Constant Illumination Control of Filament Lamp by Phase Delay of AC Voltage

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Abstract

In this paper, a constant illumination level control of a reading lamp is considered, with the microcontroller PIC, by continuously adjusting the illumination level on a desk from the filament lamp. The illumination, from the filament lamp, is transformed into the voltage by the phototransistor on the desk. From the voltage thus transformed, we can know the illumination level on the desk indirectly. For the purpose of constant illumination level control, the phase control of the AC voltage, in terms of the triac, is adopted. Since the transformed voltage through the phototransistor is small, the voltage is amplified by the operational amplifier. The amplified voltage is applied to the microcomputer PIC and A/D converted in the PIC with a resolution of 10 bits. The microcontroller program is implemented as follows. If the A/D converted value is larger than the reference input value, the phase delay of the AC voltage, applied to the filament lamp, is set to increase. Then the brightness of the filament lamp decreases, and vice versa. According to these adjustments of the illumination level on the desk, the feedback control of the constant illumination level from the reading lamp, is carried out.

Keyword: Constant illumination control, Dimmer, Triac, Phototransistor, A/D conversion

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1. Introduction

The illumination level, on the desk, from the filament lamp is influenced by the surrounding circumstances such as the interior illumination, outdoor light by the sun, night darkness, etc. Since the illumination level in the daytime is high in general by the brightness of the sun, for the illumination level, on the desk, to be constant, the brightness of the filament lamp should be weakened. This operation makes it possible to reduce the electric power consumed in the filament lamp. Conversely, in a dark room at night, to realize the constant illumination level on the desk, from the filament lamp, it might be required to brighten the lamp filament. Namely, we aim to maintain the constant brightness, on the desk, from the filament lamp, regardless of the variation of the brightness in the room by the surroundings. For this tuning the illumination level of the filament lamp, the phase control of the AC voltage is useful. As an optical sensor, the phototransistor is adopted. The brightness of the filament lamp is transformed into the relatively small voltage by the phototransistor. Hence, the small voltage obtained by the phototransistor is amplified by the operational amplifier. Then the amplified voltage is applied to the PIC and A/D converted with the resolution of 10 bits. As the illumination level on the desk becomes bright, the voltage applied to the PIC becomes high. Accordingly, to keep the fixed illumination level on the desk, from the filament lamp, the following operations are embedded in the PIC program.

(1) If the illumination level on the desk, from the filament lamp, is larger than that of the reference input, the phase delay of the AC voltage, applied to the filament lamp, is set to increase.

(2) If the illumination level on the desk, from the filament lamp, is smaller than that of the reference input, the phase delay of the AC voltage, applied to the filament lamp, is set to decrease.

The rest of this paper is organized as follows. In section2, the block diagram is illustrated for the constant illumination control system. In section 3, the schematic used in the constant illumination control is illustrated. Also, the control program for the constant illumination control is listed. Then the experimental results are described for the constant illumination control, when the interior light is turned on from an off state.

2. Block diagram on the feedback control for the constant illumination level

Fig.1 illustrates the block diagram on the feedback control for maintaining the illumination level, on the desk, of the filament lamp constant.

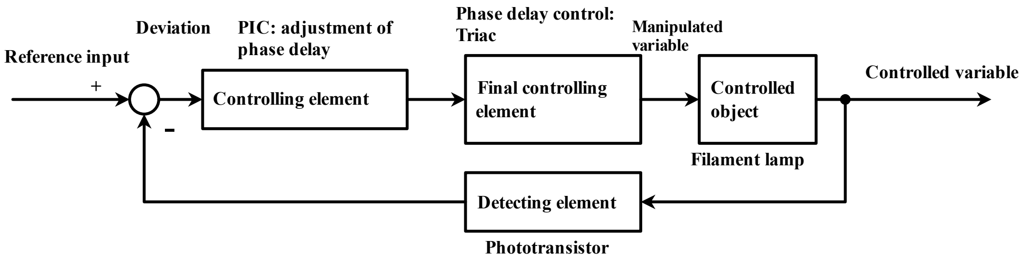

Fig.1 Block diagram on the feedback control for the constant illumination of the filament lamp.

Explanations on the block diagram:

(1) Illumination of the filament lamp is transformed into the voltage in accordance with the brightness of the filament lamp.

(2) The detected voltage by the phototransistor is small. Hence, the voltage is amplified by the operational amplifier.

(3) The amplified voltage, obtained in step (2), is A/D converted in the microcomputer PIC with the resolution of 10 bits. In this case, the voltage $0-5$ [V] corresponds to the levels of $0-1023$.

(4) The reference input is set to the value between $0-1023$. In the experiment in section 3, the reference input is set to 300 , 500 and 800 respectively.

(5) By comparing the reference input with the A/D converted value in the PIC, the phase delay of the AC voltage is adjusted so that the illumination level of the filament lamp approaches the value of the reference input. For this purpose, according to the following adjustment rules, the PICBASIC PRO program (see Fig.3) is made.

The adjustment rules:

1. If the A/D converted value in the PIC is larger than the value of the reference input, the phase delay of the AC voltage is set to increase. According to this manipulation, the illumination level of the filament lamp tends to be dark.
2. Conversely, if the A/D converted value in the PIC is smaller than the value of the reference input, the phase delay of the AC voltage is set to decrease. According to this manipulation, the illumination level of the filament lamp tends to be bright.
3. These two rules are adopted iteratively.

In the next section, the experiment for the constant illumination control of the filament lamp is explained.

3. Experiment for constant illumination control

At first, the circuit diagram on the constant illumination control of the filament lamp is illustrated in Fig.2.

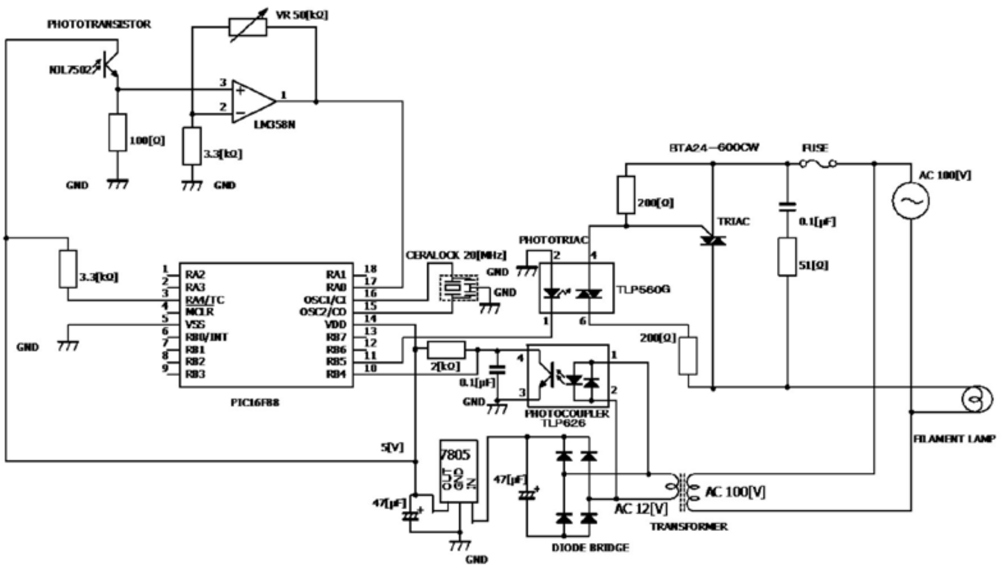

Fig.2 Circuit diagram on the phase control of the filament lamp.

The steps for generating the phase delay voltage in Fig.2 are described as follows [1].

(1) The AC voltage 100 [V] is dropped to AC 12 [V] by the transformer.

(2) The photocoupler detects the zero-cross points of the AC waveform of 12 [V].

(3) Each time the zero-cross point is detected, the pulse signal is sent to the port RB4 of PIC16F88.

(4) Upon receiving this pulse signal in the PIC, after the time corresponding to the phase delay, from the port RB5 of the PIC, the pulse signal is output to the phototriac.

(5) The trigger pulse from the phototriac is input to the gate of the triac. Then the phase delay AC voltage generated from the triac is applied to the filament lamp.

The behaviors of the phototransistor and the operational amplifier in Fig.2 are explained as follows.

(1) In accordance with the brightness of the the filament lamp, the collector current flows in the phototransistor. This current generates the DC voltage in the resistance connected to the phototransistor.

(2) The voltage is amplified by the operational amplifier.

(3) If the amplified voltage is applied to the analog input of the PIC, the analog voltage is converted to the digital values with the resolution of 10 [bits] by the A/D conversion in the PIC.

The method in adjusting the phase delay, for the brightness on the desk to make near to the assigned value, between 0 and 1023, by the PIC program, are described as follows.

(1) In the PIC program, the reference input is set to the assigned value, e.g. 300, 500 and 800.

(2) The phase delay is adjusted in the program so that the brightness on the desk becomes constant as possible even if the brightness in the room is fluctuated. The precise adjustment rules are explained, with regard to the PICBASIC PRO program using PIC16F88, in the below.

The A/D converted value in PIC 16F88 through the analog input port RA0 can be displayed on the LCD (liquid crystal display). Such circuit diagram and the corresponding PICBASIC PRO program are shown in [2]. This circuit is omitted in Fig.2. The A/D converted value is compared to the reference input, which is the assigned value.

The PICBASIC PRO program list, to control the illumination level on the desk constant as possible, given the reference input, is shown in Fig.3.

```
TRISA.0=1
TRISA.1=1
TRISA.2=1
TRISA.3=1
TRISB.0=0
TRISB.1=0
TRISB.2=0
TRISB.3=0
TRISB.4=1
TRISB.5=0
TRISB.6=0
TRISB.7=0
widthx  var word         ‘ Storage of Input Pulse Width (16 bits up to 65536)
okure   var word
PORTB.0=0
PORTB.1=0
PORTB.2=0
PORTB.3=0
PORTB.4=0
PORTB.5=0
PORTB.6=0
PORTB.7=0
‘
```

```
‘ Define ADCIN parameters
DEFINE ADC_BITS   10                  ‘ Set number of bits in result
DEFINE ADC_CLOCK       3              ‘ Set clock source (3=rc)
DEFINE ADC_SAMPLEUS  50   ‘ Set sampling time in micro seconds
           adval var word
     moku var word
        vin var word
        moku=500                   ‘ Reference input=500
        CMCON  = 7                 ' Analog comparators off
        ADCON1 = 0                 ' PortA is analog
        ADCON1 = %10000000
         B1      var     word
         B0      var     word
         okure=500
         ADCIN 0 , adval
         pauseus 100
loop1:
        PORTB.5=0
        ADCIN 0 , adval            ' Read channel 0 to adval
        vin=adval
        if okure < 50 then
        okure=50
        endif
        if okure > 7300 then
        okure=7300
        endif
        if moku > vin then       ' decrease phase pin=8
        okure=okure-10
        else
        okure=okure+10
        endif
        Pulsin PORTB.4, 1, widthx  'Read the width of coming-in pulse and store it in
        If 300 <widthx < 700 Then   'Restrict the width of pulse
        Pauseus okure
        Else
```

```
Goto loop1
Endif
Pulsout PORTB.5, 2 'Output "H" pulse for 20 us (2 x 10us=20us)
Goto loop1
End
```

Fig.3 Constant illumination control program by PICBASIC PRO.

In Fig.3, the reference input is set to the assigned value 500. In the constant illumination control on the desk, the A/D converted value of the voltage, applied to the PIC, is adjusted to make near the reference input. For this purpose, the rules for adjusting the phase delay of the AC voltage in each iteration are described as follows.

(1) If the A/D converted value is greater than the reference input 500, the phase delay is increased by 10 [μs]. By this adjustment, the RMS value of the AC voltage applied to the filament lamp decreases. Then the filament lamp becomes slightly darker.

(2) If the A/D converted value is smaller than the reference input 500, the phase delay is decreased by 10 [μs]. By this adjustment, the RMS value of the AC voltage applied to the filament lamp increases. Then the filament lamp becomes slightly brighter.

Table 1, corresponding to the reference input, shows the illumination level [lx] on the desk, measured by the illumination level meter, and the analog voltage, applied to PIC16F88, which is A/D converted in the PIC. Here, the voltage is measured by the digital multimeter.

Table 1 Illumination level and the voltage applied to the PIC corresponding to the reference input.

Reference input	Illumination level [lx]	Voltage applied to PIC[V]
300	193	1.6 V
500	269	2.9 V
800	448	3.8 V

Since the phase delay is varied according to the adjustment rules in the above, as the reference input increases, the illumination level and the voltage applied to the PIC increase. As a result, the A/D converted value approaches the reference input in each iteration of the adjustment.

Fig.4 shows the phase delay waveform of the AC voltage to the reference input level 500 when the interior light is on during the experiment. Conversely, Fig.5 shows the phase delay waveform of the AC voltage to the reference input level 500 when the interior light is off during the experiment. In Fig.4, the RMS value of the AC Voltage is 82.4 [V]. In Fig.5, the RMS value of the AC voltage is 86.7 [V]. Since the interior light is off in Fig.5, for the illumination level on the desk to be constant, the RMS value in Fig.5 is larger than that in Fig.4. Here, the actual RMS value of the AC voltage is calculated by multiplying the RMS value displayed on the digital oscilloscope by 10.

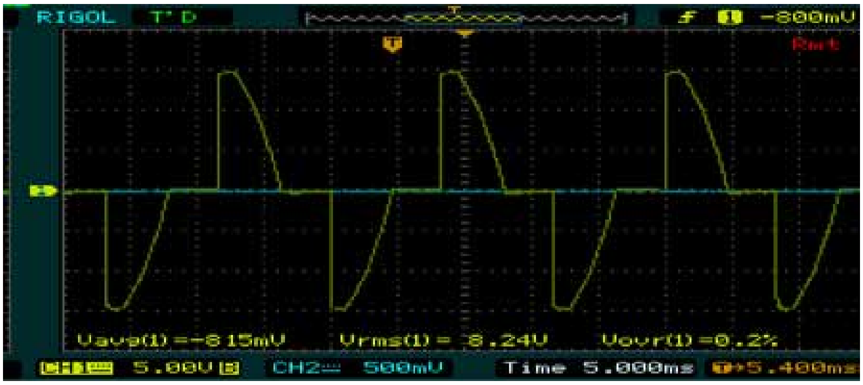

Fig.4 Phase delay waveform of AC voltage to the reference input level 500 when the interior light is on during the experiment.

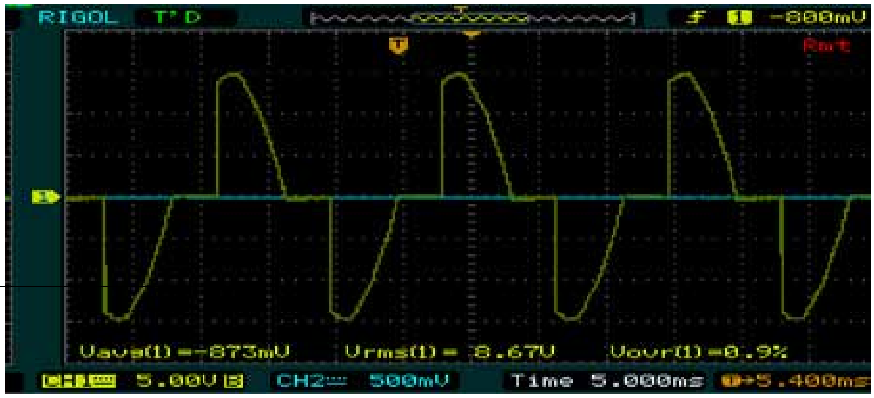

Fig.5 Phase delay waveform of AC voltage to the reference input level 500 when the interior light is off during the experiment.

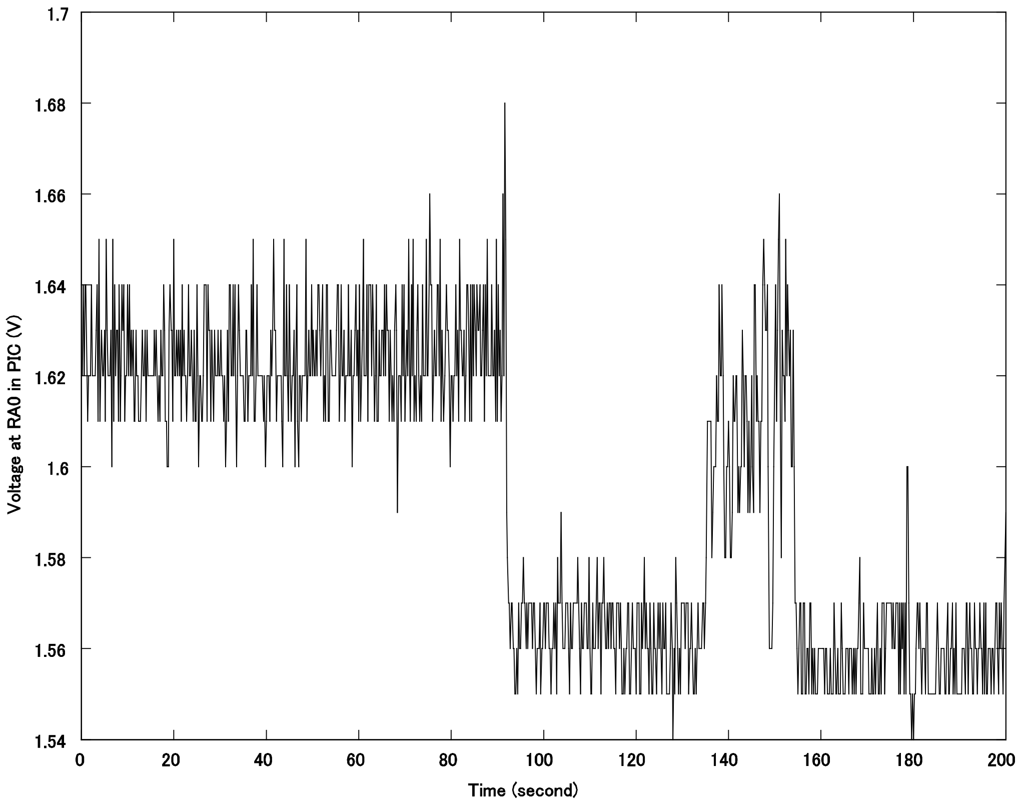

Fig.6 Voltage applied to the PIC vs. time [s].

Fig.6, for the reference input 300, illustrates the voltage applied to the terminal RA0 of the PIC16F88 vs. time [s]. The room light is turned off, at the beginning, then after almost 90 [s], the room light is turned on. The maximum value of the voltage is 1.68 [V] and the minimum value of the voltage is 1.54 [V]. During 200 [s] in Fig.6, the variation of the voltage applied to the PIC is 0.14 [V].

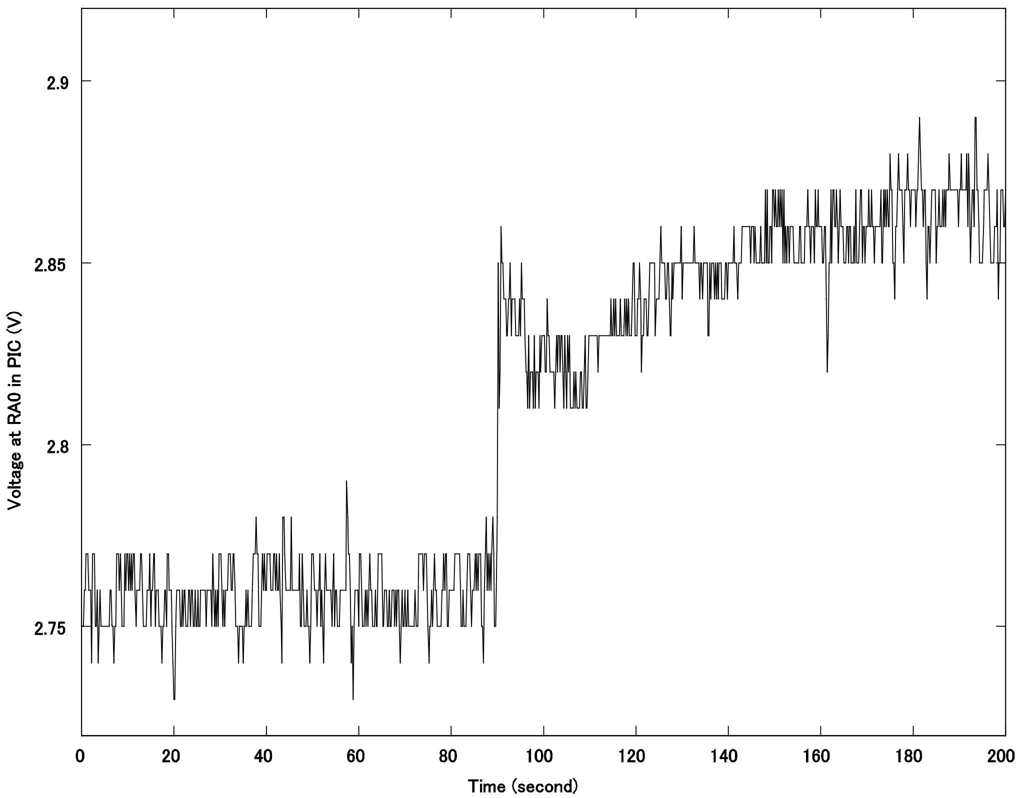

Fig.7 Voltage applied to the PIC vs. time [s].

Fig.7, for the reference input 500, illustrates the voltage applied to the terminal RA0 of the PIC16F88 vs. time [s]. The room light is turned off, at the beginning, then after almost 90 [s], the room light is turned on. The maximum value of the voltage is 2.88 [V] and the minimum value of the voltage is 2.75 [V]. During 200 [s] in Fig.7, the variation of the voltage applied to the PIC is 0.13 [V].

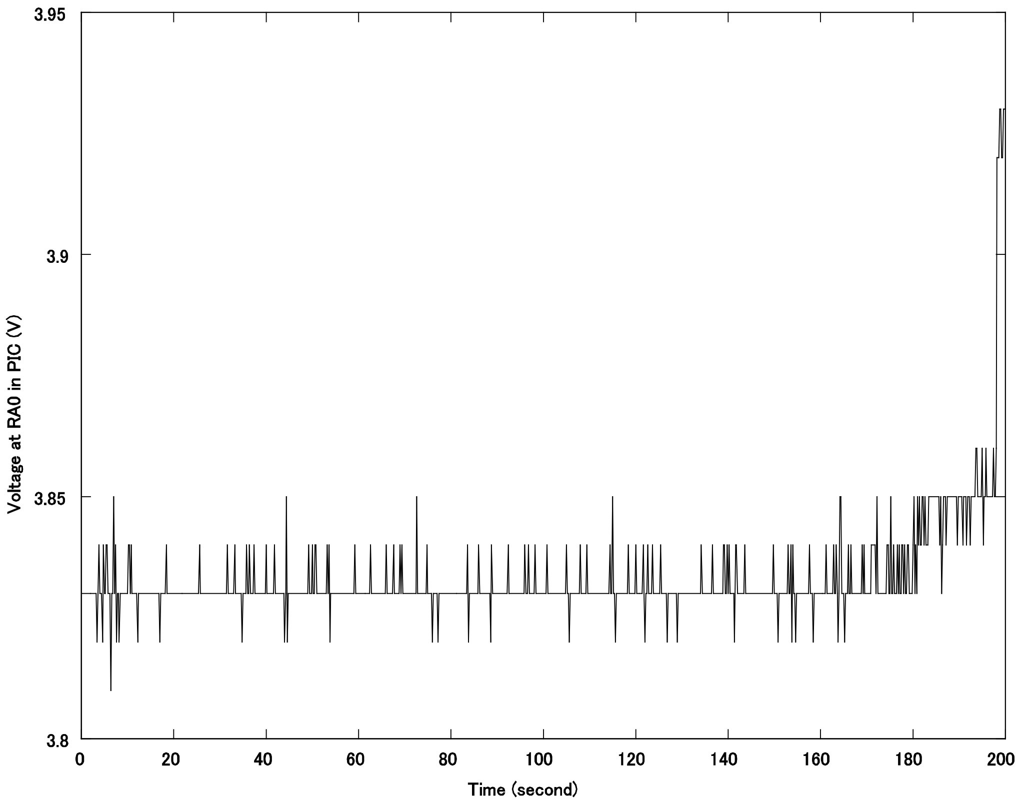

Fig.8 Voltage applied to the PIC vs. time [s].

Fig.8, for the reference input 800, illustrates the voltage applied to the terminal RA0 of the PIC16F88 vs. time [s]. The room light is turned off, at the beginning, then after almost 90 [s], the room light is turned on. The maximum value of the voltage is 3.9 [V] and the minimum value of the voltage is 3.83 [V]. During 200 [s] in Fig.8, the variation of the voltage applied to the PIC is 0.07 [V].

From Figs.6-8, the main results are summarized as follows.

(1) In the case of the reference inputs 300, 500 and 800, the variations of the voltage applied to the PIC16F88 are 0.13, 0.14 and 0.07 [V]. Since these variation voltages are small, even if the room light is turned on from being turned off, these variations might be negligible, in the constant illumination control.

(2) For the reference value 300, the voltage of the terminal RA0 is 1.6 [V]. For the reference value 500, the voltage of the terminal RA0 is 2.9 [V]. For the reference value 800, the voltage of the terminal RA0 is 3.8 [V]. From this result, as the reference input increases, the voltage applied to the PIC16F88 increases.

4. Conclusions

In this paper, the constant illumination control of the filament lamp on the desk is studied by tuning the phase delay of the AC voltage. In the adjustment of the phase delay, the rules are programmed with the PICBASIC PRO for the microcontroller PIC.

In the study of control engineering, for the high school and university students, the understanding of the circuit diagram and the programming concerned with the microcotroller PIC, etc. are required. Particularly, the block diagram of Fig.1, regarding to the constant illumination control of the filament lamp, might help for the students to understand the concept of the feedback control.

References

[1] Electronic work 31, Control of Triac by PIC, -PIC Controlled Dimmer, PICBasic Pro-: http://homepage3.nifty.com/kanasho/eproj31.htm (in Japanese)

[2] Cornerstone Robotics: http://www.cornerstonerobotics.org/picbasic.php