DEVICE FOR POSITION ESTIMATION OF SURFACE MOVING VEHICLE

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Abstract:

Ultrasonic range finder works by transmitting a short pulse of sound at a frequency inaudible to the ear ultrasonic sound or ultrasound. Afterwards the microcontroller listens for an echo. The time from transmission to echo reception lets you calculate the distance from the object. The project uses 5 standard transistors to receive and transmit the ultrasound and a comparator to set the threshold echo detection level - so there are no special components other than the microcontroller. The ultrasonic transducers are standard 40kHz types. You can get ultrasonic transducers optimized for 25kHz, 32kHz, 40kHz or wide bandwidth transducers. This project uses a 40kHz transducer but it will still work with the others if you make simple changes to the software (where it generates the 40kz signal). The receiver and generator circuits will work as they are. The 40kz signal is easily generated by the microcontroller but detection requires a

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sensitive amplifier. The maximum distance is limited by the sensitivity, gain and noise performance of the receive amplifier and also the transmit power and duration of transmission.

Index Terms: Transmission, Sensitivity, Ultrasound, Transducer, Gain

I. INTRODUCTION

Embedded systems are electronic devices that incorporate microprocessors with in their implementations. The main purposes of the microprocessors are to simplify the system design and provide flexibility. Having a microprocessor in the device helps in removing the bugs, making modifications or adding new features are only matter of rewriting the software that controls the device. Or in other words embedded computer systems are electronic systems that include a microcomputer to perform a specific dedicated application. The computer is hidden inside these products. Embedded systems are ubiquitous. Every week millions of tiny computer chips come pouring out of factories finding their way into our everyday products.

Embedded systems are self-contained programs that are embedded within a piece of hardware. Whereas a regular computer has many different applications and software that can be applied to various tasks, embedded systems are usually set to a specific task that cannot be altered without physically manipulating the circuitry. Another way to think of an embedded system is as a computer system that is created with optimal efficiency, thereby allowing it to complete specific as quickly as possible. Embedded systems designers usually have a significant grasp of hardware technologies. They use specific programming languages and software to develop embedded systems and manipulate the equipment. When searching online, companies offer embedded systems development kits and other embedded systems tools for use by engineers and businesses. Embedded systems technologies are usually fairly expensive due to the necessary development time and built in efficiencies, but they are also highly valued in specific industries. Smaller businesses may wish to hire a consultant to determine what sort of embedded system will add value to their organization.

CHARACTERISTICS: Two major areas of differences are cost and power consumption. Since many embedded systems are produced in tens of thousands to millions of units range, reducing cost is a major concern. Embedded systems often use a (relatively) slow processor and small memory size to minimize cost.The slowness is not just clock speed. The whole architecture of computer is often intentionally simplified to lower costs. For example, embedded systems often use peripherals controlled by synchronous serial interfaces, which are ten to hundreds of times slower than comparable peripherals used in PCs. Programs on an embedded system often run with real-time constraints with limited hardware resources: often there is no disk drive, operating system, keyboard or screen. A flash drive may replace rotating media, and a small keypad and LCD screen may be used instead of a PC's keyboard and screen.

Firmware is the name for software that is embedded in hardware devices, eg: in one or more ROM/Flash memory IC chips. Embedded systems are routinely expected to maintain 100% reliability while running continuously for long periods, sometimes measured in years. Firmware is usually developed and tested too much harsher requirements than is general-purpose software, which can usually be easily restarted if a problem occurs.

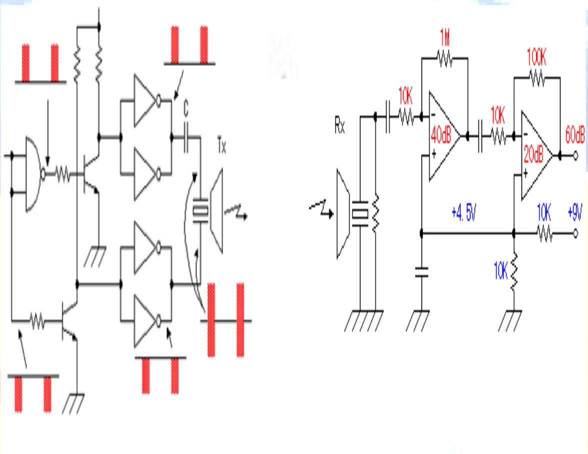
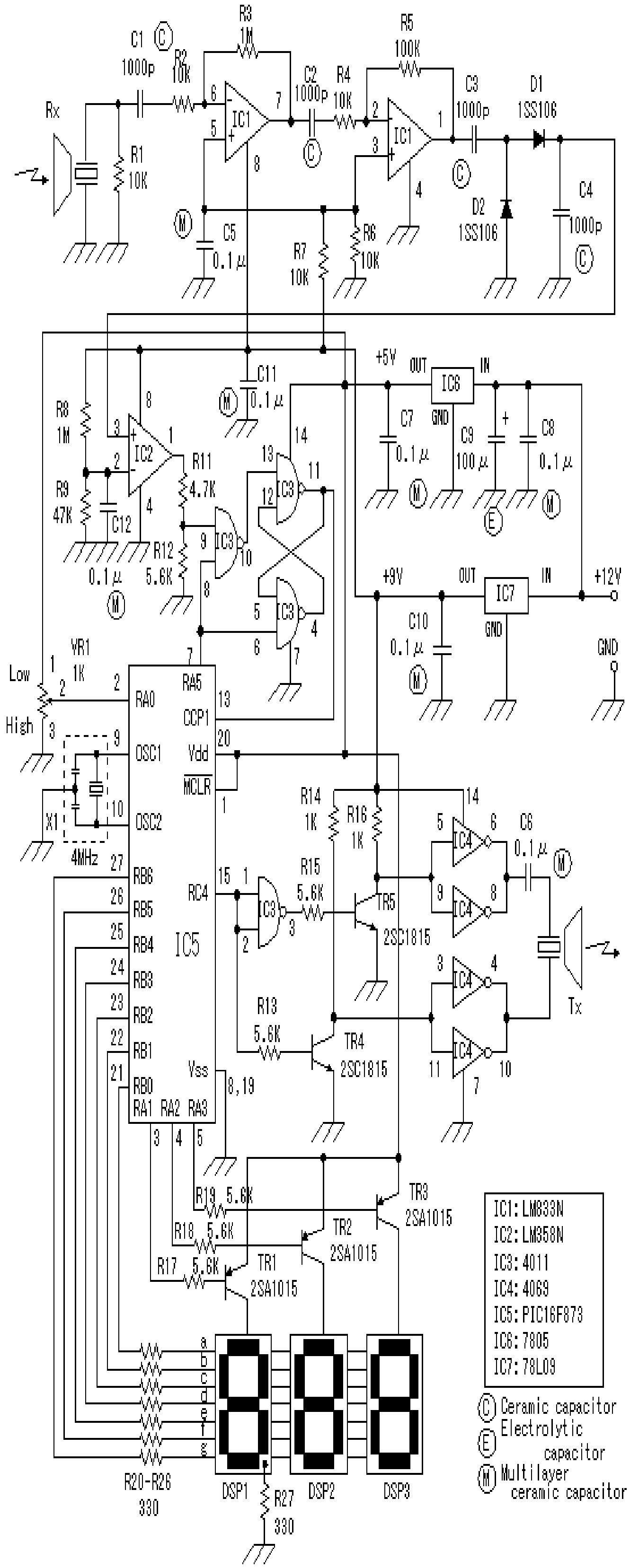
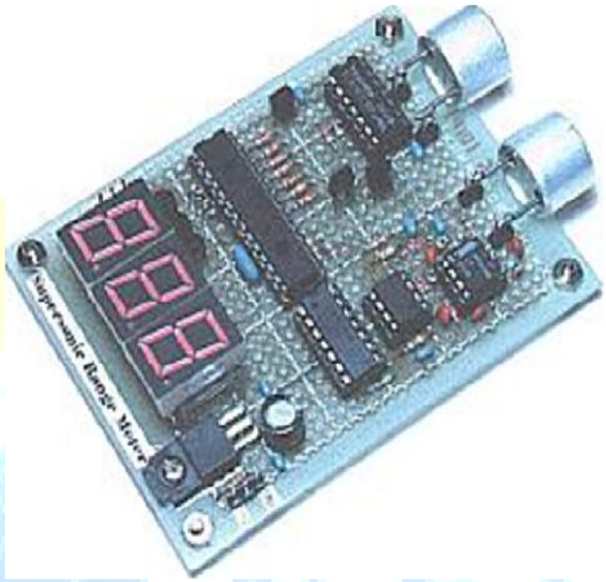


Fig1. TRANSMITTER RECEIVER CIRCUIT



Rx
Tx
C1 1000p
R1 10K
R2 10K
R3 1M
C2 1000p
R4 10K
R5 100K
C3 1000p
D1 1SS106
D2 1SS106
C4 1000p
C5 0.1μ
R6 10K
R7 10K
IC1
IC2
IC3
IC4
IC5
IC6
IC7
R8 1M
R9 47K
C12 0.1μ
R11 4.7K
R12 5.6K
C11 0.1μ
+5V
C7 0.1μ
C9 100μ
C8 0.1μ
+9V
C10 0.1μ
+12V
GND
Low
High
VR1 1K
X1
4MHz
RA0
RA5
CCP1
OSC1
Vdd
MCLR
OSC2
RB6
RB5
RB4
RB3
RB2
RB1
RB0
RC4
Vss
RA1 RA2 RA3
R14 1K
R16 1K
R15 5.6K
TR5 2SC1815
C6 0.1μ
R13 5.6K
TR4 2SC1815
R19 5.6K
TR3 2SA1015
R18 5.6K
TR2 2SA1015
R17 5.6K
TR1 2SA1015
R20-R26 330
DSP1
DSP2
DSP3
R27 330
IC1: LM833N
IC2: LM358N
IC3: 4011
IC4: 4069
IC5: PIC16F873
IC6: 7805
IC7: 78L09
Ⓒ Ceramic capacitor
Ⓔ Electrolytic capacitor
Ⓜ Multilayer ceramic capacitor

Fig2. CIRCUIT DIAGRAM



1. **CIRCUIT DESCRIPTION**

In order to fulfill this application there are few steps that has been performed i.e.

1) Designing the power supply for the entire circuitry.
2) Selection of microcontroller that suits our application.
3) Selection of distance sensor.

Complete studies of all the above points are useful to develop this project.

A). POWER SUPPLY SECTION:

In a typical linear power supply, AC line voltage is first down-converted to a smaller peak voltage using a transformer which is then rectified using a full wave bridge rectifier circuit. A capacitor filter is then used to smoothen the obtained sinusoidal signal. The residual periodic variation or ripple in this filtered signal is eliminated using an active regulator.

To obtain a DC power supply with both positive and negative output voltages, a center-tapped transformer is used, where a third wire is attached to the middle of the secondary winding and it is taken as the common ground point. Then voltages from the opposite ends of the winding will be positive or negative with respect to this point. The voltage of +5V and +9V are made with +12V power supply using the 3 terminal regulator.+9V are used for the transmitter and the receiver.100-mA type is used because few needed electric currents. In other circuit, +5V is used. +5V voltage is used for the lighting-up of LEDs, because they are controlled by PIC. The about 10-mA electric current per segment flows through the LED. So, it becomes about 80 mA when all segments(eight) light up. Because few electric currents of the other IC occur, I think that you can use a 100-mA type, too. I used a 1A type for the safety.

B). Selection of Microcontroller

As we know that there are so many types of microcontroller families that are available in the market. Those are

1) 8051 Family
2) AVR microcontroller Family
3) PIC microcontroller Family
4) ARM Family

Basic 8051 family is not enough for our application. Hence we are concentrating on higher end controller family.In order to fulfill our application I have selected PIC16F873.

C). DIFFERENT CIRCUITS

Signal amplification circuit: The ultrasonic signal which was received with the reception sensor is amplified by 1000 times(60dB) of voltage with the operational amplifier with two stages. It is 100 times at the first stage (40dB) and 10 times (20dB) at the next stage. As for the dB (decibel), refer to "Logarithm Table". Generally, the positive and the negative power supply are used for the operational amplifier. The circuit this time works with the single power supply of +9 V. Therefore, for the positive input of the operational amplifiers, the half of the power supply voltage is applied as the bias voltage. Then the alternating current signal can be amplified on 4.5V central voltage. When using the operational amplifier with the negative feedback, the voltage of the positive input terminal and the voltage of the negative input terminal become equal approximately. This is called virtual grounding. So, by this bias voltage, the side of the positive and the side of the negative of the alternating current signal can be equally amplified. When not using this bias voltage, the distortion causes the alternating current signal. This technique is often used when using the operational amplifier which needs two kinds of powers in the single power. As for the operation of the operational amplifier, refer to "Operation explanation of the triangular wave oscillator".

Detection circuit: The detection is done to detect the received ultrasonic signal. This is the half-wave rectification circuit with Shottky barrier diodes. The DC voltage according to the level of the detection signal is output to the capacitor behind the diode. The Shottky barrier diodes are used because the high frequency characteristic is good. As for the Shottky barrier diode, refer to "Diodes".

Signal detector: This circuit is the circuit which detects the ultrasonic which returned from the measurement object. The output of the detection circuit is detected using the comparator. At the circuit this time, the operational amplifier of the single power supply is used instead of the comparator. The operational amplifier amplifies and outputs the difference between the positive input and the negative input. In case of the operational amplifier which doesn't have the negative feedback, the output becomes the saturation state by a little input voltage. Generally, the operational amplifier has over 10000 times of mu factors. So, when the positive input becomes higher a little than the negative input, the difference is tens of thousands of times amplified and the output becomes the same as the power supply almost.(It is the saturation state) Oppositely, when the positive input becomes lower a little than the negative input, the difference is tens of thousands of times amplified and the output becomes 0 V almost.(It is in the OFF condition) This operation is the same as the operation of the comparator. However, because the inner circuit of the comparator is different from the operational amplifier, the comparator can not be used as the operational-amplifier.

At the circuit this time, the output of the detection circuit is connected with the positive input of the signal detector and the voltage of the negative input is made constant.

$$\mathbf{Vrf} = (\text{Rb x Vcc})/(\text{Ra} + \text{Rb})$$

$$= (47^{\text{K-ohm}} \text{ x } 9^{\text{V}})/(1^{\text{M-ohm}} + 47^{\text{K-ohm}})$$

$$= \mathbf{0.4V}$$

So, when the rectified ultrasonic signal becomes more than 0.4 V, the output of the signal detector becomes the H level (Approximately9V). This output is lowered with the resistor to make fit with the input of signal holding circuit (TTL:0V to 5V).

Signal holding circuit: This is the holding circuit of detected signal. SR (Set and Reset) flip-flop is used. For the details of SR-FF, refer to "The operation explanation of the D-type flip-flop".

The detector is made to be not operate in the constant time(About 1.5 milliseconds) after sending out a transmission pulse to prevent from the wrong detection which is due to the influence of the transmission pulse. This operation is controlled with the software of PIC. When using the capture feature of PIC, this circuit isn't indispensable. Capture operation is done by the change of the capture input in the once. The reason why I am using this circuit is to confirm signal detection operation within the reflected signal detection time(About 65 milliseconds).

When sending out next ultrasonic pulse, the output of this circuit is checked. And when the output is L level, an error display is done because the reflected signal could not be detected.

Transmitter circuit: The inverter is used for the drive of the ultrasonic sensor. The two inverters are connected in parallel because of the transmission electric power increase.

The phase with the voltage to apply to the positive terminal and the negative terminal of the sensor has been 180 degrees shifted. Because it is cutting the direct current with the capacitor, about twice of voltage of the inverter output are appied to the sensor. The power supply voltage of this drive circuit is +9V. It is converting voltage with the transistor to make control at the operating voltage of PIC(+5V). Because C-MOS inverters are used, it is possible to do ON/OFF at high speed comparatively.

LED display circuit: Three 7 segment LEDs are used for 3-digit display. As for the lighting-up of the LED, 1 digit is displayed in the order with the software of PIC. At the circuit this time, I make light up it when the terminal of PIC is L level. So, ANODE COMMON type is used as the LED. The anode common type is the type which the side of the positive(Anode) of the LED is connected inside. It lights up when grounding(L level) a cathode in the segment to want to make light up.

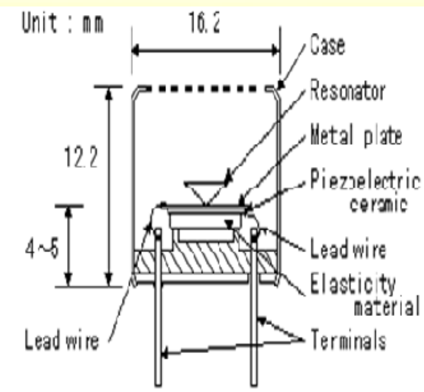
As the 7 segment LED, the others have a cathode common type. When you buy them, the specification of the type should be checked.

Resonator: I used 4-MHz resonator. I used 4 MHz in the relation of the timer in the count time. When using 4-MHz clock, it is 1 microsecond per count for the counter count up time. Timer1 to use for capture is a maximum of 65535 counts(16 bits). So, a maximum of 65.535 milliseconds count is made. The propagation speed of the sound in air is 343 m/second in case of 20°C. In the time which goes and returns in the 10-m distance, it is $20^{m}/343^{m/sec}$ = 0.0583 seconds (58.3 milliseconds). As the range meter this time, it is an exactly good value.

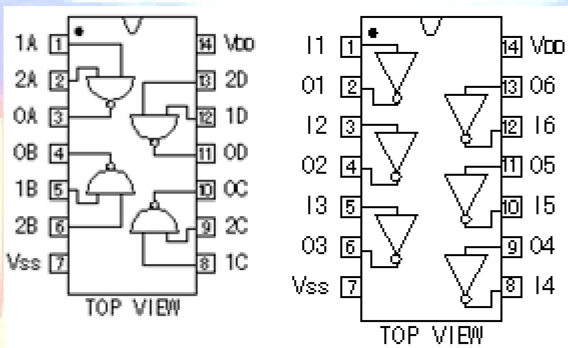
Ultrasonic sensor: I used the ultrasonic sensor for the air which is made by the Nippon Ceramic company. This sensor separates into the two kinds for the transmitter and the receiver. For the transmitter, it is T40-16 and for the receiver, it is R40-16. T shows the thing for the transmitter and R shows the thing for the receiver. 40 shows the resonant frequency of the ultrasonic (40kHz) 16 shows the diameter of the sensor.

Because the one of the terminal is connected with the case, when grounding, the terminal on the side of the case should be used. The brief specification of the ultrasonic sensor is shown below.

Item		Spec
Frequency(KHz)		40
Sound pressure level (Db)		115 <
Sensitivity (dB)		-64 <
Size (mm)	Diameter	16.2
	Height	12.2
	Interval	10.0



NAND GATES: As for this IC, the four NAND circuits of 2 inputs are accommodated. It is used to compose SR-FF and to hold the detection condition of the ultrasonic. I used 4011B.



NAND GATE & INVERTERS

Inverters: This IC is the IC of the CMOS which the six inverters are housed in. At the transmitter circuit, it is used for the drive circuit of the ultrasonic sensor. I have used 4069UB.

7 segment LED: I use SL-1199 made by Sanyo Electric Co in Japan. The size is 18.8mm(H) x 12mm(W) x 8mm(D).

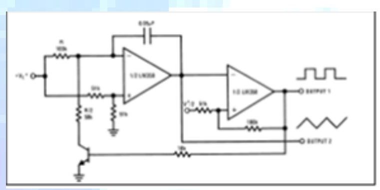
IC socket: PIC16F873 is 28 pins of the slim type. When you can not get a slim-type 28 pin socket, two sockets of 14 pins can be used. In the circuit this time, I used two 14 pin sockets.

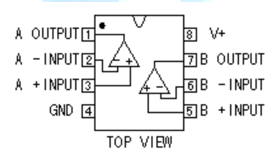
LM 358: Low Power Dual Operational Amplifier

General Description:

The LM158 series consists of two independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifiers, dc gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM158 series can be directly operated off of the standard +5V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional ±15V power supplies. The LM358 and LM2904 are available in a chip sized package (8-Bump micro SMD) using National’s micro SMD package technology.





This IC is the single power supply-type operational amplifier. This IC is used for the detection of the received signal.

2. **MICROCONTROLLER PIC16F873:**

Features:

1. Compatible with MCS®-51Products
2. 2K Bytes of Reprogrammable Flash Memory
   i. -Endurance: 10,000 Write/Erase Cycles
3. 2.7V to 6V Operating Range
4. Fully Static Operation: 0 Hz to 24 MHz
5. Two-level Program Memory Lock
6. 128 x 8-bit Internal RAM
7. 15 Programmable I/O Lines
8. Two 16-bit Timer/Counters

9. Six Interrupt Sources
10. Programmable Serial UART Channel
11. Direct LED Drive Outputs
a. On-chip Analog Comparator
12. Low-power Idle and Power-down Modes
a. Green (Pb / Halide-free) Packaging Option

RESULT & PERFORMANCE TEST

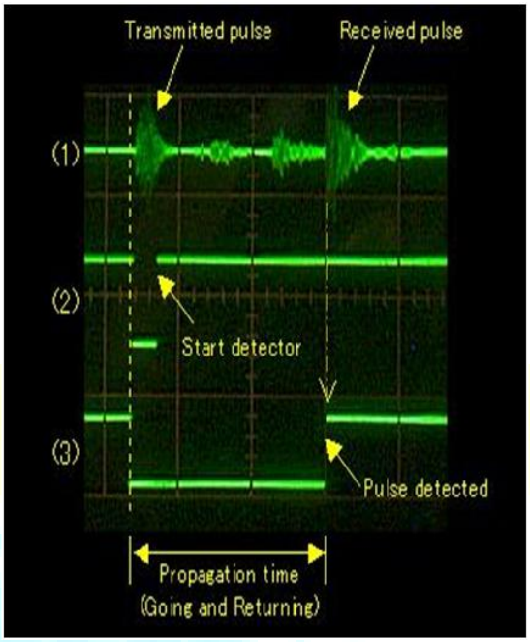
a). Detection operation confirmation: I confirmed the performance of the Ultrasonic Range Meter.

The photograph on the above page is the one to have observed the signal when measuring a 2.36m distance. Observation points are shown below.

(1) is 1st pin of IC1 (It is a signal after the amplification with the operational amplifier.)

(2) is 8th pin of IC3 (It is a detection holding circuit gate signal by PIC.)

(3) is 11th pin of IC3 (It is an output signal of the detection holding circuit.).When (2) is an L level, the detector stops. You can find that a malfunction by the transmission pulse is prevented. The prevention time of this circuit is about 1.5 milliseconds. There is possibility to malfunction when short any more.Some feeble reflection signals are received until it detects a reception pulse. Because the threshold voltage of the signal detector of IC2 is working effectively, those feeble signals are not detected.The signal of (3) changes to H level from L level when detecting a reception pulse. This signal is detected by the capture feature of PIC and the propagation time of the ultrasonic is measured.



b). Measuring range: The ultrasonic transmission time of this Meter is 0.5 milliseconds. So, it isn't possible to do long-range measurement.

Most short distance

:

29 cm This distance is decided by the time to prevent from an influence by the transmission pulse. When measuring a long distance, the sending-out time of the transmission pulse must be expanded. In this case, it is necessary to expand in the prevention time, too, and the shortest measurement distance becomes long.

Most long distance

:

3.6 Cm This distance is decided by the length of the transmission pulse. The ultrasonic energy becomes big when the transmission time is long and the long-range measurement is possible. However, as the explaining at the most short distance, the shortest measurement distance becomes long.

When wanting to do long-range measurement, it is possible to change software even if it doesn't change hardware of it. In this case, I think that it is better when putting a sound horn to concentrate a ultrasonic.

c). Temperature calibration feature: I confirmed a display in distance measurement of 1 m.

Dial condition	Display	Temperature for displaying 1.00
Full turn to right	0.98	**8.6°C**
Full turn to left	1.11	**83.0°C**

The temperature to display 1.00 is a calculation value. At this equipment, it isn't possible to do an adjustment with detailed calibration value. It is 8 steps. So, it is a reference value.

To change a calibration range, the change of the software processing by the value which A/D converted is needed.When doing this confirmation, I found the opposite connection of the calibration resistor. The connection in the center is right but the connection in the both edges is opposite. I intended to turn to the right when the ambient temperature was high. However, the actual operation is opposite. Because it is not in the problem in case of practical use, I don't change it. A schematic and a pattern drawing are corrected.

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