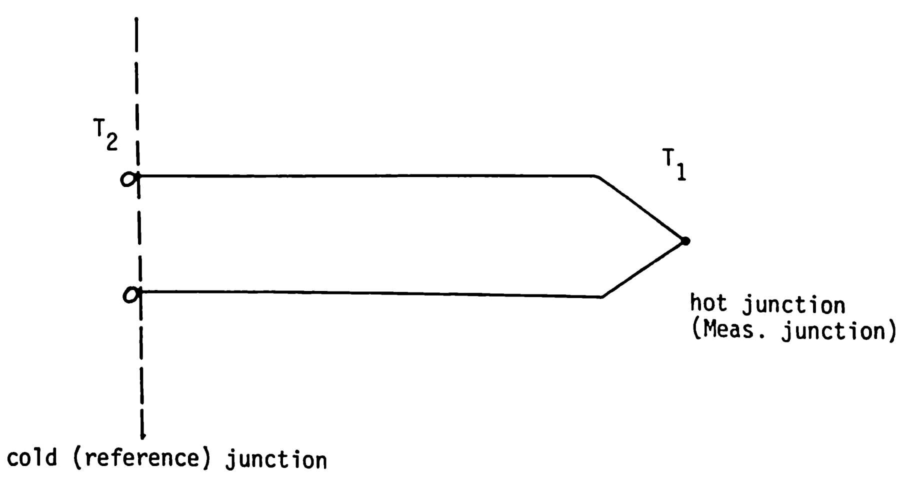
It is however very cumbersome for continuous control systems to do the ambient compensations manually. (The correction of T_2 from ambient to 0°C [32°F]). Thus, we must provide an automatic ambient compensation circuit.

The ambient compensation circuit must continuously monitor the ambient temperature and correspondingly compensate the cold (reference) junction to 0°C. This can be done by using thermostatic elements or thermocouples that monitor and provide corrections for automatic ambient compensation.

Controller Setpoint

A suitable means of adjusting the setpoint of the temperature controller throughout the whole measurement range must be provided. This is easily done through the use of IC comparators.

Fig. 2



$$\text{Temf} = f\,(T_1 - T_2)$$

Temf: output of thermocouple in mV

T_1 : temperature to be measured at the measuring junction

T_2 : reference temperature (usually ambient)

The Indicating Temperature Controller*

I. Specifications:

Input: Thermocouple
Types: R; S; K; J; E
(depending on plug in range card)

: Resistance Bulbs
Types: Pt; Ni; Cu
(depending on plug in range card)

Range: To be specified by customer on order and depending on the sensor characteristics.

Power Requirements: 200V/110V 60 Hz@ 5 V.A.
Ambient Temperature: 70°C max
Relative Humidity: 80% max
Ambient Temperature Compensation: 15-45%
Sensor Failsafe: If the sensor circuit breaks, the controller responds as if input is above setpoint.
Line Voltage Stability Factor: +17%; −13%
Ambient Temperature Stability Factor: ±1%/°C/hr.

Circuit Description:

The thermocouple output to the measuring circuit goes to a scaling and inverting amplifier (IC_1). Ambient temperature compensation is provided by $T_1 T_2$ and T_3. The output of IC_1 goes to the meter readout indicating the system's temperature status. The output of IC_1 is also tied to the inverting input of our Setpoint amplifier (IC_2) comparator. When the measured temperature is above setpoint, the output of IC_2 (pin 6) goes low and Q_1 is switched off. The coil driver circuit Q_2 turns off thus disconnecting power to the heating system. The coil driver now switches on when the measured temperature is below setpoint.

Monitoring and setting of the control setpoint is done through IC_3. The adjustment of R_{12} (setpoint adjust) is done with the aid of IC_3 and the meter circuits. The setpoint may then be adjusted anywhere within the measuring range.

Calibration Procedure:

1. With the instrument off, rotate mechanical zero adjust of meter until meter reads 0°C.
2. Turn power on. Disconnect the ambient compensation terminal from pin 2 of IC_1. Short the thermocouple positive and negative inputs and adjust R_7 until pin 6 of IC_1 with respect to ground reads 0 MV. (Use an accurate voltmeter.)
3. Flip OP-S.P. switch to S.P. Position (down). Rotate R_{12} (set point adjust potentiometer) to full counterclockwise position. Adjust R_{15} until meter reads 0°C.

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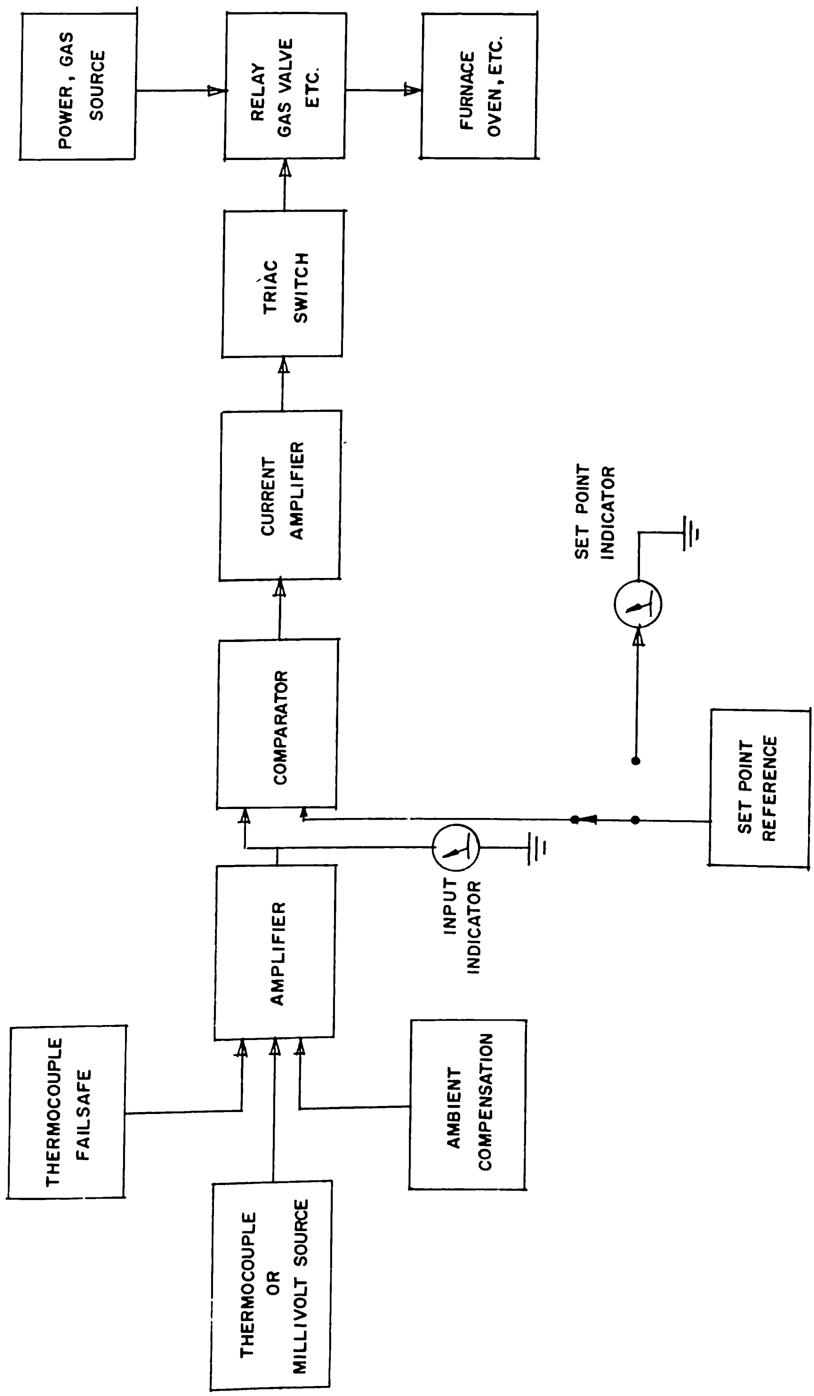
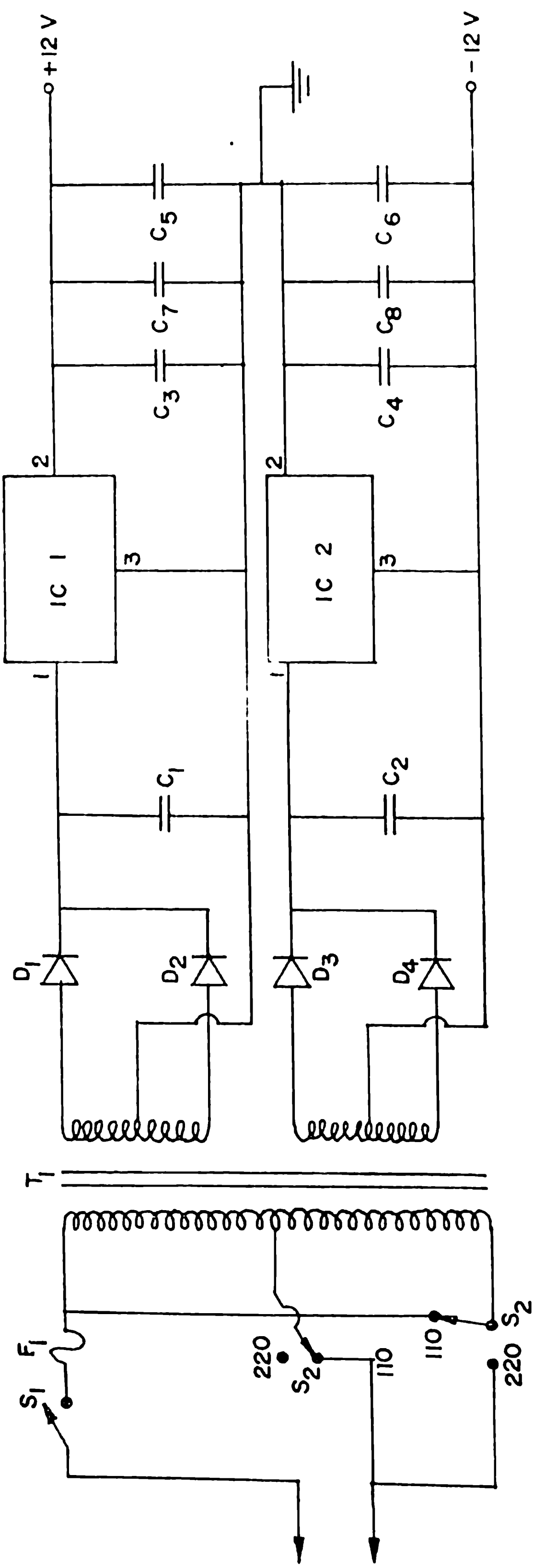
4. Rotate R_{12} to full clockwise position. Adjust R_{17} until meter reads 1500°C.
5. Flip the OP-S.P. switch to OP position (up). With shorted TC input, reconnect the ambient compensation terminal to pin 2 of IC_1. The meter should read the ambient temperature.
6. Apply 1500°C on the millivolt equipment (Type K) to T.C. inputs. Adjust R_{11} until relay clicking is heard.
7. Adjust R_9 until meter reads 1500°C.
8. The instrument is now fully adjusted.
9. Input from standard and T.I. readings can now be taken. Recommended interval is 100°C.

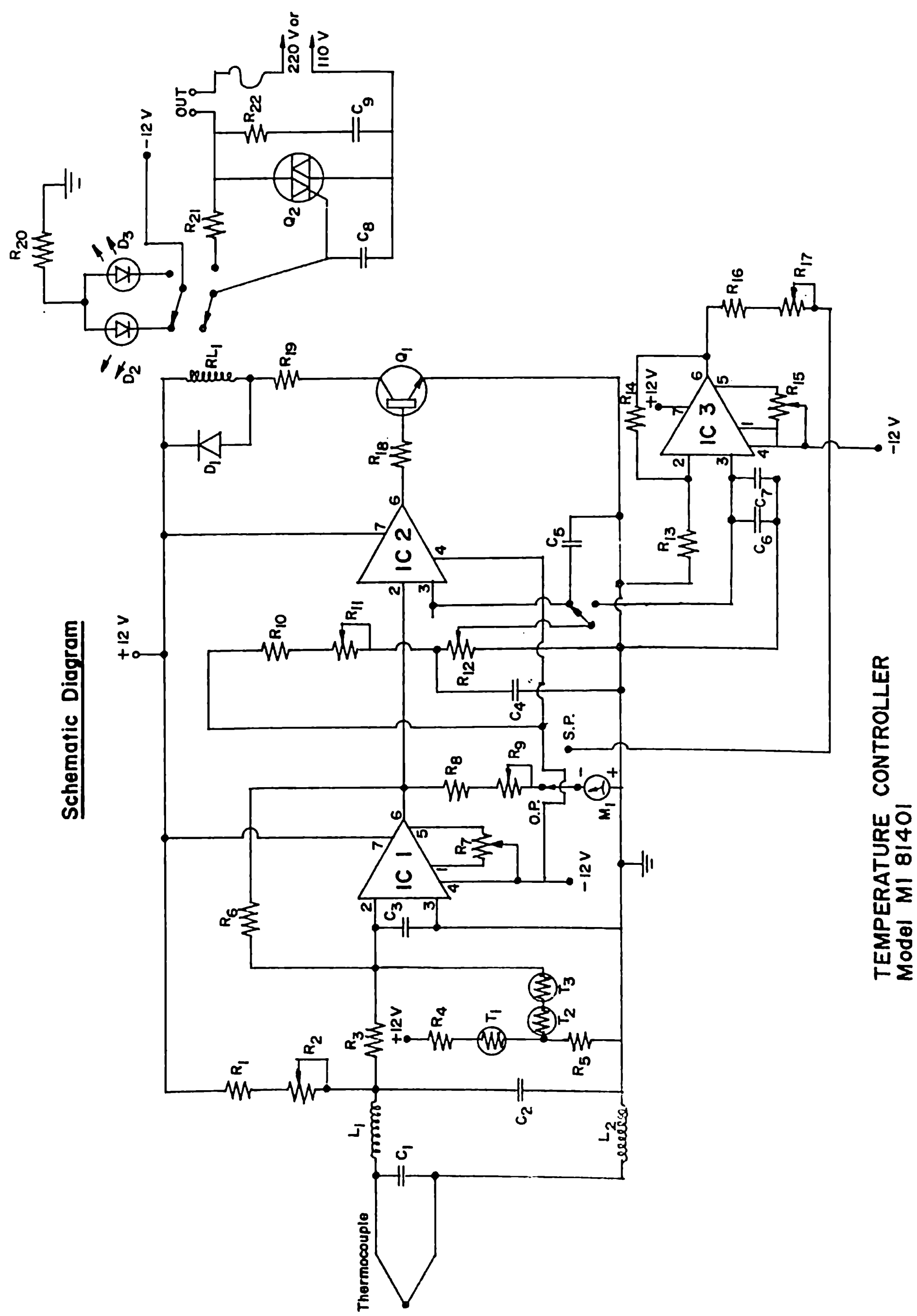


BLOCK DIAGRAM

Schematic Diagram



POWER SUPPLY FOR TEMPERATURE CONTROLLER


Schematic Diagram
Thermocouple
+12 V
-12 V
OUT
220 V or
110 V
S.P.
O.P.
IC 1
IC 2
IC 3
TEMPERATURE CONTROLLER
Model MI 81401