Microcontroller Application Example

(Environment Temperature Control System)

Microcontroller

- A microcontroller contains all components which allow it to operate standalone, and it has been designed in particular for monitoring and/or control tasks.

- A major application area for microcontrollers are embedded systems.

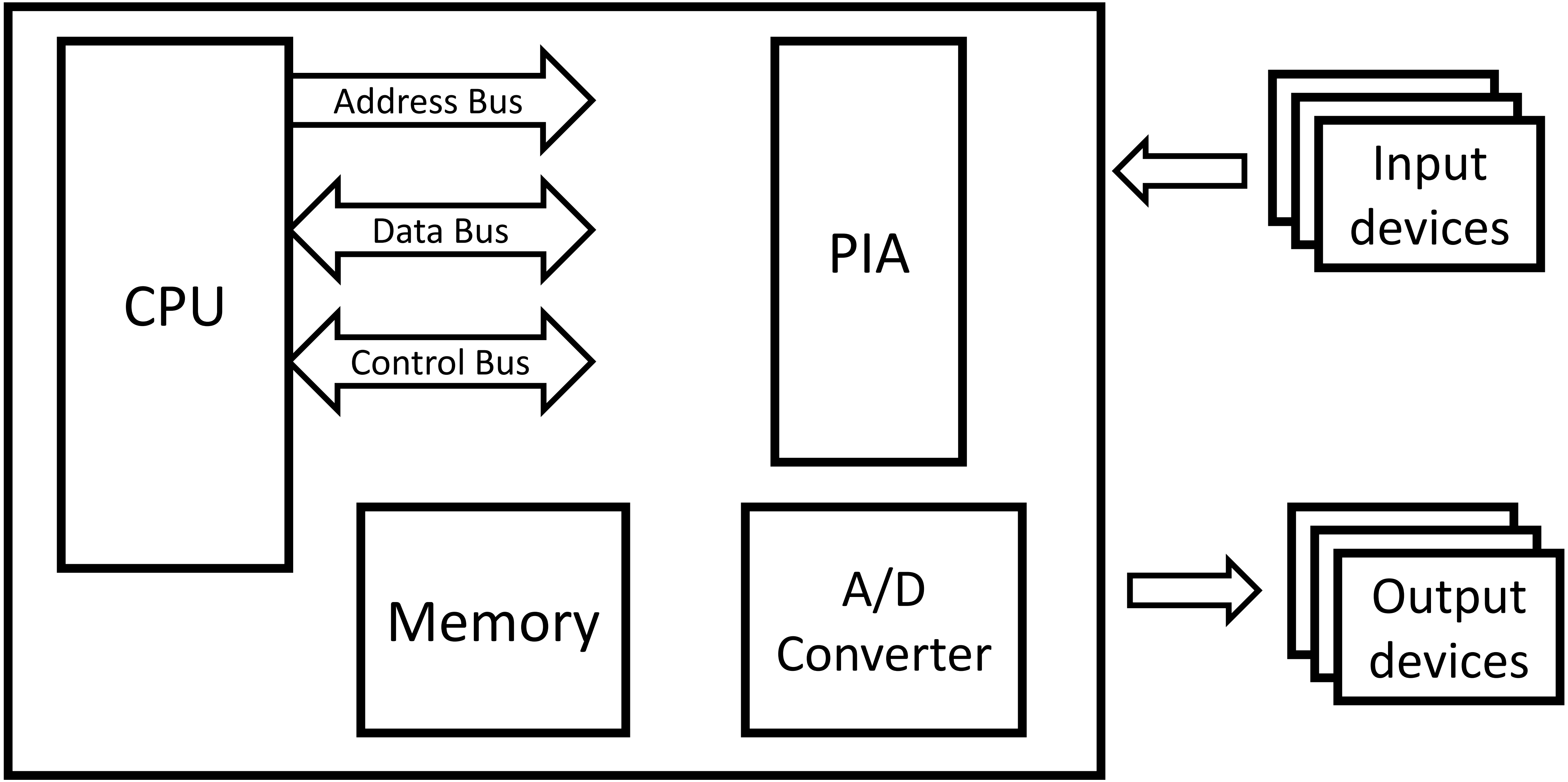
- In embedded systems, the control unit is integrated into the system.

Environment Temperature Control System

(Source: E.Adalı, Mikroişlemciler/Mikrobilgisayarlar Book, page 462)

- A microcontroller-based system will be designed to control temperature of an environment.
- The system will continuously monitor the environment temperature, and will turn on the heater or the cooler automatically.
- User Input: Two keys (Increment key and Decrement key) will be used by user to enter the targerted temperature.
- Sensor Input: A sensor will measure the environment temperature, and will send analog signal to A/D Converter.
- LED Displays Output: The target temperature will be shown on 3 LED displays. (each is 7-segment). Only one LED will be selected at a time, three LEDs will be scanned in a loop. Example: 24.7 degrees will be shown as 247 in three LEDs.
- Heater and Cooler Output: Program will turn on the heater or the cooler based on the targeted temperature and the measured temperature.

Microcontroller



PIA

PORT-A

K0-K6 : LED segments

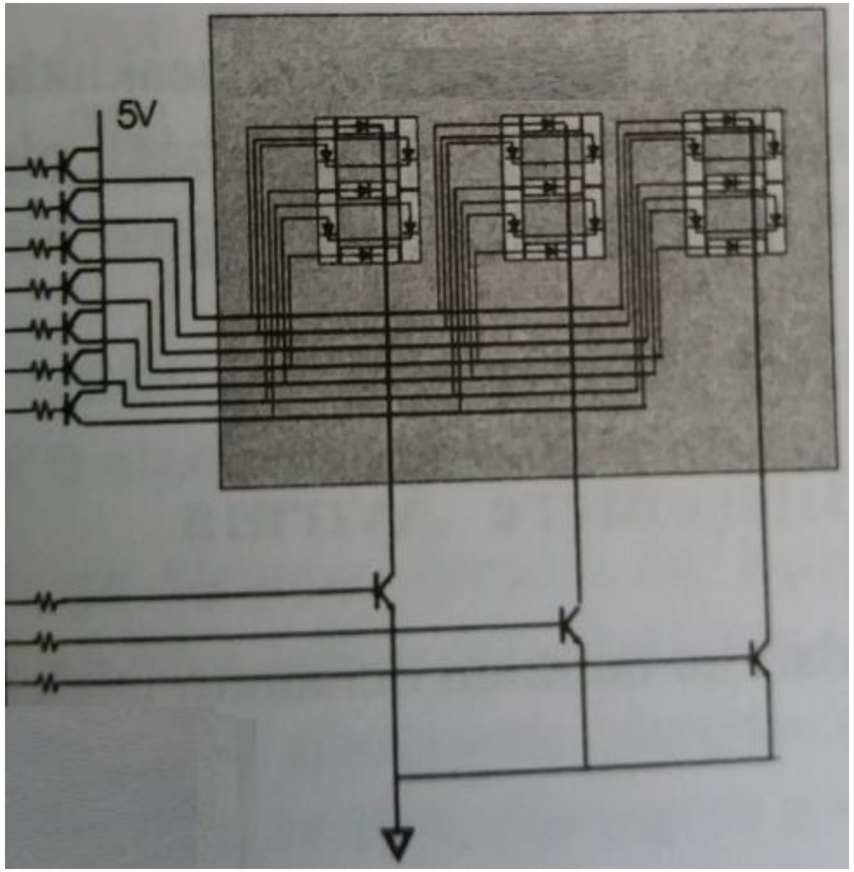
K0
K1
K2
K3
K4
K5
K6
K7

PORT-B

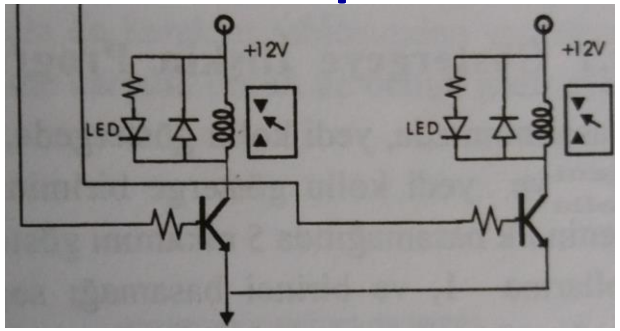
K0-K2 : LED selection
K3 : Heater
K4 : Cooler
K5 : Increment Key
K6 : Decrement Key

K0
K1
K2
K3
K4
K5
K6
K7

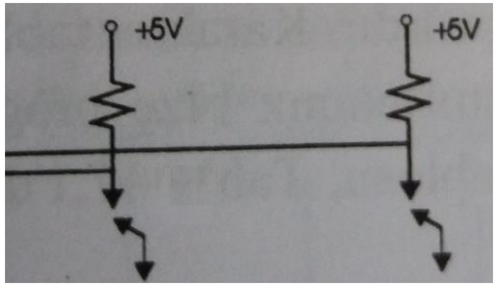
LED Displays outputs



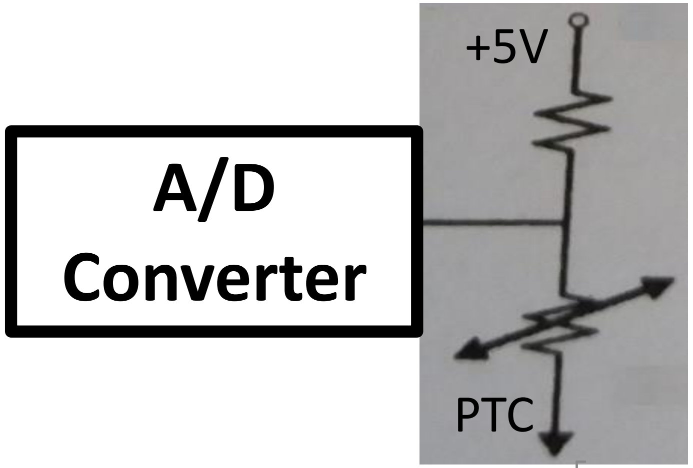
Heater and Cooler outputs



Key inputs



Temperature Sensor input



Specifications of System

- The initial default temperature for system will be assigned as 21.0 C^0 degrees.

- When user presses the Increment or Decrement key, 0.5 degrees will be added or subtracted from the current target temperature.

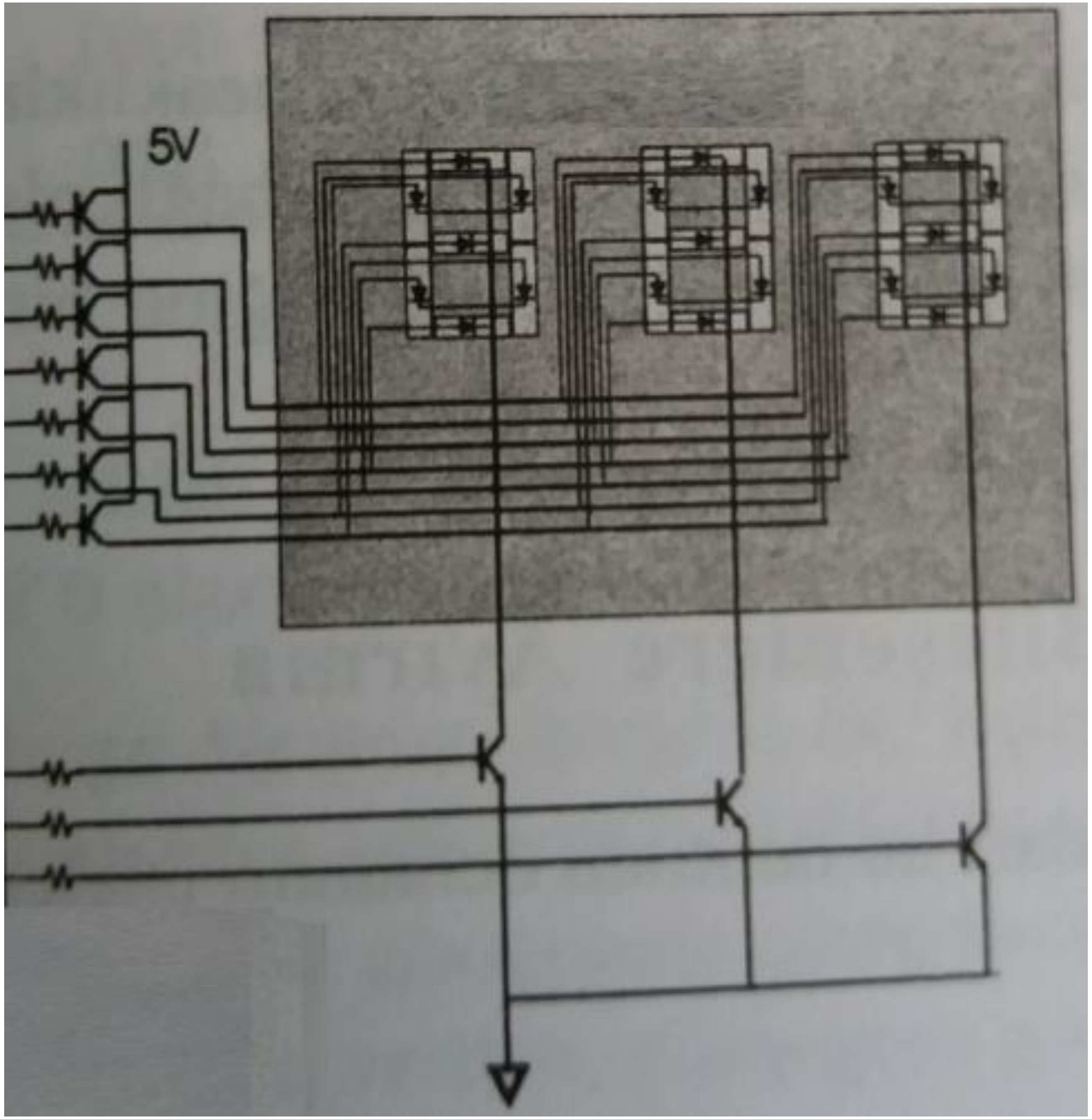
- The target temperature will be stored in memory without the fraction point (as three digits).
  (For example: 24.7 degrees will be stored in memory as 247 in three bytes, one byte for each decimal digit).

- When the difference between the Measured temperature and the Target temperature is at least 0.3 degrees, then CPU will send a control signal to the Heater or the Cooler.

LED Display Outputs (3)

7-Segments driving (from PIA.A)

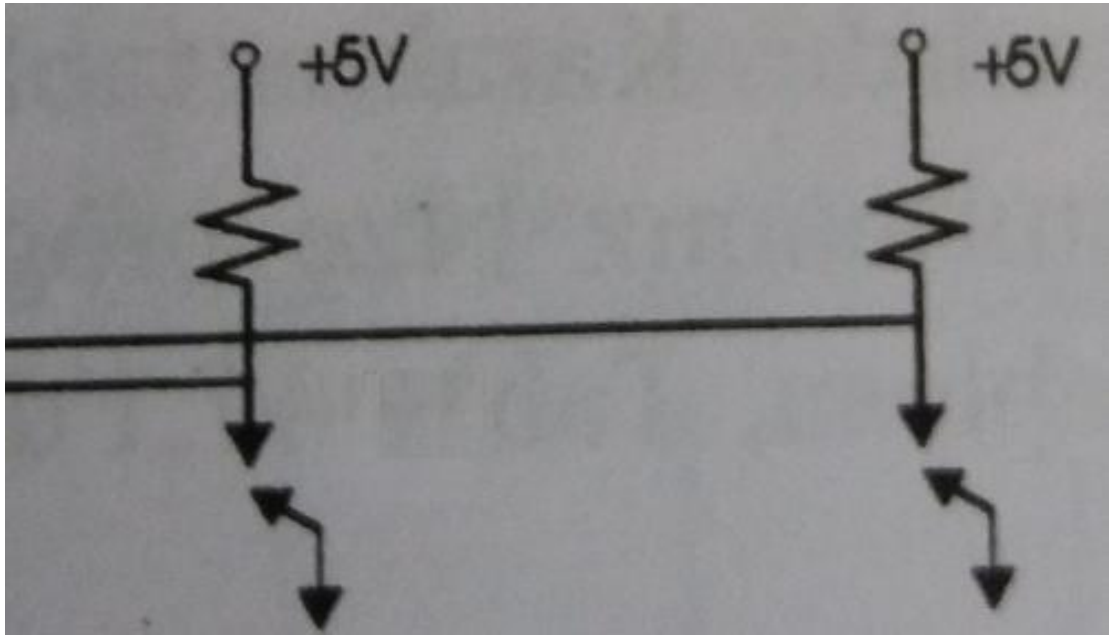
LED selecting (from PIA.B)
(Only one LED is selected at a time)



Key inputs (2)

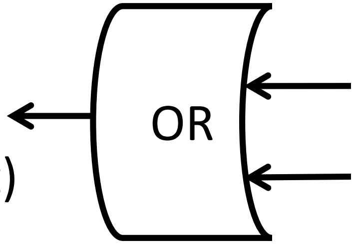
(for temperature adjustment by user, also interrupt driven)

To PIA.B data register



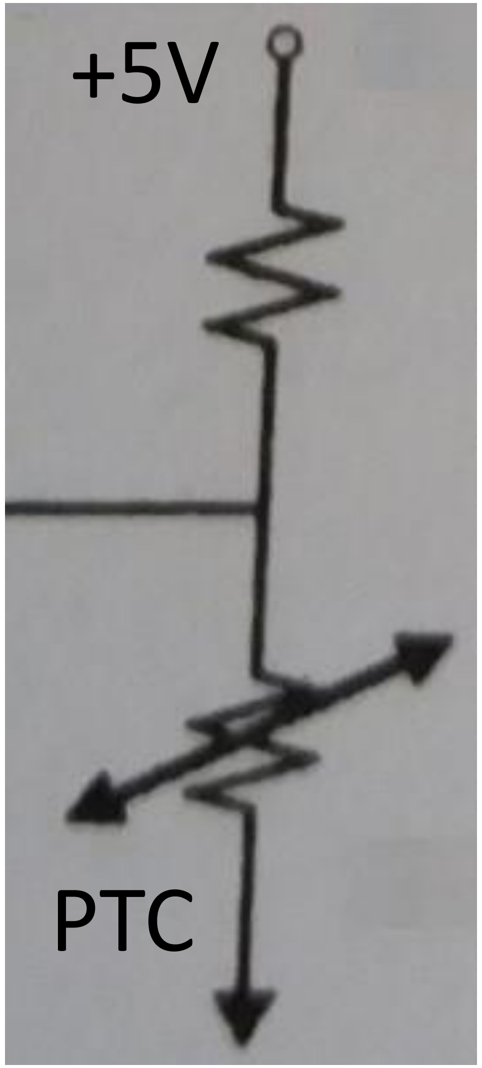
Increment key **Decrement key**

RDY input of PIA.B (For interrupt)



Temperature Sensor Input (1)

To ADC
(Analog to Digital Converter)



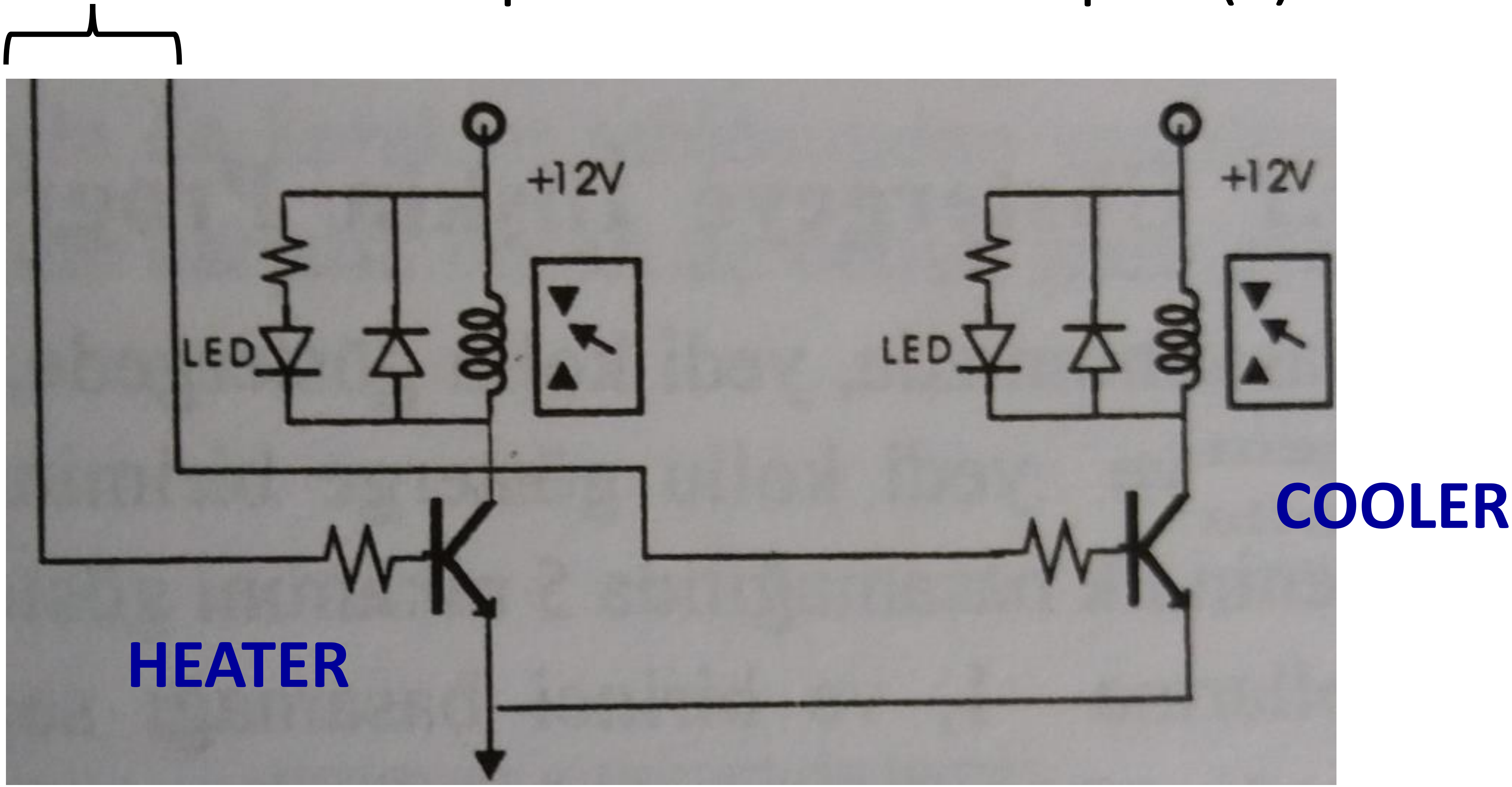
<u>PTC</u> : Positive Temperature Coefficient

Other name : Thermistor
(Thermo Resistor)

PTC is a special resistor which changes its resistance by the temperature.

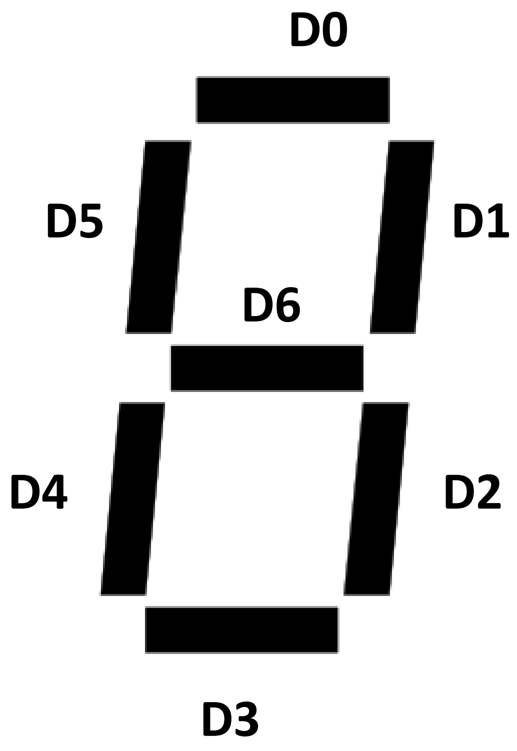
Temperature Control Outputs (2)

From PIA.B



Character Table in Memory for a LED

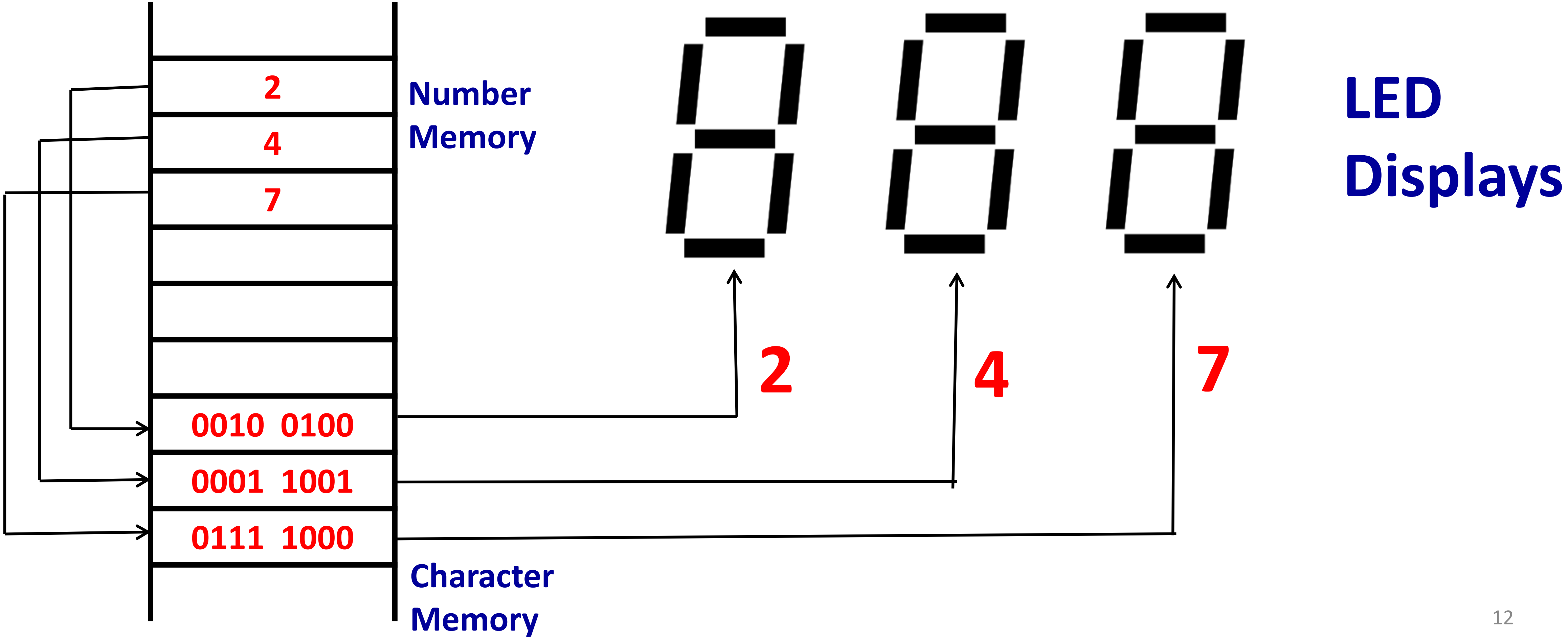
- A LED can display numerical characters between 0 and 9.
- Each LED has 7-segmenst.
- The following character table will be stored in memory in advance.
- A segment will light only when it is **logical 0**.
- The D7 segment will be not be used (0).



Number	7-Segment Value (D0-D6)
0	0100 0000
1	0111 1001
2	0010 0100
3	0011 0000
4	0001 1001
5	0001 0010
6	0000 0010
7	0111 1000
8	0000 0000
9	0001 1000

Memory for Number and Character to LED displays

- There will be three number digits to show the targeted temperature. (Example: 24.7 degrees)
- These three numbers will be stored in a memory location (3 bytes).
- Also corresponding three Characters will be stored in another memory location (3 bytes).

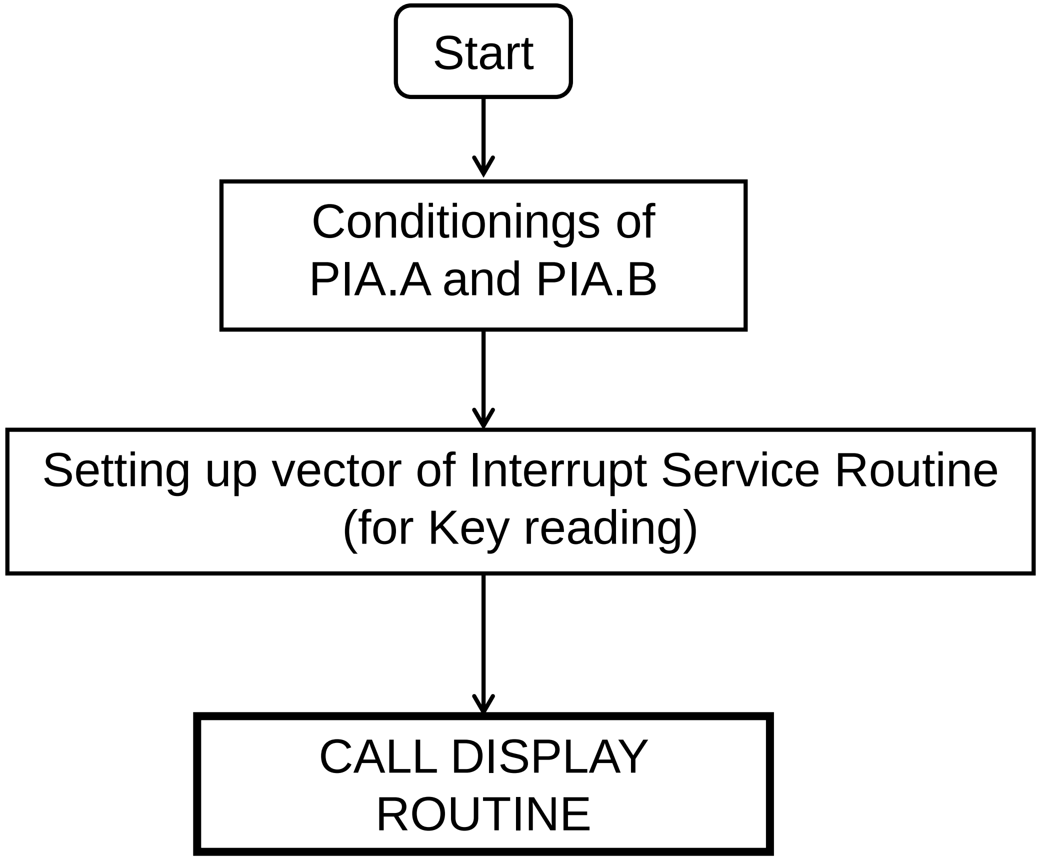


Analog to Digital Converter

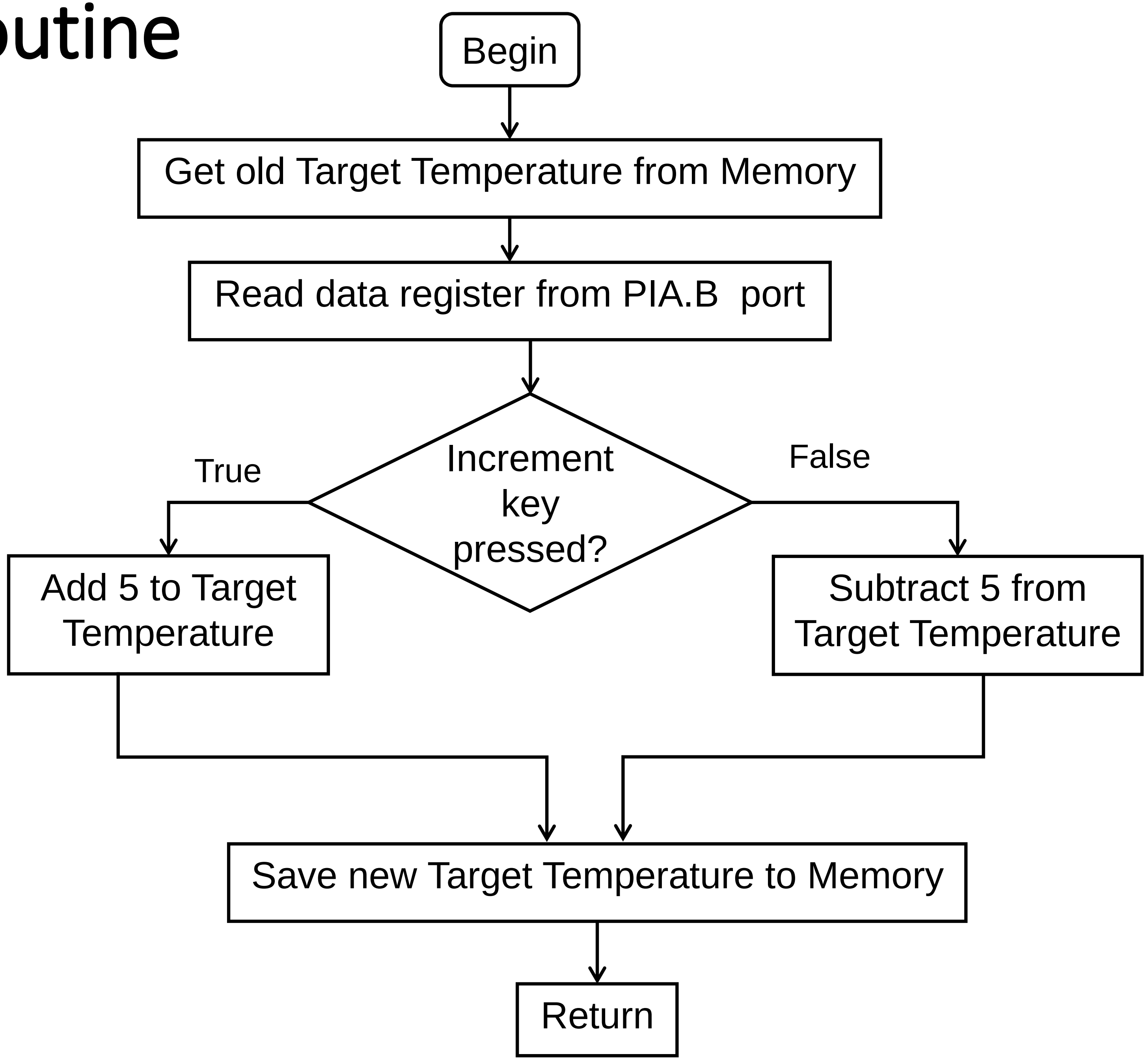
- A/D Converter is designed to operate between 15 and 40 degrees of temperatures.
- It can convert the measured voltages to logical digital signals (1or 0).
- Step of temperature conversion is 0.1 degrees.

Measured Temperature	Sensor Output (Voltage)	A/D Converter Output (to CPU input)
15.0	0	0000 0000
15.1	0.019	0000 0001
15.2	0.038	0000 0010
15.3	0.057	0000 0011
15.4	0.076	0000 0100
. . . .	. . . .	. . . .
39.9	4.901	1111 1110
40.0	5	1111 1111

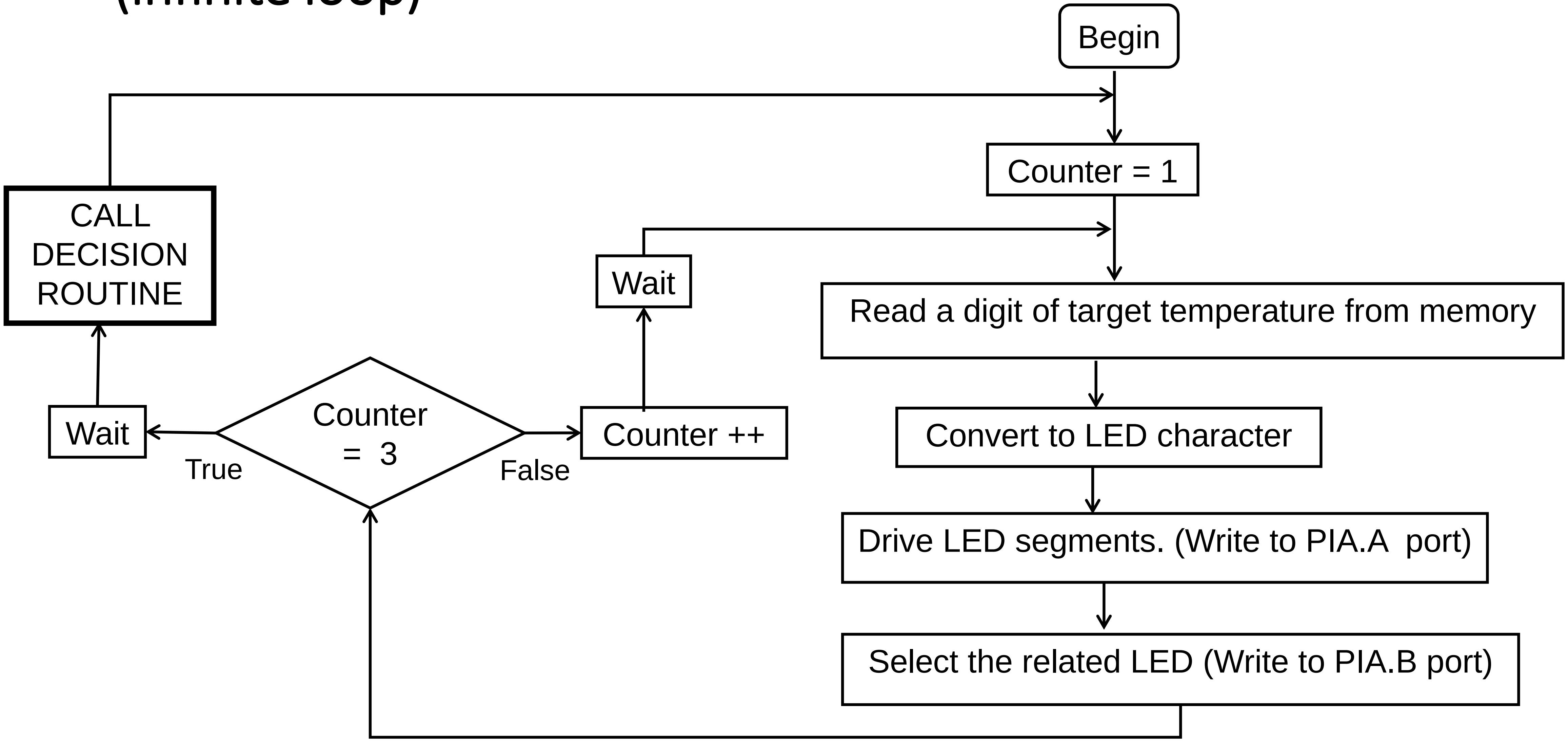
Main Program



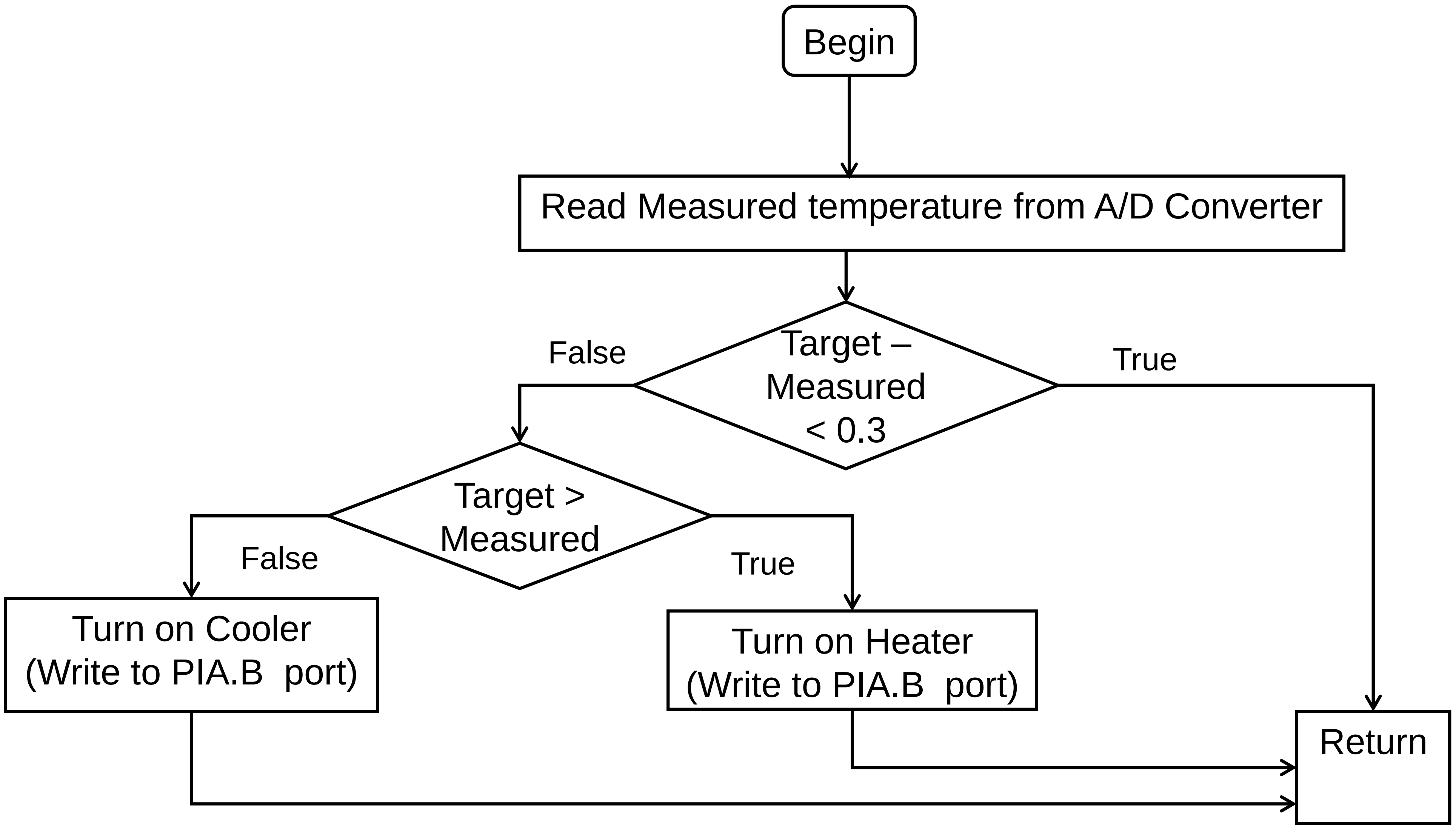
Interrupt Service Routine
(for Key inputs)



DISPLAY ROUTINE
(infinite loop)



DECISION ROUTINE



Main Program

ADC not implemented on Mikbil.
Program can't be tested.

```
ADC     EQU    $80                    ; Isolated (dedicated) address of Analog to Digital Converter

TARGET_TEMP          RMB  1      ;Target temperature
  DAT   210                        ;Initial environment temperature is 21.0 degrees.

DISPLAY_MEMORY       RMB  3      ;Memory for LED Display Numbers (3 byte)
CHARACTER_MEMORY     RMB  3      ;Memory for LED Display Characters (3 byte)
SAVE                 RMB  2      ;Temporary memory area for saving the Index Register (SK)

*LED Segment Codes (Character Table)
CHARACTER_TABLE   RMB 10
  DAT  %01000000   ;0
  DAT  %01111001   ;1
  DAT  %00100100   ;2
  DAT  %00110000   ;3
  DAT  %00011001   ;4
  DAT  %00010010   ;5
  DAT  %00000010   ;6
  DAT  %01111000   ;7
  DAT  %00000000   ;8
  DAT  %00011000   ;9
```

Main Program (contined)

```
START
* Conditionings of PIA.A and PIA.B
 LDA A, $FF
 STA A, <YÖNLEN.A>             ;All bits of PORT.A are transmitter (output)

 LDA A, %0001 1111
 STA A, <YÖNLEN.B>             ;First 5 bits of PORT.B are transmitter (output),
*                              ; others are receiver (input)

 STA YG, $03FF                 ;Stack pointer prepared before subroutine callings

* When RDY input of PIA.B goes from 1 to 0, then PIA.B will generate interrupt.
 LDA A,%00000010
 STA A,<DURDEN.B>              ;Write to CONTROL/STATUS register

*Interrupt Service Routine address label READ_KEY is stored in interrupt vector
          STA READ_KEYS, <$FFF8>

 BSR  DISPLAY_ROUTINE
 INT
```

Interrupt Service Routine for Key Reading

```
READ_KEYS
* Target temperature will be stored as 10 fold.

ORG READ_KEY
  LDA A, <TARGET_TEMP>      ;Get the old target temperature

  LDA B, <İSKELE.B>         ;Read the keys
  AND B, %0110 0000         ;Bits 5. and 6. filtered
  CMP B, %0100 0000         ;Is it the Increment key?
  BEQ INCREMENT

DECREMENT
  SUB A, 5
  BRA  UPDATE
INCREMENT
  ADD A, 5
UPDATE
  STA A, TARGET_TEMP        ;Save the new target temperature
  RTI
```

LED Displays Routine

```
* LED Displays Routine (infinite loop)

DISPLAY_ROUTINE
   LDA B, 01                              ;LED digit counter
   LDA SK, <DISPLAY_MEMORY>               ;Beginning address of LED display numbers

GET_NUMBER
   LDA A, <SK+0>                          ;Read number to be displayed
   STA SK, SAVE                           ;Save SK
   LDA SK, <CHARACTER_MEMORY>             ;Beginning address of LED display characters

SEARCH
*Searching for character that corresponds to the number
   CMP A,00
   BEQ FOUND
   DEC A
   INC SK
   BRA SEARCH
```

LED Displays Routine (contined)

```
FOUND
  LDA A, <SK+0>         ;Read corresponding character to be displayed
  STA A, <İSKELE.A>     ;Write LED segments to PIA.A port
  STA B, <İSKELE.B>     ;Write related LED selector to PIA.B port
  LDA SK, <SAVE>        ;Read SK back
  INC SK
  INC B                 ;Going to next LED
  CMP B, $04            ;All LED displays finished?
  BEQ CONTINUE

  BSR WAIT
  BRA GET_NUMBER

CONTINUE
  BSR WAIT
  BSR DECISION_ROUTINE
  BRA DISPLAY_ROUTINE
```

```
* WAIT Routine
WAIT
    LDA SK,50000
LOOP
    DEC SK
    BNE LOOP
    RTS
```

DECISION Routine

```
DECISION_ROUTINE
 STA A, <ADC>        ; Turn on Analog to Digital Converter
  BSR WAIT
  LDA A, <ADC>       ; Read measured temperature from Analog to Digital Converter output register
  LDA B, <TARGET_TEMP>      ;Get target temperature
  CMP A, B
  BHI COOLER
HEATER
*Turn on the heater
  SUB B,A
  CMP B, 3                ;Difference is less than 0.3 degrees?
  BLT EXIT
  SET 3, <İSKELE.B>     ;Third bit of PIA.B controls the heater
  BRA EXIT
COOLER
*Turn on the cooler
  SUB A,B
  CMP A, 3                ;Difference is less than 0.3 degrees?
  BLT EXIT
  SET 4, <İSKELE.B>    ;Fourth bit of PIA.B controls the cooler
EXIT RTS
```