Ultrasonic Ranging System Manual

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600 SERIES OEM KIT

7000 SERIES OEM KIT

9000 SERIES OEM KIT

ULTRASONIC RANGING SYSTEM MANUAL

Description, operation and user information for conducting tests and experiments with SensComp's Ultrasonic Ranging System Components

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A. Introduction

Your OEM Kit contains the parts to assemble two complete Ultrasonic Ranging Driving Systems. The kit contains the following components needed for the driving system:

- An acoustical ultrasonic transducer (Figure 1-1)
- Either a 6500 or a 9000 Series Ranging Module circuit board (Figure 1-2).

We suggest that you check the components in your OEM Kit to be sure that your kit is complete and also familiarize yourself with them. You can find the OEM Kit list of components in Appendix A.

Together these components become the ultrasonic sound source and returning echo receiver (with supporting drive electronics) that you can use to construct a system to measure distance or to detect the presence of objects. The measuring or detection range will vary depending on the kit that you have obtained.

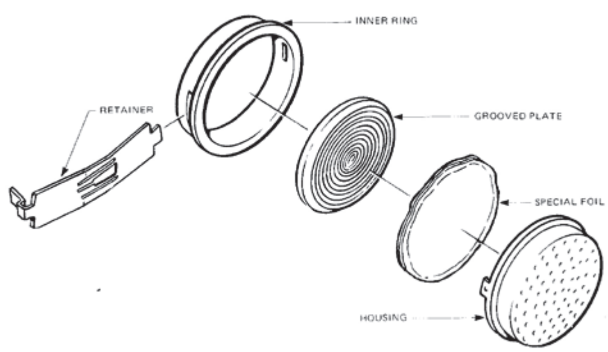


FIGURE 1-1 SERIES 600 TRANSDUCER

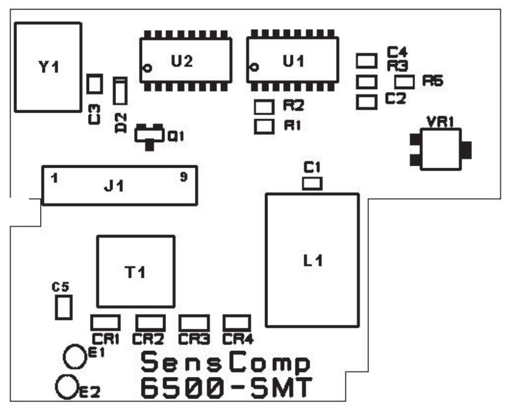


FIGURE 1-2 RANGING MODULE

The range for the OEM kit will depend on the model you have:

- 6500 OEM Kits – approximately 0.5 feet to 35 feet.
- 9000 OEM Kits – approximately 1 foot to 18 feet.

B. Operation

1. Ultrasonic Transducer

The principal component in this system is the transducer (Figure 1.1), which acts as both loudspeaker and microphone. The transducer is designed to transmit the outgoing signal (like a loudspeaker) and then switch to become a microphone to receive the reflected signal (the echo).

2. Ranging Module

The Ranging Module controls the operation of the ultrasonic transducer. Every time you switch the INIT input signal from a Logic 0 to a Logic 1, a burst of sound is transmitted from the transducer. This sound wave travels toward a target, and then is reflected back to the same transducer, which is now in a receive mode. When the Ranging Module receives the reflected returning echo signal, it then generates an ECHO output (the ECHO output changes from a Logic 0 to a Logic 1). The elapsed time between initial transmission (INIT) and echo detection (ECHO) can then be converted to distance in your external circuits (user hardware) by calculating how long it took for the speed of sound to travel to the target and back.. For a transmitted pulse to leave the transducer, strike a target two feet away, and return to the transducer, requires an average time delay of 3.55 milliseconds.

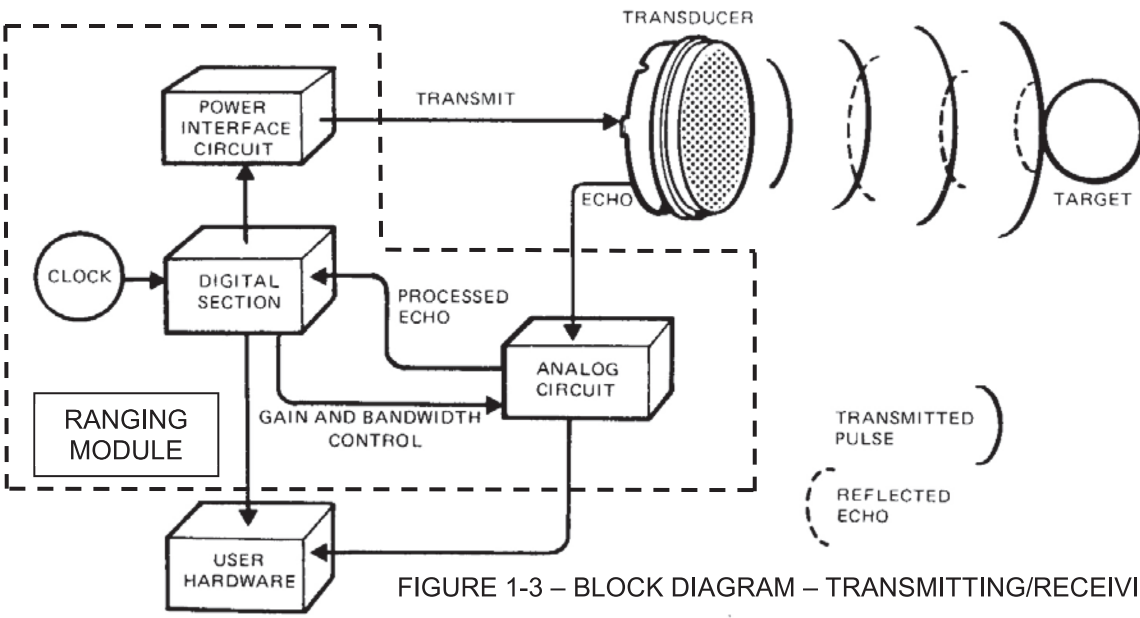
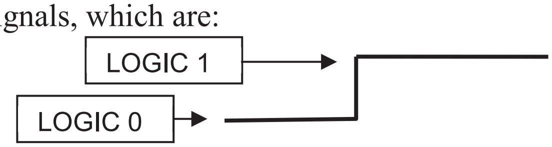


FIGURE 1-3 – BLOCK DIAGRAM – TRANSMITTING/RECEIVING

C. TTL Logic Levels

The Ranging Module inputs and outputs are TTL compatible signals. This manual will use the terms Logic 0 and Logic 1 to describe the state of these signals, which are:

TTL Logic 1 = +4 volts DC
TTL Logic 0 = 0 volts DC



D. Normal Operation

Figure 1-4 shows the timing between INIT and ECHO during normal operation when a target is detected,

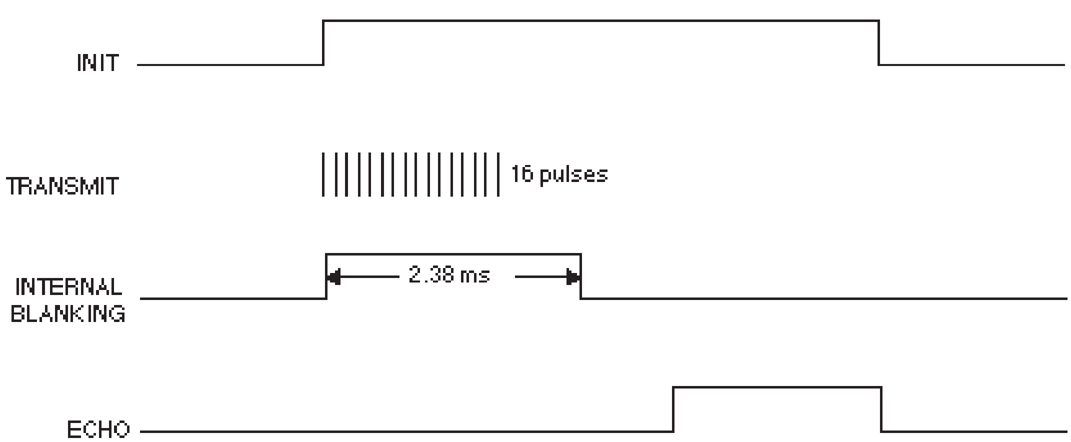


FIGURE 1-4 –INIT/ECHO TIMING

Signal INIT initializes the cycle, and ECHO reports that a reflected sound wave has been received.

- The Ranging Module transmits 16 ultrasonic pulses out to the transducer.
- The Ranging Module has internal blanking for 2.38 ms before it internally switches to the receiving mode (to compensate for transducer ringing during transmit).
- The transducer receives the returning echo into the Ranging Module, generating ECHO.

Using the INIT input and the ECHO output only, without using other input control signals, the distances you should obtain are:

- 6500 Ranging Module – distances from 0.4 to 10.7 meters (15.75 inches to 35 feet)
- 9000 Ranging Module – distance from 0.4 to 5.4 meters (15.75 inches to 18 feet)

E. Calculating Distance or Proximity Detection.

The received ECHO output (Figure 1-4) indicates that the reflected transmitted signal has been received. By measuring the time between the rising edge of INIT and the rising edge of ECHO, you can calculate the distance between the transducer and the target(s):

$$D = \frac{\upsilon \cdot t}{2}$$

D = Distance
υ = Speed of sound
t = INIT time to ECHO time

Since the speed of sound is affected by temperature, you should take this into account during your calculations. A good approximation for the change to the speed of sound as temperature changes is:

$$\upsilon = 331.4 \text{ meters/second} + (0.6)(\text{Temperature in Celsius})$$

A. Introduction

Information provided in this chapter will help you install and operate the components of your OEM Kit.

B. Equipment Needed

- **Your OEM Kit**
- **External Power Supply**
- **External Clock for Starting a Write/Read Cycle**
- **External Measuring Device for measuring the time for the Write/Read Cycle**

C. External Power Supply Required

Supply Voltage: 4.5 – 6.8 Volts DC (5 VDC nominal) at 2-2.5 amperes

Ranging Module Connections:
Pin 9 to +5 VDC (Positive power supply terminal
Pin 1 to Ground (Negative power supply terminal)

Your 6500 (or 9000) Ranging Module requires an external power supply capable of providing a regulated 5.0 volts DC at a current up to 2 amperes. This supply should be isolated and well regulated.

The Ranging Module both transmits and receives ultrasonic signals. Normally, the Ranging Module will require approximately 100 ma of current from your power supply. However, during the short 0.5-1.0 millisecond transmit burst cycle, the power supply must provide 2 to 2.5 amperes of current. This instantaneous high current can be supplied from your power supply, or you can use a capacitor of sufficient capacitance to supply this current. We suggest using an electrolytic (or tantalum) capacitor of approximately 500-1000µf with a voltage rated of 16 VDC or higher (Caution: observe polarity of the capacitor when installing).

D. OEM Kit Connections

CAUTION:

Be certain that the transducer is properly connected to the ultrasonic circuit board before applying power. Applying power to the board with the transducer disconnected may damage the board.

1. 6500 Ranging Module to Transducer (Electrostatic)

We supply the 6500 Sonar Ranging Module with a 2-conductor ribbon cable for interconnecting the module to either our Series 600 or our Series 7000 Electrostatic Transducers (see Figure 2-1). This cable assembly contains two clips that provide easy connection to the protruding tabs on the transducer. One of the cable conductors will have a white stripe. This is the negative (-) lead and should be connected to the (-) terminal on the transducer. You can order a replacement cable assembly from SensComp (PID# 604789 Cable Assembly) at a nominal charge.

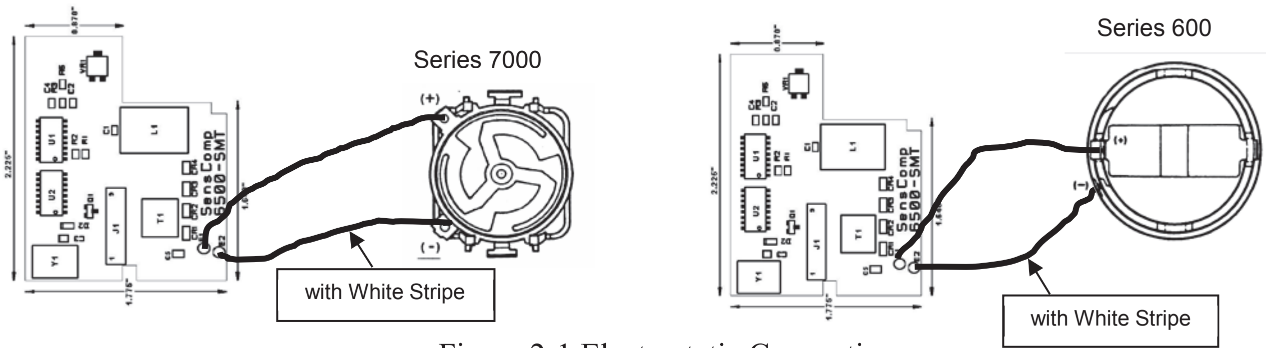


Figure 2-1 Electrostatic Connections

2. 9000 Ranging Module to Transducer (Piezoelectric)

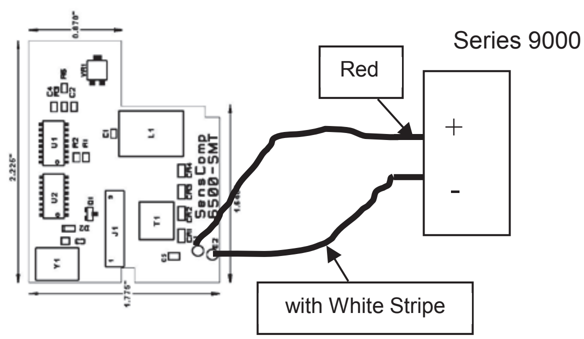


Figure 2-2 9000 Connections

We supply the 9000 Sonar Ranging Module with a 2-conductor ribbon cable for interconnecting the module to our Series 9000 Piezoelectric Transducer. This cable assembly contains two heat-shrink covered connectors that provide easy connection to the protruding pins on the transducer. We have color coded the heat-shrinking on the connectors for polarity. The “Red” connector should connect to the transducer’s “+” terminal, and the “Black” connector to the transducer’s “-” terminal.

3. Ranging Module J1 Connections

The Ranging Module has a 9-pin ribbon cable connector (J1) for connecting the module to an external power supply and other external circuits for operation. Your Kit comes with a mating ribbon cable and an external 9-pin connector attached to the this cable. This external connector can be inserted into an external Printed Circuit Board (PCB) or you can attach wires to this connector for connecting to a power supply and other external circuits.

Ranging Module J1 Connector (only signals marked ** are necessary for basic operation. You do not need to connect to the other pins):

**	J1- 1	GND	Power Supply Ground
	J1- 2	BLNK	Blanking (for multiple echo receiving)
**	J1- 4	INIT	Initialize a Transmit/Receive Cycle
	J1- 6	OSC	Internal 49.4 KHz Oscillator (see Note 3.1)
**	J1- 7	ECHO	Received Echo Detected (see Note 3.1)
	J1- 8	BINH	Inhibit Internal Blanking
**	J1- 9	V+	Power Supply Positive Voltage Input (4.5-6.8 V DC)

Note 3.1: OSC and ECHO outputs are TTL-compatible Open Collector NPN outputs. A 4.7 KΩ resistor connected between each output and +5 VDC is required to observe the output signal.

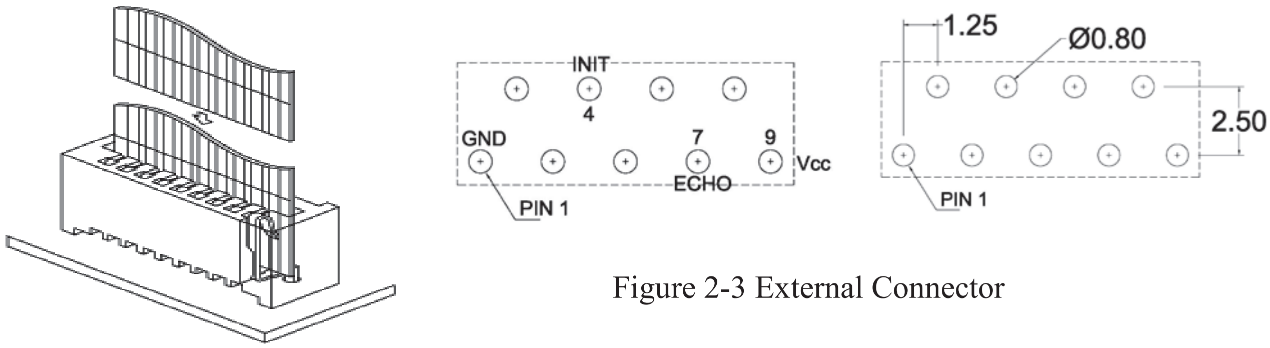


Figure 2-3 External Connector

E. Connecting Inputs and Outputs (Basic Operation)

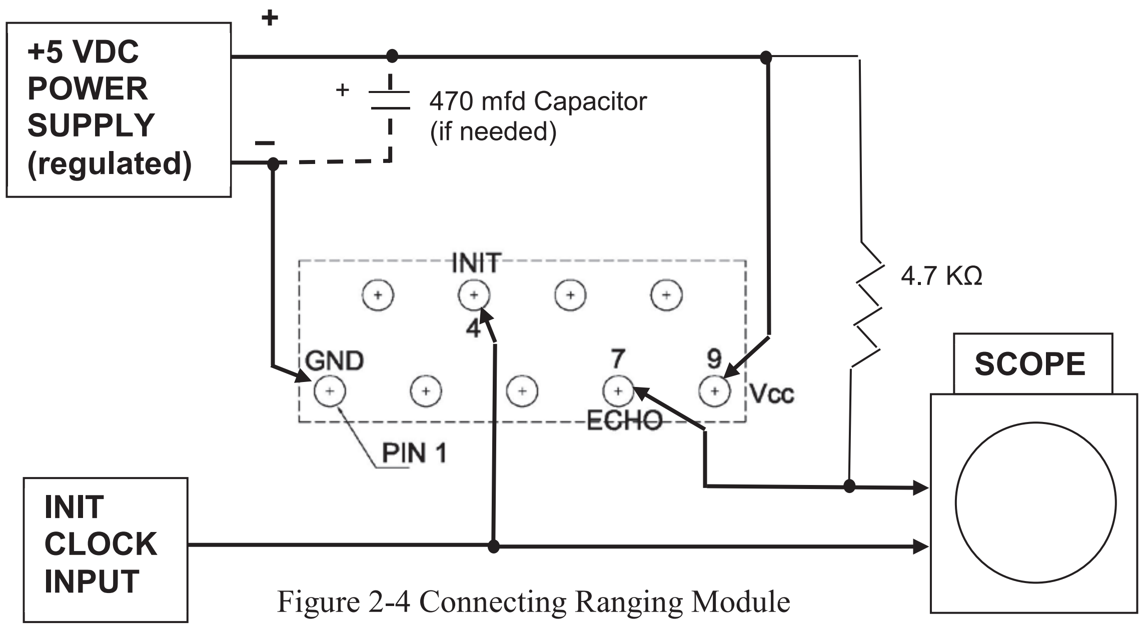


Figure 2-4 Connecting Ranging Module

Other than the transducer, you only need to make four connections to the Ranging Module for obtaining measurements or detecting presence of an object. These 4 connections, shown in Figure 3-4, are:

+5 Volt DC Power Source:

J1- 1	GND	Power Supply Ground
J1- 9	V+	Power Supply Positive Voltage Input (4.5-6.8 V DC)

Input clocking signal (0 to 4 VDC logic level, at a frequency less than 50 Hertz)

J1- 4	INIT	Initialize a Transmit/Receive Cycle

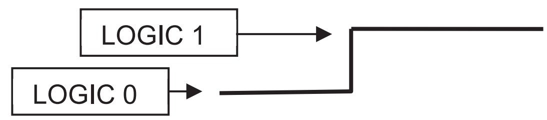
Output target detection return (Echo) – This output MUST have a pull-up resistor to +5 VDC.

J1- 7	ECHO	Received Echo Detected.

F. TTL Logic Levels

The Ranging Module inputs and outputs are TTL compatible signals. This manual will use the terms Logic 0 and Logic 1 to describe the state of these signals, which are:

TTL Logic 1 = +4 volts DC
TTL Logic 0 = 0 volts DC



G. Initialize (INIT) Input Clocking

The INIT input to the Ranging Module requires a clocking source for operation. The clocking repetition rate should be less than 50 Hz. This source can either be a waveform or function generator providing TTL logic level outputs, or any oscillator circuit that provides the appropriate output. Appendix YY provides some suggested circuits that you may wish to use for your clocking source.

CAUTION

The INIT input frequency should never be higher than 100 Hz. Higher frequencies will cause component damage to components on the Ranging Module board.

When first using the OEM Kit Ranging Module, we suggest your repetition rate be at10 Hz (10 times a second) or less. This provides the time needed to capture an echo signal from targets that are a longer distance from the transducer. As you gain more experience, you may wish to adjust this timing to match the distance you are measuring.

H. Making Measurements

The Time of Flight (TOF) for an ultrasonic cycle is the time between a burst of ultrasonic pulses (started by INIT) to travel to a target, reflected back, received by the transducer, and creating a reflected ECHO signal.

When the input INIT signal changes from a Logic 0 to a Logic 1, the Ranging Module performs a write, then read, cycle. The transducer transmits 16 ultrasonic pulses out into the air. When these pulse of sound bounce off a target object, these reflected ultrasound signals are received by the transducer, and the Ranging Module then generates an ECHO return signal. The time between these two signals can then be used to determine the distance to, and/or the presence of, an object (Figure 2-5).

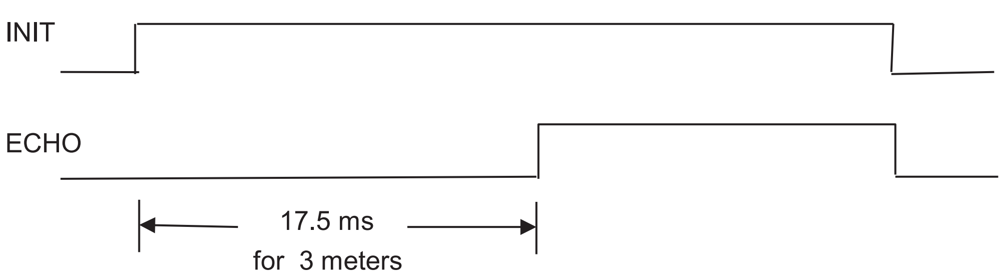


Figure 2-5 – INIT/ECHO Timing

Note: The INIT signal **must** remain at a Logic 1 (HIGH) until after receiving the ECHO signal.

NOTE: The ECHO output **must** have a 4.7 KΩ pull-up resistor between the ECHO pin and +5 VDC, as shown in Figure 2-4.

The time between INIT and ECHO can be easily observed using a dual-channel oscilloscope. If the time base is sufficiently accurate, the oscilloscope can also be used to measure the timing between these two signals:

Oscilloscope Channel 1 – INIT
Oscilloscope Channel 2 – ECHO
Oscilloscope Time Base – 20 milliseconds/division, Channel 1 triggering, rising edge

For more accurate measurements we would suggest a high speed counter that can be turned on by INIT and turned off by ECHO. The resulting count can then be calculated to determine the start-stop time lapse.

The minimum distance you can detect without using other Ranging Module inputs is approximately 0.41 meters (16.1 inches). Measuring to 6 inches requires overriding the Ranging Module's internal damping factor (to compensate for transducer ringing), and is described in chapter 3.

I. Formulas (Basic)

Using the time of flight between INIT and ECHO, you can then calculate the distance between the sensor and the target as follows:

$$\mathbf{D}\text{ (distance)} = \frac{\mathbf{T}\text{ (time: INIT to ECHO)} \;\mathbf{X}\; \upsilon\text{ (speed of sound)}}{\mathbf{2}\text{ (sensor to target and back to sensor)}}$$

A. Introduction

The information in Chapter 2 provided basic connection and operating information for using the OEM Kit components. This chapter will continue with more advance information to help you use the ultrasonic components to their full extent. Bear in mind that **these are only suggestions** to help you get started. There may be other ways to adapt this module to your needs; however, these circuits will allow immediate use of this device for your evaluation.

B. Transducer Connections

The 2-conductor Transducer Cable Assembly is already mounted to the Ranging Module. It contains clips for connecting to the Series 600 or the Series 7000 Electrostatic Transducers, or connector sockets for connecting to the Series 9000 Piezoelectric Transducer. If you wish to use your own cable between the Transducer and the Ranging Module, we suggest you use either twisted pair for short distances or coaxial cable for longer distances. The 6500 OEM Kits contain extra Female Transducer Clips for making your own cables.

- Series 600 or Series 7000 Transducers: Connect the wire marked “E1” on the Ranging Module to the “+” connection of the transducer, and the wire marked “E2” to the “-” connection of the transducer. See Figure 3-1 for the “E1” and “E2” markings of the Ranging Module.

- Series 9000 Transducers: Connect the wire marked “E3” on the Ranging Module to the “+” connection of the transducer, and the wire marked “E2” to the “-” connection of the transducer. See Figure 4-2 for the “E3” and “E2” markings of the Ranging Module.

Refer to the Specification Sheets in the Appendix for the transducer that you are using for the proper polarity connections.

CAUTION: Be certain that the transducer is properly connected to the ultrasonic circuit board before applying power. Applying power to the board with the transducer disconnected may damage the board.

C. Ranging Module Connections

The Ranging Module connects to a power source and to other supporting electronic circuits via a 9 pin ribbon cable (supplied with each module). The Ranging Module Connector J1 pin assignments are:

J1-	1	GND	Power Supply Ground
J1-	2	BLNK	Blanking (for multiple echo receiving)
J1-	4	INIT	Initialize a Transmit/Receive Cycle
J1-	6	OSC	Internal 49.4 KHz Oscillator (see Note 2.1)
J1-	7	ECHO	Received Echo Detected (see Note 2.1)
J1-	8	BINH	Inhibit Internal Blanking
J1-	9	V+	Power Supply Positive Voltage Input (4.5-6.8 V DC)

Note 4.1: OSC and ECHO outputs are TTL-compatible Open Collector NPN outputs. A 4.7 Kohm resistor to +5 VDC is required to observe signals at these outputs See Figure 3-1

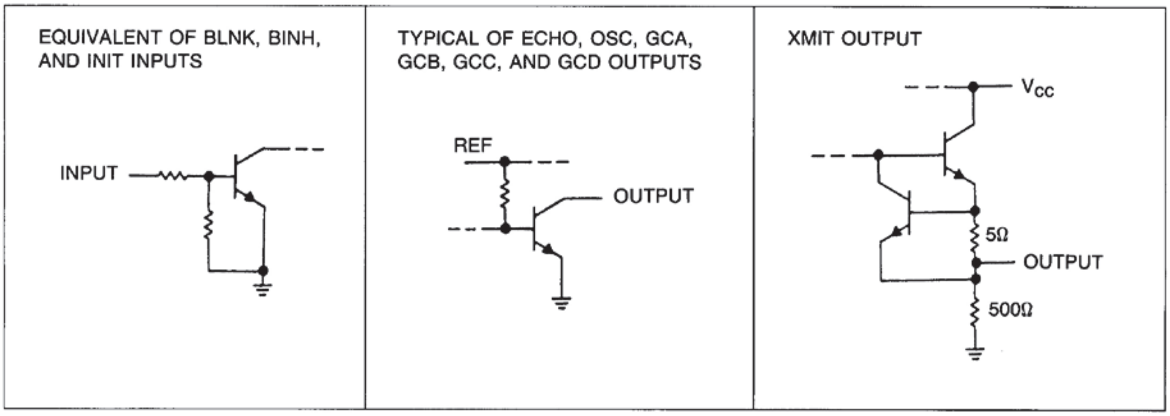


FIGURE 3-1 RANGING MODULE INPUTS/OUTPUTS

D. Schematic

Figure 3-2 is the schematic for the 6500 Ranging Module. A more detailed schematic for either the 6500 Ranging Module or the 9000 Ranging Module can be found in the Ranging Module Specifications (Appendix).

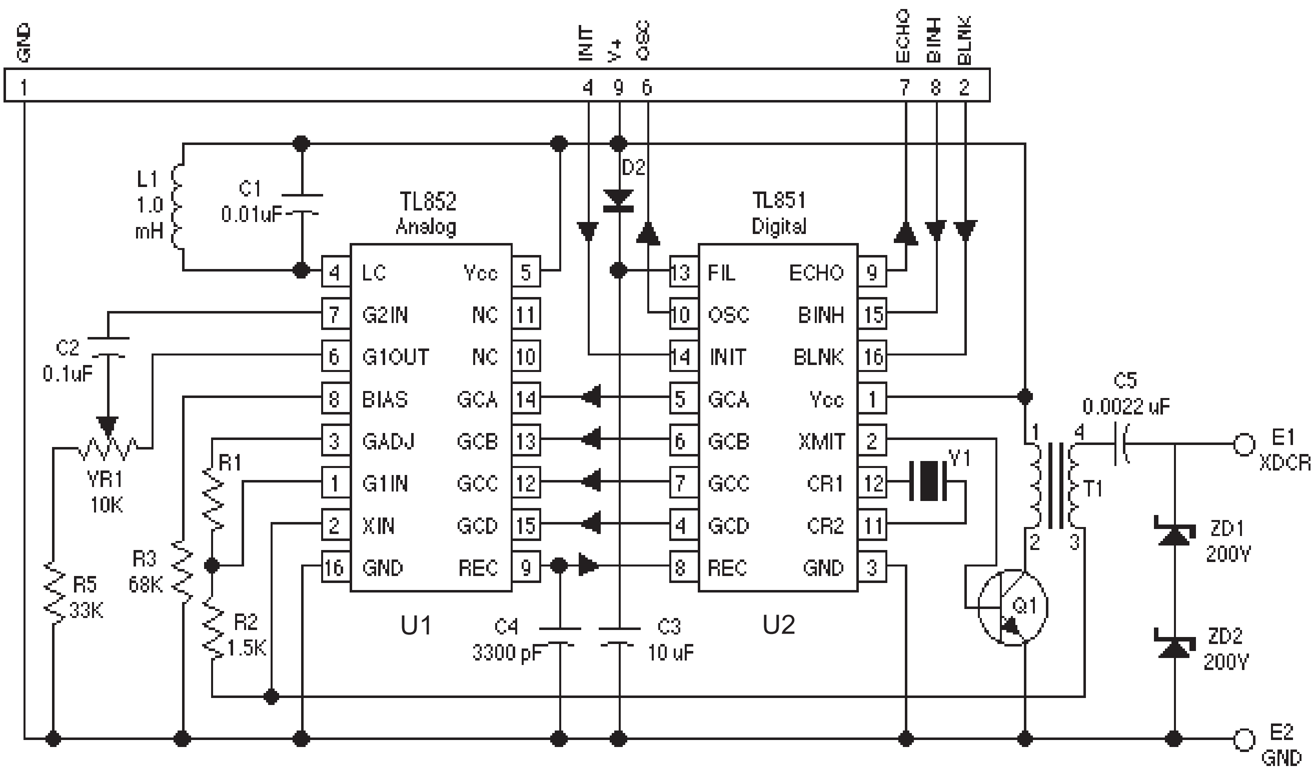


FIGURE 3-2 RANGING MODULE SCHEMATIC DIAGRAM

E. Parts and Layout

The Ranging Module Component Layout and Parts List are shown in Figure 3-3.

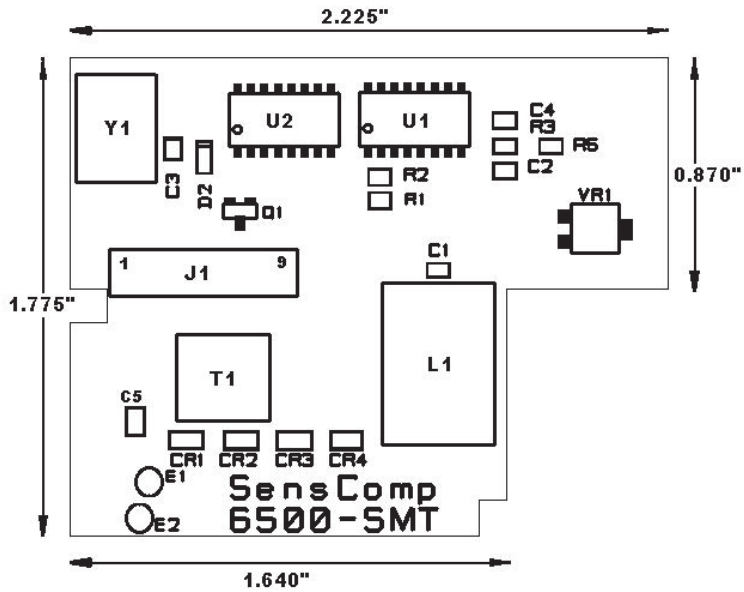


FIGURE 3-3 COMPONENT LAYOUT

REF	DESCRIPTION
C1	Cap Polypropylene Film 0.01 µf
C2	Cap Ceramic 0.01 µf
C3	Cap Solid Tantalum 10 µf
C4	Cap 3300 pf
C5	Cap Polypropylene Film 0.0022 µf
D2	Diode Schottky SD103C
E1	Transducer Output +
E2	Transducer Output -
J1	9 Pin Connector
L1	Variable Inductor 1 mH
Q1	Transistor NPN FMMT619
R1	Resistor - Factory Selected
R2	Resistor 1.5K ¼ W 5%
R3	Resistor 68K ¼ W 5%
T1	Transformer
U1	Analog IC – TL852
U2	Digital IC – TL851
VR1	Variable Resistor 10K
Y1	Ceramic Resonator
CR1,2	Diode, Zener, 91V
CR3,4	Diode, Zener, 110V

F. Operation

There are two basic modes of operation for the Sonar Ranging Modules:

- Single-echo mode (default). The BLNK input is always at a logic low (no input). This is the normal method of operation for detecting a single target (see Figure 3-4).
- Multiple-echo mode. The BLNK input is used to detect multiple targets during a single transmit cycle (see Figure 3-5).

In addition, the blanking time (internally set to 2.38 ms) can be shortened to allow measurements to closer distances, as shown in Figure 3-5. For our electrostatic transducers, this distance can be as short as 6 inches when a shorter blanking time is applied to the BINH input.

The application of power (V_{CC}), the application of the initiate (INIT) input, the resulting transmit output, and the use of the Blanking Inhibit (BINH) input are basically the same for either mode of operation.

You must wait a minimum of 5 milliseconds after applying power (Vcc) to the Ranging Module before raising the Initialize signal INIT to a high level. During this time, all internal circuitry is reset and the internal oscillator stabilizes. When INIT is raised to a high level, drive to the transducer (XDCR) output occurs. Sixteen pulses at 49.4 KHz, with an amplitude of 0 volts to 400 volts peak to peak, excite the transducer and transmission occurs. At the end of the 16 transmit pulses, a 200 VDC bias remains on the transducer (as recommended) for optimum receiving operation.

The waveforms illustrated in Figure 3-4 represent the normal single mode operation for the Ranging Module. This figure also illustrates the timing relationships of these waveforms.

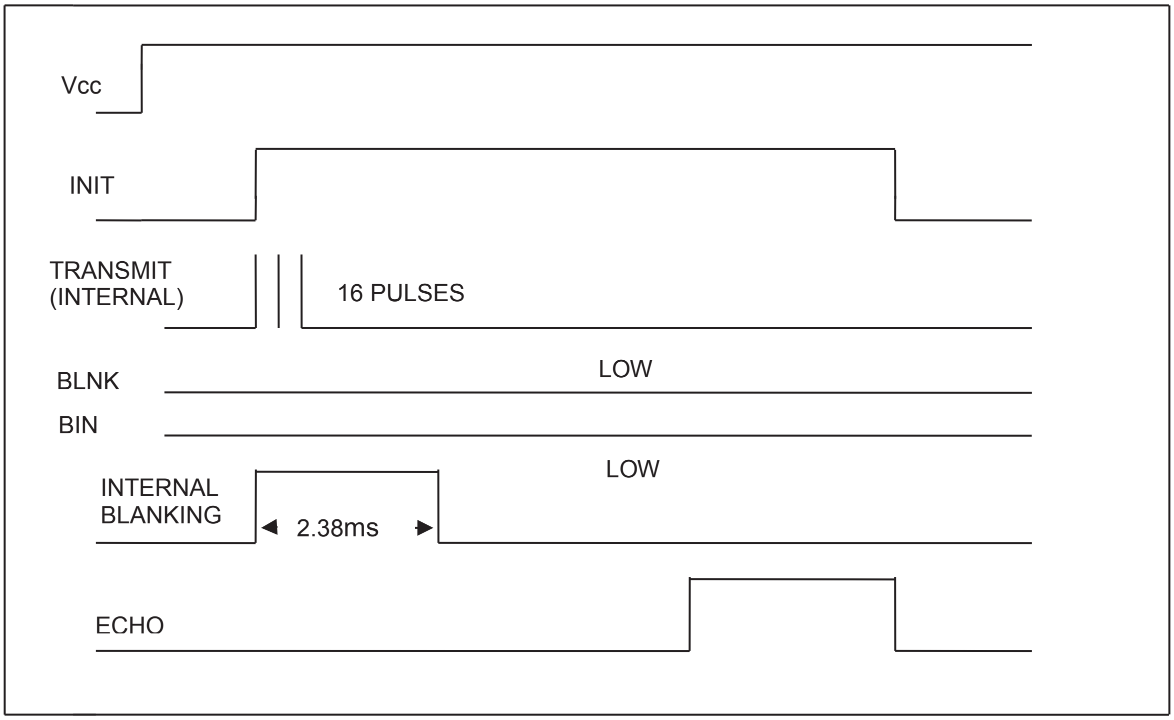


FIGURE 3-4 SINGLE MODE CYCLE WITHOUT BLANKING

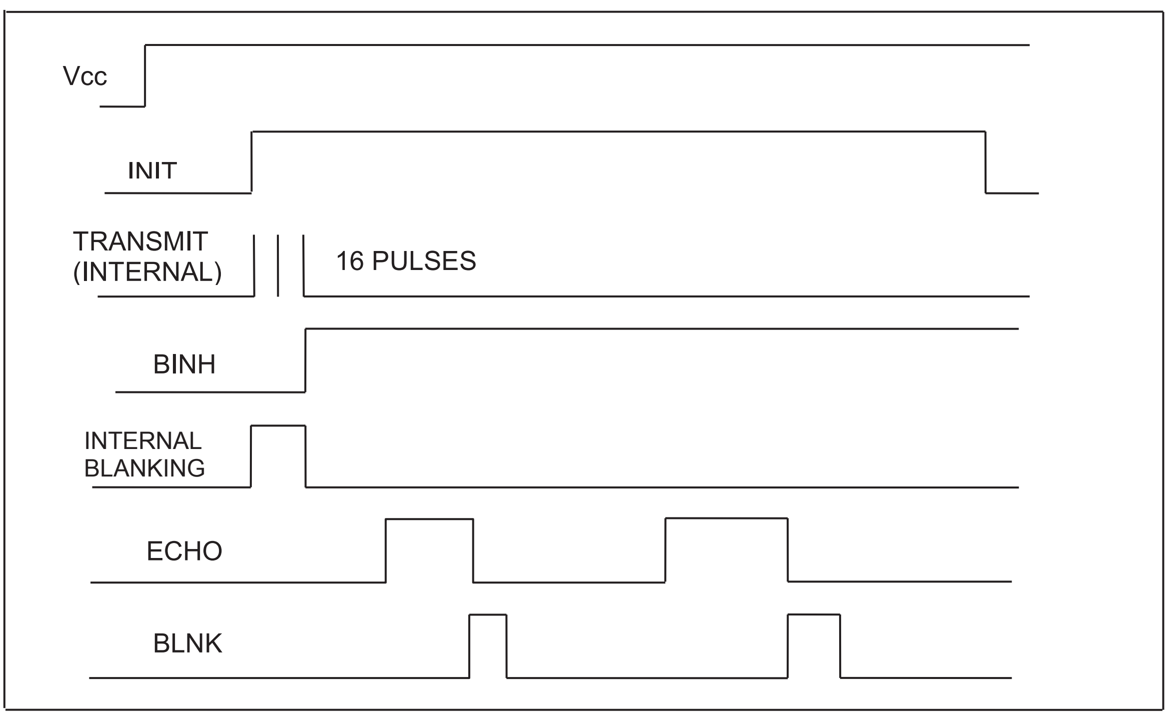


FIGURE 3-5 MULTIPLE MODE CYCLE WITH BLANKING INPUT

G. Inputs/Outputs

The following section describes both the Ranging Module's Inputs and its Outputs (both the Internal and the External signals)

1. Power (V_{CC}) Input (J1-9); Ground (GND) Input (J1-1)

The DC input voltage (+) and ground (-) connections required to power the circuits on the Ranging Module. The input power (V_{CC}) connects via connector J1 pin 9. The power supply ground (GND) connects to connector J1 pin 1.

A +5V DC, 2.5 ampere power supply is required. However, the Ranging Module requires 2 amperes of current for only the 1 millisecond transmitting burst time. At other times, the Ranging Module draws approximately 100 ma of current. Therefore, a smaller DC voltage source can be used by using a 500 mfd - 1000 mfd capacitor to supply the large burst current. This large current can be supplied.

CAUTION: Be certain that the transducer is properly connected to the ultrasonic circuit board before applying power. Applying power to the board with the transducer disconnected may damage the board.

2. Initiate (INIT) Input (J1-6)

A TTL compatible logic signal, INIT, is an input to the ultrasonic circuit board. This signal initiates a transmit/receive cycle (Figure 3-4). For proper operation, INIT should be high (+4 VDC) for 100 milliseconds and low (0 VDC) for a minimum of 100 milliseconds. INIT must remain high during the entire transmit and receive cycle until the ECHO output signal becomes high. The internal clock within integrated circuit (IC) U2 is enabled when INIT is high, and disabled when INIT is low. You can observe this clock signal at the open-collector oscillator output (OSC) on connector J1 pin 6.

NOTE: Example circuits for generating drive signal INIT are described in Appendix B. All timing relationships between transmitted signals and received echos are determined from the leading (rising) edge of the INIT signal.

3. Transmit (Internal)

The rising edge of INIT (2. above) initiates a transmit cycle consisting of 16 transmitted pulses. The output of Integrated Circuit (IC) U2 pin 2 becomes the transmitted signal to the transducer through transistor Q1 and transformer T1. At the conclusion of the 16 transmitted pulses, IC U2 switches to the receive mode, awaiting the arrival of an echo signal received by the transducer.

4. Stage 1 Receive (Internal - G1OUT)

The amplified echo can be observed at pin 6 of U1 (Figure 3-2). This signal is useful for observing the reflected returning echo signal, both below and above detectable levels, before processing.

5. Echo, Processed (Internal)

The integrating RECEIVE signal can be observed at pin 9 of U1 (Figure 3-3). This integrating analog voltage signal is useful for observing the signal strength for the returning echo signal. A level of 1.2 volts or above generates an ECHO output from the Ranging Module. Below the 1.2 volts detector threshold, an ECHO output is not created. Normally this signal would not be extracted; however, this is a recommended probe connection for adjusting the Ranging Module's gain control (VR1).

C-MOS circuits (Figure 3-6), or circuits of at least one megohm input impedance, provide a convenient way to extract this signal, if desired. This signal is useful if echos, other than the first echo, are of interest.

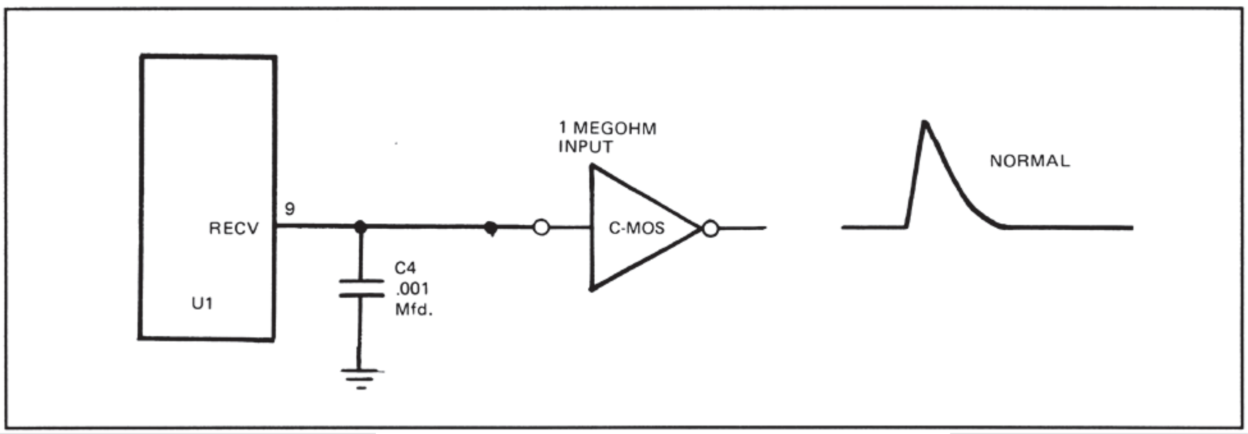


FIGURE 3-6 MODIFIED ECHO DETECTOR

6. Echo, Detected (ECHO) (J1-7)

The received ECHO output (Figure 3-4 and 3-5) indicates that the reflected transmitted signal has been received. By measuring the time between the rising edge of INIT and the rising edge(s) of ECHO, the distance between the transducer and the target(s) can be calculated.

$$D = \frac{\upsilon \cdot t}{2}$$

D = Distance
υ = Speed of sound
t = INIT time to ECHO

Divide by 2 because the sound travels twice the distance to the target (transducer to target, then back to transducer).

Note: *ECHO output is a TTL-compatible Open Collector NPN output (See Figure 3-1). A 4.7 Kohm resistor to +5 VDC is required to observe signals at this output.*

7. Blanking (Internal)

In order to eliminate ringing of the transducer from being detected as a return signal, the receive (REC) input of the ranging control IC is inhibited by internal blanking for 2.38 milliseconds after the rising edge of the initiate (INIT) signal.

8. Blanking Inhibit (BINH) Input (J1-8)

A TTL compatible logic signal, BINH, is the Blanking Inhibit input (Connector J1-pin 8) to the Ranging Module. If a reduced blanking time is desired, then the BINH input can be taken high to end the blanking of the receive input any time prior to internal blanking. This may be desirable to detect objects closer than 1.33 feet (corresponding to 2.38 milliseconds) and may be done if transducer damping is sufficient so that ringing is not detected as a return signal.

9. Blanking (BLNK) Input (J1-2)

A TTL compatible logic signal, BLNK, is the blanking input (Connector J1-pin 2) to the Ranging Module.

If there is more than one target and a single transmission detects multiple echos, then the cycle is slightly different (Figure 4-6). After receiving the first return signal which causes the ECHO output to go high, the blanking (BLNK) input must be taken high then back low to reset the ECHO output for the next return signal. The blanking signal must be at least 0.44 milliseconds in duration to account for all 16 returning pulses from the most distant target and allow for internal delay times. This corresponds to the two targets being 3 inches apart.

10. Oscillator (OSC) Output (J1-6)

The Ranging Module has an accurate time base generator controlled by a ceramic resonator.

The internal oscillator, based on the time base generator, is available as an output for external use. This OSC output signal output is at the transducer frequency throughout the Receive cycle. However, the output frequency is much higher during the short Transmit cycle, as shown on the chart below.

RANGING MODULE	RESONATOR	OSC (Transmit)	OSC (Receive)
6500	420 kHz	93.3 kHz	49.4 kHz
9000	384 kHz	83.3 kHz	45.0 kHz

This oscillator output is only present when INIT (J1-4) is at a high logic level. You can connect to J1 pin 6 to use this open collector TTL compatible NPN output.

Note: OSC output is a TTL-compatible Open Collector NPN output (See Figure 3-1). A 4.7 Kohm resistor to +5 VDC is required to observe signals at this output.

Note: To prevent cross-coupled signals and unexpected results, the OSC output should not be bundled with other inputs and outputs of the Ranging Module.

H. Adjustments

1. Ranging Module Gain

Gain changes can be made by adjusting potentiometer VR1 (Figure 3-2 and 3-3). This potentiometer adjusts the receiving amplifier's gain for the received echo signal. Usually it is left in the middle position.

By increasing the gain, you can detect signals further away at the expense of picking up unwanted side lobe reflections. By decreasing the gain, you may be able to eliminate any unwanted side lobe reflections at close ranges.

2. Factory Set Adjustments

There are two additional factory set adjustments on the Ranging Module, which should not be re-adjusted.

Adjustable Coil L1 – This inductor, in combination with C1, provide a tuned circuit peaked at the operating ultrasonic frequency for the receiving amplifier. This coil is set at the factory and should not require re-tuning. The tuned circuit eliminates noises received at other than the desired frequency.

Resistor R1 – This resistor is factory set and does not require adjustment. Changing this value may give you adverse results, and will void product warranty.

I. Robotics Application

Most applications of this system, such as positioning, guidance, or measurement systems for robots will probably involve a fair amount of computer processing. The same computer which controls the other robot functions can easily be programmed to handle the ranging system interface. This can include initiating measurements, timing the echo signals, and processing the information. All of these functions can easily be performed by a simple, inexpensive single chip microcomputer. These devices are readily available.

Several ranging systems could be controlled from a single processor, giving the device a great deal of flexibility. This is certainly a very practical approach, considering that the ranging system pricing is very economical.

The beamwidth of the signal is very important in robotics applications. It is important that the signal not spread out too much so that the system detects unwanted objects to the side, also that the beam is not too narrow to miss objects in the path of the robot. This requirement is very difficult to generalize. Many applications will require different beamwidths at different times. This can be accomplished with multiple ranging systems or with a single system that varies its beam. The beam can be varied in a number of ways. The system can use a very narrow beam and mechanically scan the transducer throughout the area of interest. This method will provide good resolution as to object size and location, but will be rather slow due to the mechanical movement required and will also require additional electronics to store or process all the information. This is relatively simple with the use of a simple microprocessor. The processor can control the scan (by means of a stepping motor for instance) and map out the area being scanned. The scan rate and angle can easily be adjusted by the processor according to a series of predetermined conditions as the robot performs its tasks.

The system can utilize a single broadband transducer and adjust the system beamwidth by changing the operating frequency according to the demands of the task. This will have other effects on the performance since the transmission of sound through air is so frequency dependent. As the frequency is increased the beamwidth is decreased; however the maximum range will be decreased due to increased absorption.

Another means which can be used to modify the system beamwidth is the use of an acoustic lens or horn. These devices can be attached to the transducer to widen or narrow the beam. A shaped reflector in the near field of the transducer can also be used to change the beam. This is especially suited to applications requiring a pancake shaped beam (i.e. wide in one direction but narrow in the orthogonal direction). These means can usually be implemented without any change to the processing electronics. With the present electronics, beamwidths of 1 degree to 360 degrees have been achieved. These changes certainly do have an effect upon the minimum detectable target at some fixed distance as well as the maximum range since a fixed amount of energy is being dispersed over a different volume.

The transducer (electrostatic or piezoelectric) used in this system is not ideally suited for all industrial environments, however, it can withstand a very wide range of conditions. Continuous transducer exposure to temperatures up to 85° C is possible. Temperatures down to -40° C are possible with no degradation of performance. Lower temperatures will result in reduced output but no permanent damage to the transducer.

The electrostatic transducer diaphragm material is Kapton with a gold plating. It can withstand a great range of vapors from solvents, etc., making it well suited for use in chemical environments. As will most electrostatic transducers, this one cannot operate in liquids; however it can work well in high moisture as long as the sensor is shielded from direct exposure to precipitation.

In conclusion, ultrasonic echo ranging systems can be of great benefit in robotics system design. The simple system described can be used effectively to provide gross positioning or collision avoidance for industrial robots. It can be easily used as a proximity indicator or even as "eyes" allowing a portable robot to travel through its environment and map it as it goes.

J. Design Considerations

1. Power Supply:

The OEM Kit operates from a DC power source providing a voltage between 4.5 VDC to 6.8 VDC. The power supply must be able to provide the high current transients (2.5 amperes).

2. Range: (with user custom designed processing electronics)

Farther

a. Use an acoustic horn to “focus” the sound (narrowing the beamwidth).

b. Use two transducers – 1 receiver and 1 transmitter – facing each other.
c. Lower the transmitting frequency (which will decrease the attenuation in air).

Closer

a. Use a shorter transmit signal (such as four cycles).
b. Use two transducers – one to transmit, one to receive (eliminates waiting for damping time).
c. Use the BINH input (connector J1-pin 8 on the Ultrasonic Ranging Module) to range closer than 1.33 feet.

3. Beam Width:

Increase

a. Use an acoustic lens (to disperse the signal).
b. Decrease the transmitting frequency.
c. Use several transducers to span the area.

Decrease

a. Use an acoustic horn (to focus the sound).
b. Increase the transmitting frequency.

4. Multiple Echo Mode

Use the BLNK input (connector J1-pin 2 on the Ultrasonic Ranging Module).

5. Oscillator Output (OSC)

The oscillator output (connector J1-pin 6 on the Ultrasonic Ranging Module) can be used for timing functions. This output is an open collector TTL output, and should be isolated from the Ranging Module inputs.

6. Resolution

a. Above all, know the target and range well, and design a system with them in mind.
b. Use a higher transmit frequency.
c. Look at phase differences of a given cycle of the transmitted signal and received echo (as opposed to using an integration technique).
d. Increase the clock frequency of the timer.

7. Accuracy: (again, you must have a well defined target).

Use a second small target, as a reference, at a known distance in the ranging path (such as a ¼" rod several feet away), process both echoes, then normalize the second distance with respect to the first, since $t1/d1 = t2/d2$.

8. Temperature Compensation

Incorporate a temperature sensing integrated circuit to drive a Voltage Controlled Oscillator (VCO) to perform the distance interval clocking.

A. Introduction

Determining range by using ultrasonic sound waves for echo ranging is a simple process. A short burst of ultrasonic energy is generated electronically, amplified and transmitted by a transducer. The signal travels through the medium (in this case air), reflects from the target object, and returns to the transducer. This signal is then received, amplified, and processed by the system electronics. The time for this round trip can then be determined, and knowing the correct speed of sound, the distance to the object calculated.

The simple ultrasonic echo ranging system included in the OEM Kit is composed of only two parts: the transducer and the electronics drive module. The transducer is either an electrostatic or a piezoelectric type transducer used to both transmit the signal out, and also receive the returning echo. The electronic sonar ranging module contains all of the circuitry needed to generate the transmit signal, drive the transducer, receive the echo, and process the information received by the transducer.

The distance from the transducer to the target can then be computed with additional circuitry, knowing the speed of sound in air (or other gas) and the time interval between the transmit signal and the received echo as provided by the sonar ranging module. The system operates over a distance range of 0.15 to 10.7 meters (6 inches to 35 feet), increasing the receiving amplifier gain and decreasing the bandwidth with time to compensate for signal losses over the distance range. Then, to minimize the system's susceptibility to noise pick-up, a signal integration scheme is employed before the system locks onto an echo. Once the threshold level of the integrator is reached, a signal is generated to indicate a received echo. The logic level outputs for the transmit signal and received echo can be used to perform control functions or calculate distance to the object with a minimum of additional circuitry.

B. Echo Ranging

While the act of echo ranging is very simple, some of the processes involved are not. The propagation of acoustic energy through a fluid medium is very complex. Fortunately, it is very well understood, especially at the frequencies of interest, and most of the relationships for attenuation, reflection, etc. can be simplified to quite satisfactory accuracy.

The major acoustical factors affecting the performance of a sonar ranging system are related to the transducer performance, operating frequency, and the desired maximum range.

Neglecting the function of the electronics, we then have two major relationships to analysis. The first is the relationship between transducer size, beamwidth, and operating frequency.

To analyze transducer radiation characteristics, we can treat the transducer as a plane circular piston set in an infinite baffle. Its radiation characteristic function then is given by:

$$P(\theta) = \frac{2\,J_1(ka \sin\theta)}{(ka \sin\theta)}$$

where: k = wave number = $2\pi/\lambda = 2\pi f/c$

a = piston radius

θ = azimuthal angle

We are interested in the radiation pattern beamwidth as a function of frequency and transducer size. The beamwidth is most commonly expressed as the angle intercepted by the points either side of the principal axis where the radiation pattern is 3dB less than the on axis value ($\theta = 0$).

Therefore we can set: $2 J_1(x)/x = -3dB = 1/\sqrt{2}$

To solve this relationship exactly requires an iterative procedure; however, a very good approximation can be achieved by expansion of the Bessel function to only 3 terms.

Expanding and solving yields: $x = 1.62$, where $x = ka \sin\theta$

Therefore $\theta = \sin^{-1}(x/ka) = \sin^{-1}(1.62/ka)$

This is the angle from the central axis to one -3dB point. Therefore, the 3dB full angle beamwidth is:

$$2\theta = \alpha = 2\sin^{-1}(1.62/ka).$$

A plot of beamwidth versus frequency and transducer radius is shown in Figure 4-1. This graph provides an easy method given any two parameters to find the third, or given a desired beamwidth to see the appropriate combinations of transducer size and operating frequency.

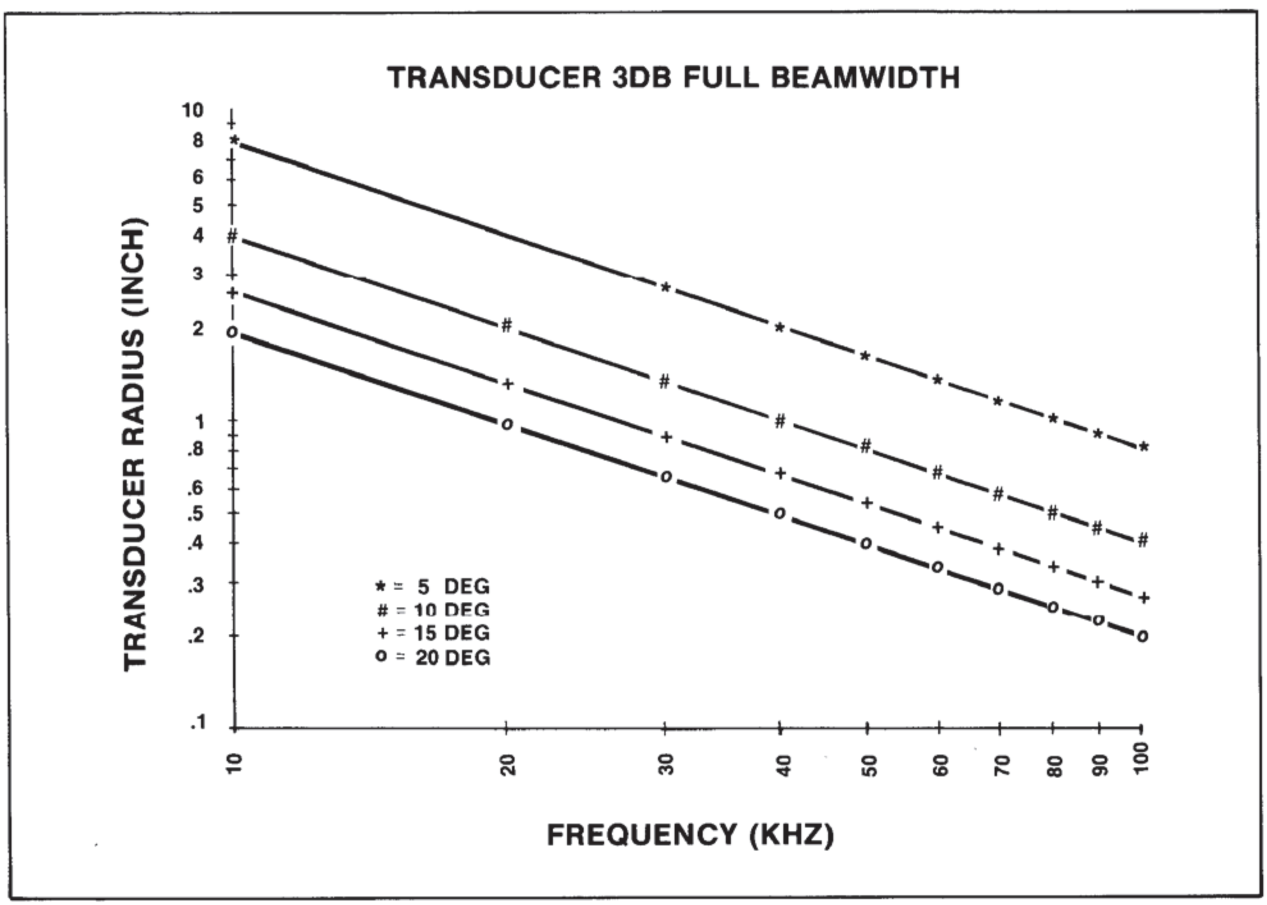


Figure 4-1 BEAMWIDTH/FREQUENCY/RADIUS

The second relationship to be analyzed is between range and operating frequency. The maximum range of a sonar system is a function of frequency due to the frequency dependence of the attenuation of sound in air. The mechanism of this loss is very complex, however, relationships have been developed to calculate losses for any combination of temperature, relative humidity, and frequency. Calculations of these losses agree well with actual measurements. The loss factor is defined such that:

$$P = P_O e^{-mx/2}$$

where m = absorption coefficient
P_O = initial pressure
x = distance

This relationship shows the attenuation of the sound pressure with distance only due to absorption and not including other factors. The absorption coefficient is the factor affecting the sound pressure attenuation and is normally expressed in units of inverse distance. To more easily evaluate the effects, an attenuation constant, A_0, can be defined as:

$$A_O = 4.343m \text{ in dB/foot.}$$

Figure 4-2 shows a plot of attenuation due to air absorption as a function of frequency and distance traveled. The distance shown is total path length and not target range.

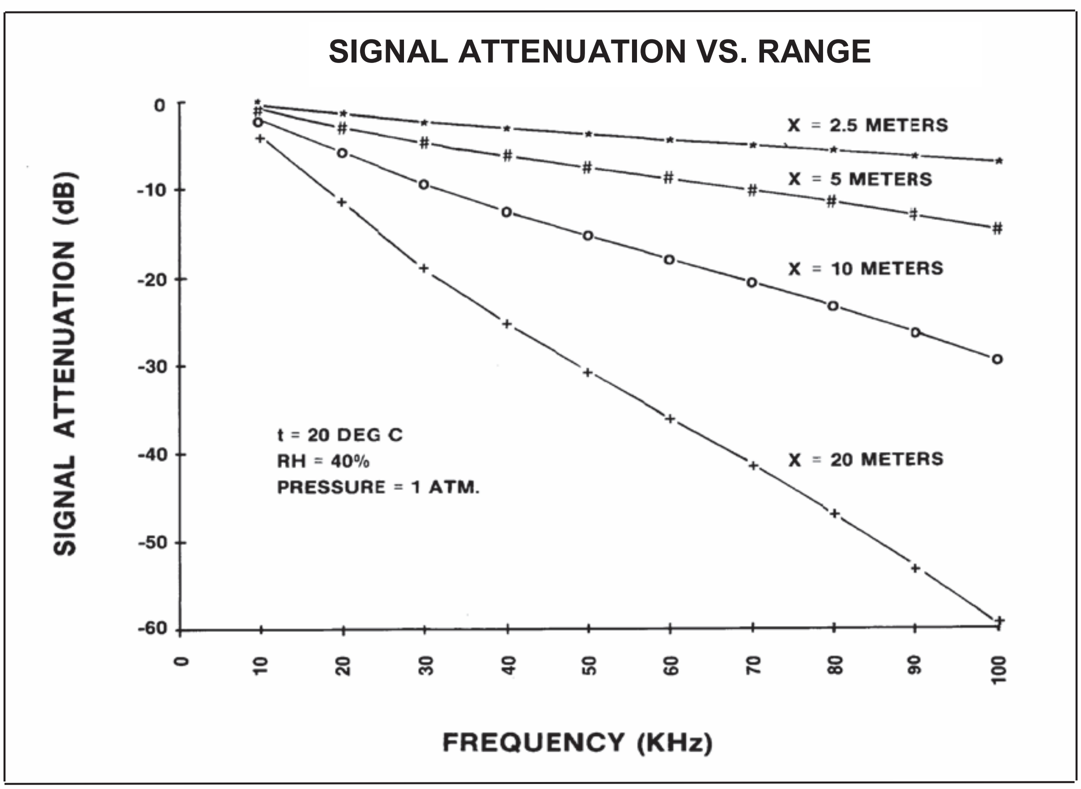
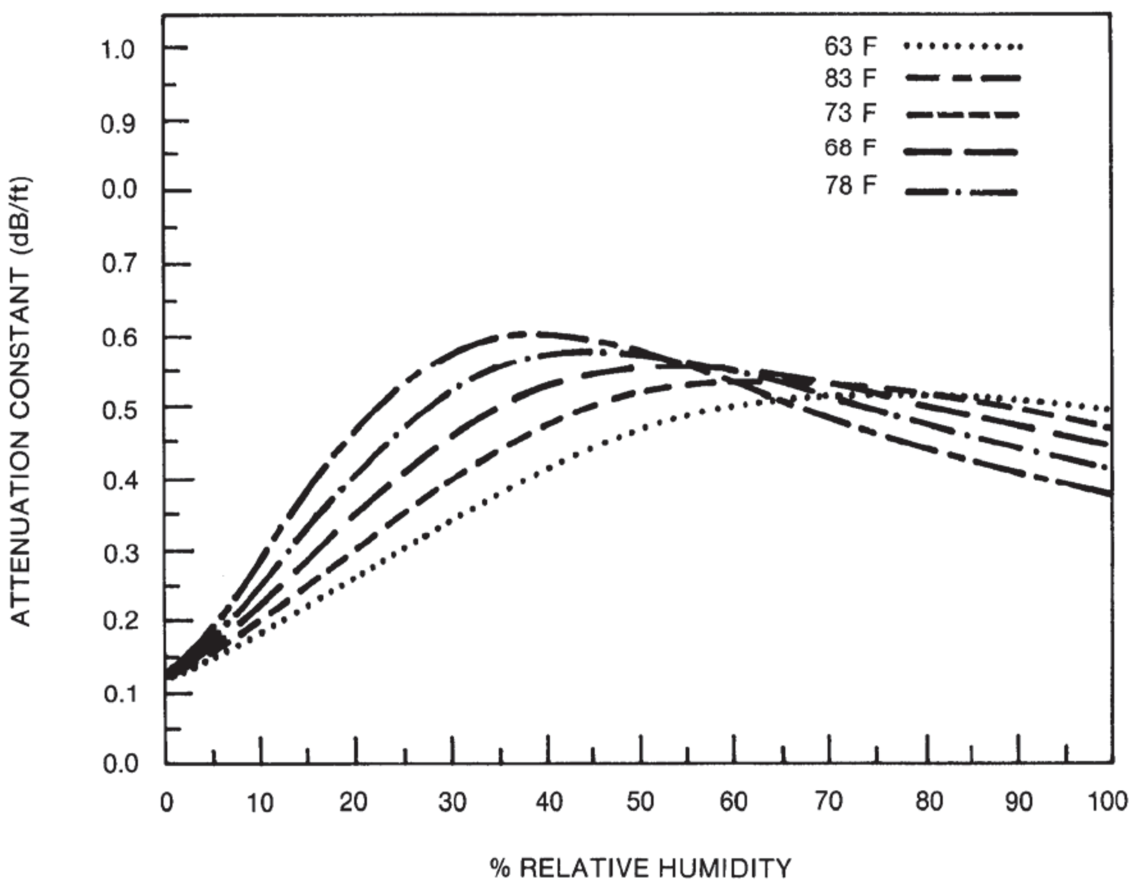


FIGURE 4-2 ATTENUATION VS. RANGE

The value of A_O depends strongly on frequency, temperature, and relative humidity and is shown in Figure 4-3 for 50 kHz over a range of 63° to 83° F.

ATTENUATION CONSTANT AS A FUNCTION OF
TEMPERATURE AND RELATIVE HUMIDITY

deg F	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%
63	.2162	.2570	.2984	.3387	.3764	.4104	.4398	.4642	.4833	.4975	.5070	.5124
68	.2456	.2973	.3480	.3950	.4362	.4703	.4968	.5157	.5276	.5335	.5343	.5311
73	.2823	.3462	.4506	.4567	.4972	.5264	.5447	.5537	.5551	.5505	.5418	.5302
78	.3272	.4033	.4687	.5189	.5526	.5710	.5767	.5730	.5626	.5479	.5309	.5127
83	.3807	.4671	.5330	.5751	.5952	.5981	.5889	.5723	.5516	.5291	.5063	.4842



FREQUENCY: 50000 Hz PRESSURE: 1 fltm.

FIGURE 4-3 ATTENUATION CONSTANT

It is interesting to note that the most severe attenuation is not at the extreme ranges of humidity, but actually falls in the mid-range for the higher temperatures, so that system gain figures should usually be adjusted for this worst case.

The information presented in these two figures can be used to determine the desired characteristics for modifications to the system to meet other performance requirements.

1. Resolution

Typically with ultrasonic echo ranging systems a resolution of one wavelength can be achieved. This depends upon the type of detection scheme employed. Here the scheme is a fairly simple integration technique. Whenever the received signal is above a predetermined threshold level, a current source is turned on to charge a storage capacitor. There is a continuous drain on the capacitor to prevent the possibility of a series of noise spikes from continually adding to the charge until the threshold is reached, yielding a false detection. The charge rate is about ten times the discharge rate. With this detection scheme, the system can resolve to 0.25 inches of distance range with a constant target and certain other constraints as follows.

2. Speed of Sound

In order to achieve the maximum resolution possible, the correct speed of sound must be known. The speed of sound in air is determined from the following relationship (meters/second):

$$c = 331.4 \sqrt{T_K/273}$$

where T_K is the ambient temperature in degrees Kelvin.

This yields an approximate relationship valid over a range from -30° C to +30° C:

$$C = 331.4 + 0.607\, T_C \text{ m/s}$$

where T_C is the ambient temperature in degrees Celsius.

It is easily seen from this relationship that the speed of sound in air is greatly affected by the temperature. If accurate values of distance are desired, then the temperature must be known. For a system designed to operate over a normal environmental range of 60° C, there will be a ± 5% change in sound speed at the extremes. If the echo ranging system is being used to provide accurate distance values, a correction for changes in ambient temperature must be made. This can be done manually or automatically if a microprocessor is employed.

The speed of sound at 20° C is 343.2 m/s (1125 ft/s). It varies only slightly with humidity (maximum of 0.35% at 20° C) and is virtually independent of pressure and, thus, of height above sea level.

Only temperature has some influence: 331.3 m/s at 0° C, 354.7 m/s at 40° C; i.e., 7% variation from 0° to 40° C. Variation with frequency is negligible.

3. Absorption of Ultrasound in Air

The absorption as a function of relative humidity and temperature in dB/10 m is shown in Table 1.

The transmitted signal power decreases as l/d^2 (d=distance). Most objects scatter the signal randomly, such that the echo power decreases again with the same factor l/d^2. In addition, there is an exponential loss in signal strength with distance, due to attenuation or absorption of sound in air. Thus, the reflected signal power varies as $(e^{2ad})/d^4$ with distance; e.g., a 60 kHz echo at 20° C is approximately 60 dB weaker at 5 m than at 25 cm.

4. Reflection of Ultrasound from an Object

The signal strength of the echo depends on the surface structure of the objects to be detected. Usually only limited parts of these will reflect much energy back as echo. The phases of the reflected waves can interfere with each other. Therefore, an object can produce large variations of the echo signal depending on surface geometry (comparable to the effect called "speckle' in laser optics). This interference effect is wavelength (i.e. frequency) dependent. If the echo is very weak at one frequency, there are other frequencies at which the echo would be strong.

TABLE 1
Signal Loss in db per 10 M

Frequency kHz	Temperature °C	10%	30%	50%	70%	90%	Relative Humidity
	0	5.92	6.85	7.98	9.21	10.47	
	20	8.18	15.08	20.20	22.00	21.40	
	40	19.50	27.20	20.50	16.10	13.50	

The largest difference between numbers is approximately 20 dB. A careful gain calibration obviated a compensation for temperature or humidity in the system.

C. Ultrasonic Transducer

The key to the Ultrasonic Ranging System is the unique Electrostatic or Piezoelectric Transducer. Two different technologies are used to create this transducer, each with their own strengths and weaknesses.

Electrostatic Transducers offer much higher transmitting output levels and greater receiving sensitivity than comparable Piezoelectric Transducers. Due to their larger size, they also offer reduced beam angles (< 15 - 17 degrees). Electrostatic Transducers also offer a very broad bandwidth, from less than 35 kHz to over 100 kHz.

Piezoelectric Transducers offer a more economical solution. They are constructed to operate at a single frequency, with a very narrow bandwidth. Due to their Piezo elements, the Piezoelectric Transducer does not require a bias voltage for transmitting and/or receiving.

1. Electrostatic Transducer

The key to the system is the unique electrostatic transducer (Figure 4-4). It is composed of a very thin, Kapton-film diaphragm vacuum coated with gold to form the negative electrode. The positive electrode is the coined aluminum backplate which also provides the resonant structure for the diaphragm. Mechanical bias, as well as electrical contact, is provided by a stainless steel leaf spring. The transducer is 4 centimeters in diameter and weighs only 8 grams.

The system drives the transducer with a 1 millisecond tone burst at 400 Volts peak-to-peak and 200 volts DC bias, producing an output sound pressure level at 50 kHz of approximately 110 dB SPL at 1 meter. The transmitting response (Figure 4-5) is seen to be quite flat to beyond 100 kHz. This provides the transducer with very fast damping so that ranging at high gain can be achieved as quickly as possible after transmit. The very wide bandwidth and extremely high output allows the system to operate over a very wide distance range. The system is capable of a minimum range of 6 inches.

With a receiving sensitivity (Figure 4-6) of -42 dB re 1 Volt/Pascal, the transducer provides sufficient output for the system to operate to a maximum range of over 35 feet. The transducer is approximately 1.5 inches in diameter, yielding a 3dB full angle beamwidth (Figure 4-7) of approximately 15 degrees at 50 kHz.

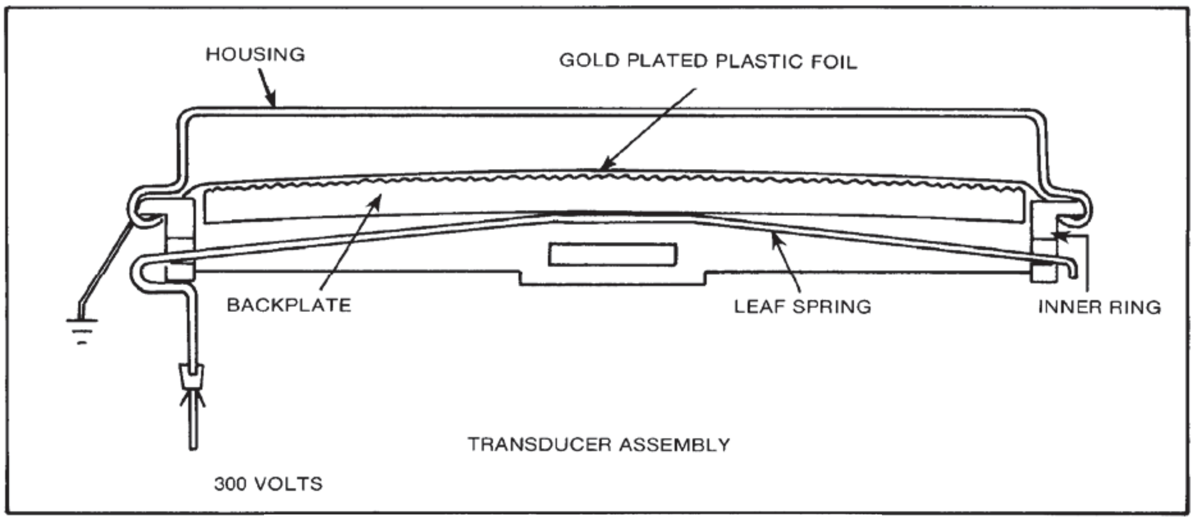


Figure 4-4 Electrostatic Transducer

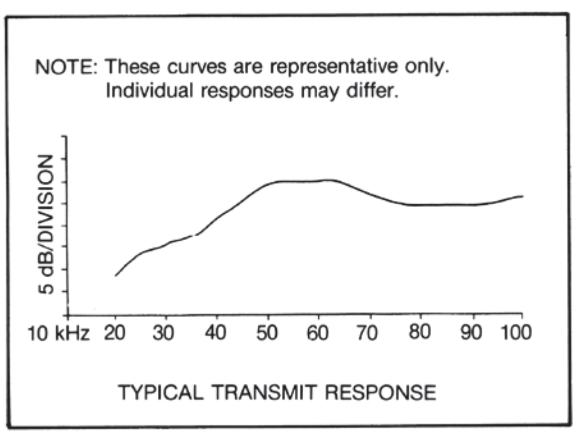


FIGURE 4-5 TRANSMIT RESPONSE

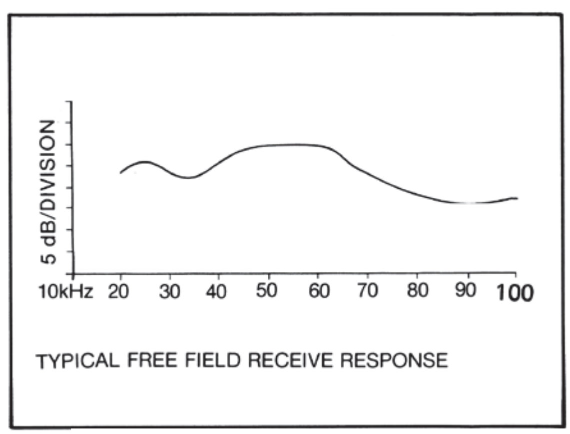


FIGURE 4-6 RECEIVE RESPONSE

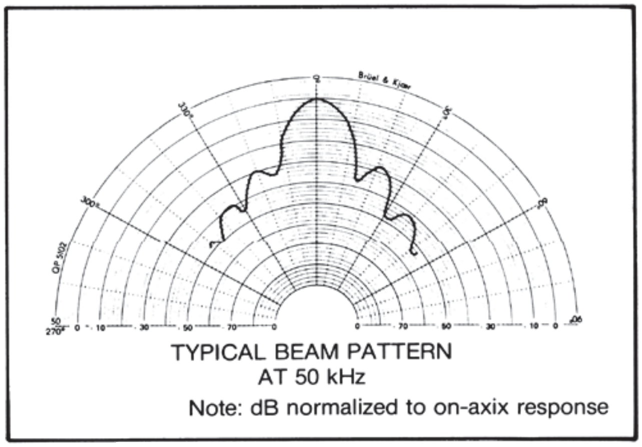


FIGURE 4-7 BEAM PATTERN

2. Piezoelectric Transducer

The key elements of a Piezoelectric Transducer are crystal or ceramic piezo materials bonded to a metal case or cone. As this Piezo material is excited by an electrical potential, e.g. a 45 kHz drive signal, the physical size of the Piezo material expands or contracts. The moving cone displaces air and generates a burst of ultrasonic sound.

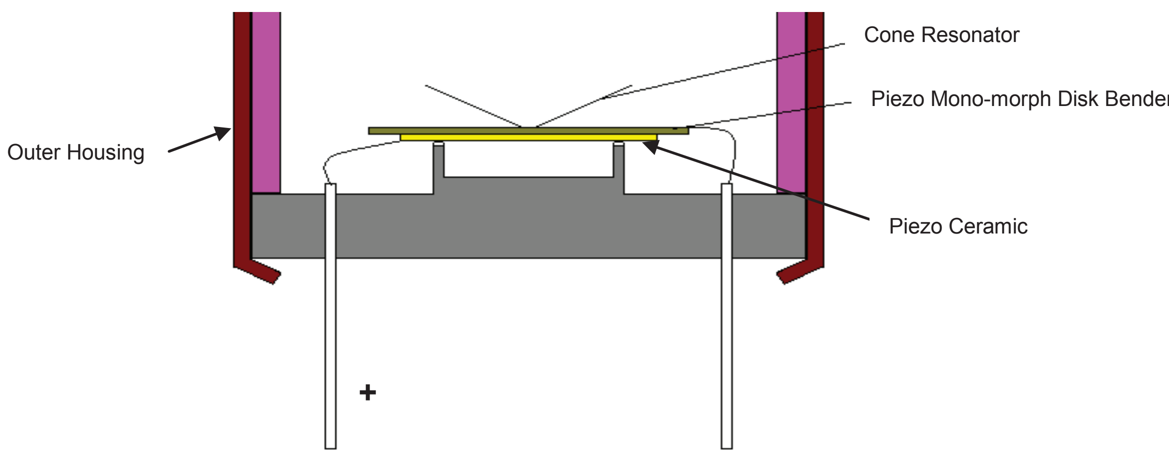


FIGURE 4-8 PIEZOELECTRIC TRANSDUCER

A Piezoelectric Transducer design features a piezo ceramic disc bender that is resonant at a nominal frequency of 20 – 60 kHz and radiates or receives ultrasonic energy. They are distinguished from the piezo ceramic audio transducer in that they produce sound waves above 20 kHz that are inaudible to humans. The ultrasonic energy is radiated or received in a relatively narrow beam.

D. Sonar Ranging Module

The sonar system electronics are integrated onto a single module (Figure 3-2) utilizing custom integrated circuits to perform the analog and digital functions. These ICs are packaged along with the necessary discrete components on a single printed circuit board. When activated, the system generates a series of 49.4 kHz pulses during a 1 millisecond long transmit period. This signal is amplified with a step-up transformer to 400 Volts peak-to-peak with a 200 Volt DC bias to drive the transducer. The bias voltage is maintained on the transducer with a storage capacitor during the time the transducer acts as a microphone to receive the echo. The receiving amplifier is blanked for 2.38 milliseconds following the end of the transmit signal to allow sufficient time for the energy in the transducer diaphragm to decay below the threshold level. The gain of the receiving amplifier increases as a function of time (Figure 4-8) to compensate for signal losses at further distances and decreases its bandwidth to reduce noise pick-up. When a signal is received by the system, a current source is turned on if the signal is above a preset threshold level. The current source charges a capacitor until the voltage on the capacitor reaches 1.2 Volts. The system generates a logic level output signal at the time of the received echo.

The time interval between the transmit signal start (INIT Input) and the received echo (ECHO Output) can then be measured with an external clock. Multiplying this time by the speed of sound yields the round trip distance to the object. If the actual distance is not required, a simpler timing circuit can be employed to determine when an object comes within some preset zone of the sensor.

1. Transmit Circuit

The transmit circuit (Figure 4-9) consists of the transducer, zener diodes (D_3,D_4), coupling capacitor (Cs), transformer (T), resistors (Rs) and (RL), and diodes (D_1 ,D_2). The transistor, Q, is driven with a square wave signal at the selected transmit frequencies. Thus, the transformer secondary charges C_S to ($V_{PRIMARY}$ x N) = (150 - 170V) on half of one cycle, and the resonant circuit of the secondary is utilized to transfer charge from C_2 onto the transducer on the remaining half cycle. Zener diode D_3 and D_4 are used to limit the transmit peak-to-peak voltage as one means of regulating system gain. Diodes D_1 and D_2 complete the signal path for the transmit current and are integrated inside the chip. These diodes are an open circuit in the receive mode. Resistor R_L lowers the Q of this circuit in the receive mode in order to respond to all transmitted frequencies.

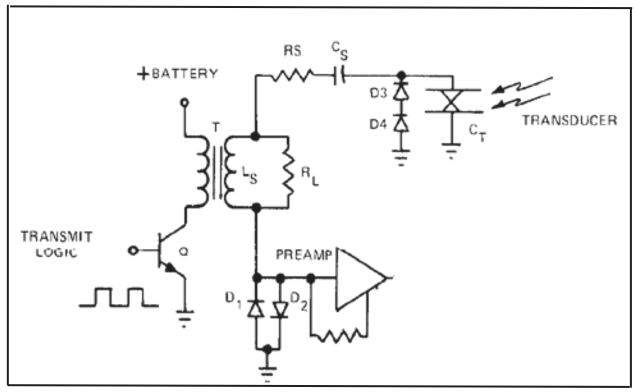


FIGURE 4-9 TRANSMIT CIRCUIT

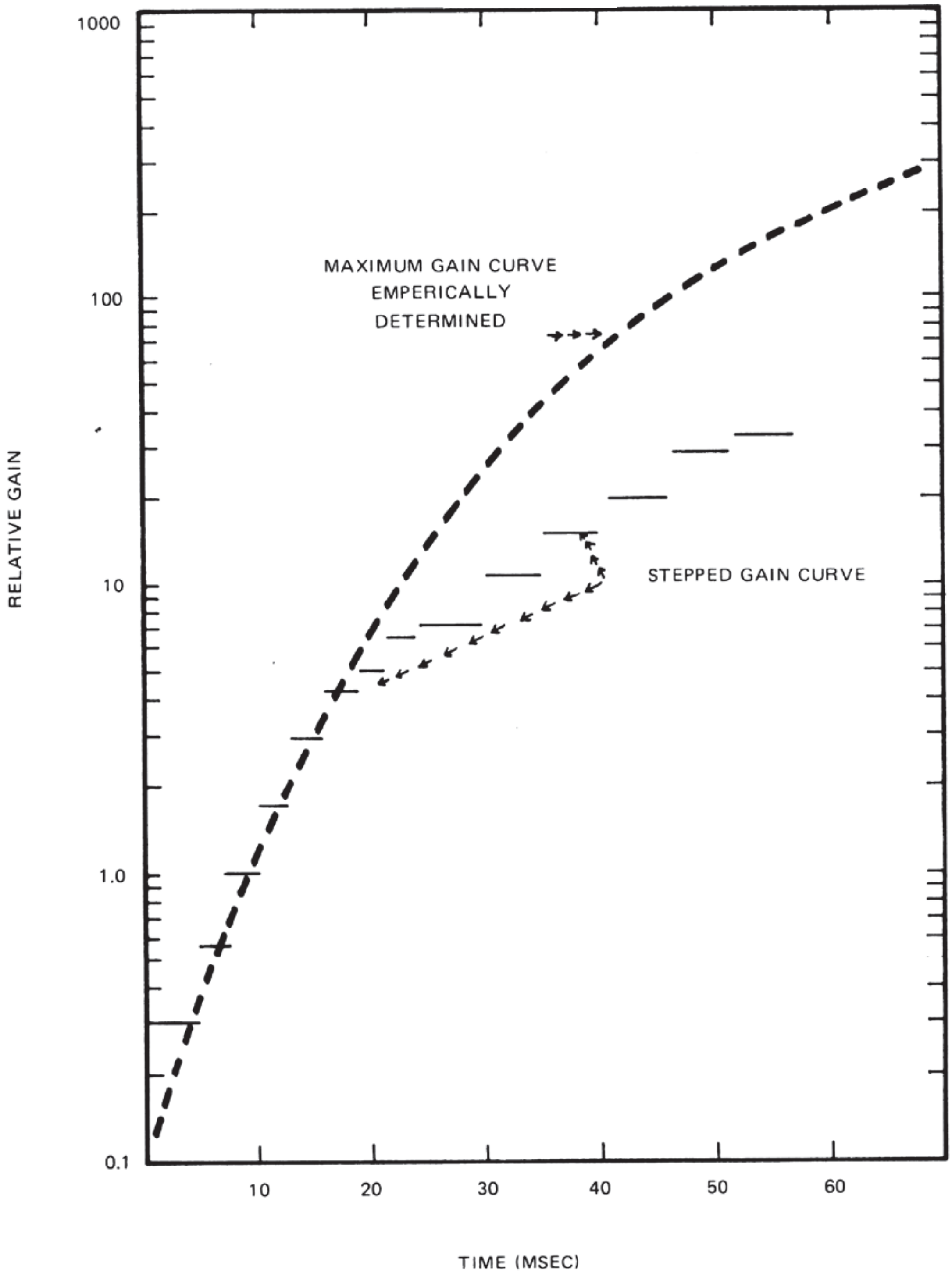
Thus, with a minimum of components, the circuit transmits with 400 volts and develops a bias of approximately 200 volts for the receive mode.

2. Receiver Ramp Gain

The system should respond only to echos from objects which are in a given solid angle around the transmit axis corresponding to a photometric acceptance angle. Any echo signal from an object far off axis is undesirable. Transducer diameter and transmit frequencies were chosen so that an object at 25 cm distance at an angle of 20 degrees (the first sidelobe) gives an echo about 20 db weaker than the same object placed on axis at the same distance. If the object is moved from 25 cm to a distance of 5 m on axis, the echo will fall off by about 60 db.

If a constant amplification were used, the operating range would be severely limited. This situation is even worse, since different objects at different temperatures and humidities will vary in echo strength by as much as 20-30 dB. It is, therefore, desirable to vary the amplification with distance: low amplification for near distance echos, high amplification for far distance echos. Since the roundtrip time for the signal is proportional to the distance, it means that the amplification should increase as a function of time. This time variable gain (ramp gain) is adjusted to the objectives of the system (Graph 1). The gain should not produce a constant signal level of a given object at different distances. It is assumed that nearer objects tend to be smaller and therefore relatively more gain is desirable. Large amplified signals improve the accuracy of the distance determination.

GRAPH 1



3. Receiver Amplifier Design

The range of receive (echo) voltages produced by the transducer is from microvolts to volts, depending on the distance, composition, and orientation of the surface of the object.
The sonar system electronic gain is controlled by a custom designed integrated circuit that operates from a DC voltage source of 4.5 to 7 volts. As a result of the dynamic range required (approximately 60 db), the circuit was designed as three cascaded amplifiers, two of which change gain as a function of time. (Figure 4-10)

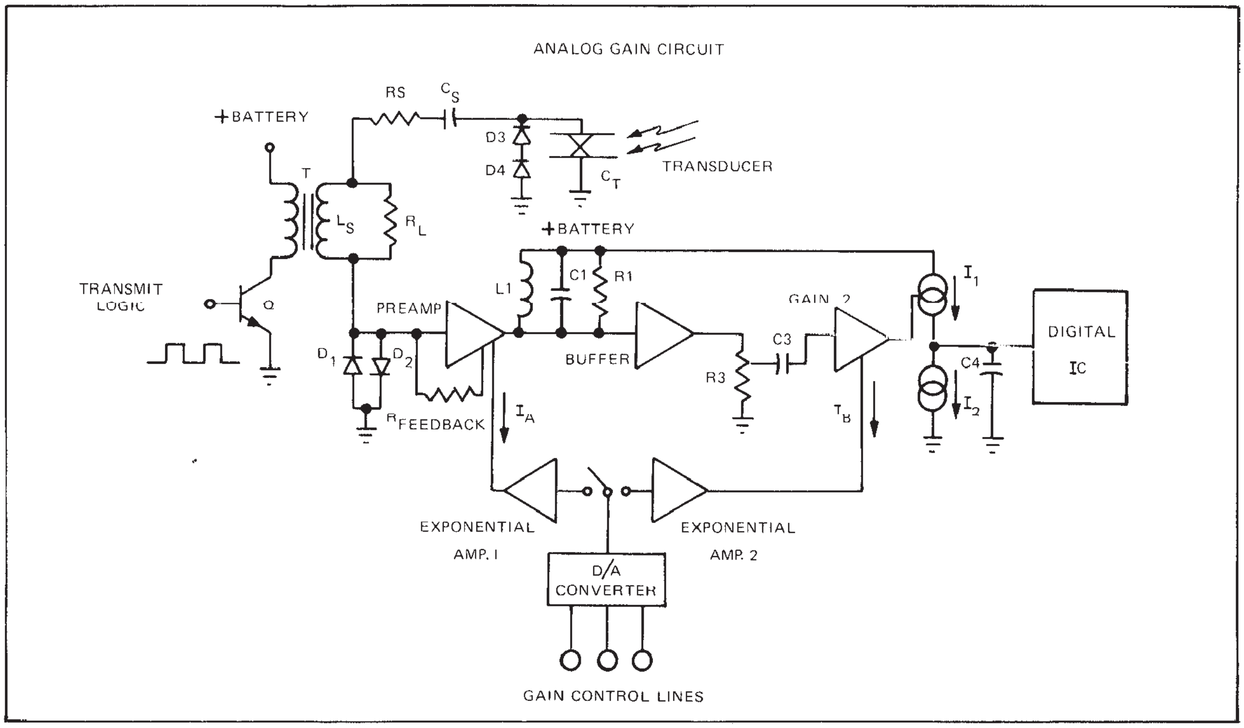


FIGURE 4-10 ANALOG GAIN CIRCUIT

Extensive testing has shown that little is sacrificed by the use of a segmented gain curve in place of a continuous gain change. These step changes lend themselves to integrated circuit manufacture.

4. Receiver Noise

A major requirement of this system was to filter extraneous noise. Noise may be thought of as frequencies different from the transmitted frequency, or “glitches” or spikes either externally generated and detected by the transducer or internally generated by the electronics. This requirement was met by:

1) A tuned circuit is used (L_1,C_1) to filter out all other frequencies (Figure 4-11). When focusing on close objects, it is important to detect early in the burst in order to obtain the best resolution. This means that it is desirable to have sufficient gain to recognize the 50 kHz portion of the transmit signal. At far distances, however, the signal most likely to be detected is the 49.4 kHz portion. This is a result of the larger dielectric absorption of air for higher frequencies and the larger portion of the transmit signal composed of this frequency. As a result of the high gain required to amplify the signal, it would also be desirable to increase the Q of the filter, so as to reject all but the 49.4 kHz signal. The Q, as well as the gain, is changed in the first eight gain steps, as shown in Graph 2.

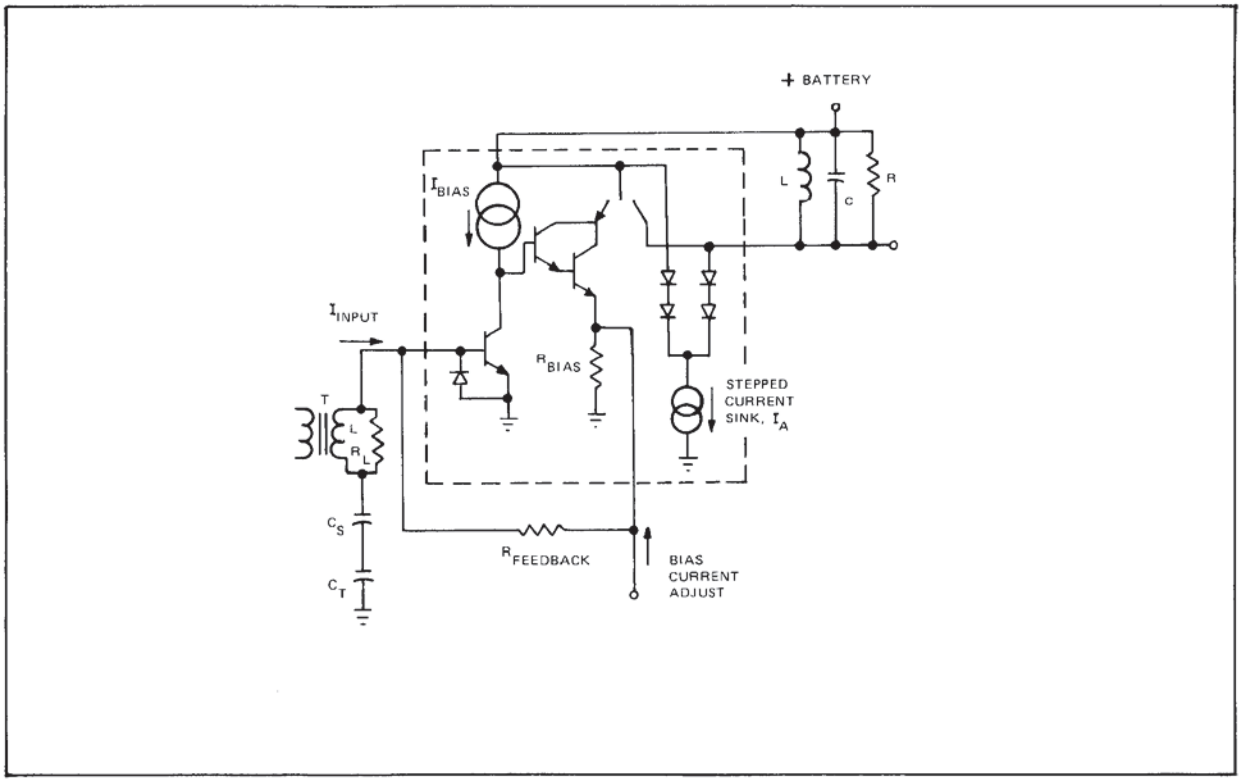
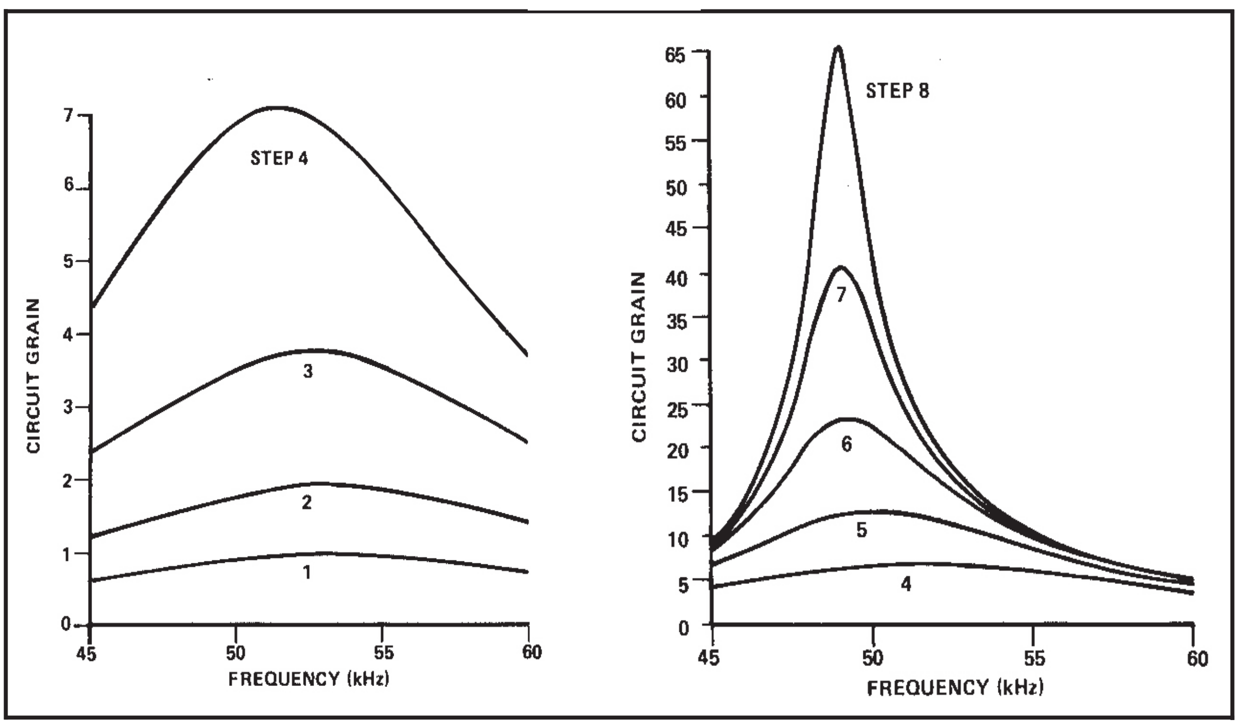


FIGURE 4-11 PREAMPLIFIER CIRCUIT

GRAPH 2



NOTE: ONLY the graphs of the first eight gain steps are included here for clarity. Step 9-11 are identical to step 8 except that each successive step is increased in gain by 4 dB. These graphs are generated from theoretical information, not experimental data

2) Gain change in the preamplifier is accomplished by varying the current, and thus the resistance, of diodes in parallel with the tuned circuit in Figure 4-11. Current change through the inductor will cause the tuned circuit to ring, causing a false detect signal. To compensate for this current change, the bias current of Q_2 is increased when the diode current is decreased, thus maintaining a relatively constant current through the inductor.

3) The detection scheme depends indirectly on the amplitude of the signal. An integrative technique is employed to discriminate against unwanted noise spikes. The charging scheme is as shown in Figure 4-12. The integration capacitor, C, is constantly being discharged by current sink, D, and is charged when current source, S, is turned on by transistor Q. The transistor turns on when the signal is $+V_{be}$. I_1 is 25 to 50 times larger than I_2, and a detect level of 1.2 volts is reached in approximately 3 pulses (with a strong return signal). 1_2 continuously discharges C_4 so that noise spikes will not have a cumulative effect and cause a false detect.

5. Receiver Preamplifier Gain

The preamplifier is represented by the schematic in Figure 4-11. The gain of the preamplifier and input circuit sections is:

$$\frac{V_O}{V_{IN}} = \frac{Z_{TUNED\ CKT}}{Z_{INPUT\ CKT}} \times \frac{R_{FEEDBACK}}{R_{BIAS}}$$

and is plotted in Graph 2.

The gain of the system is defined during manufacture by selection of $\mathbf{R_{FEEDBACK}}$

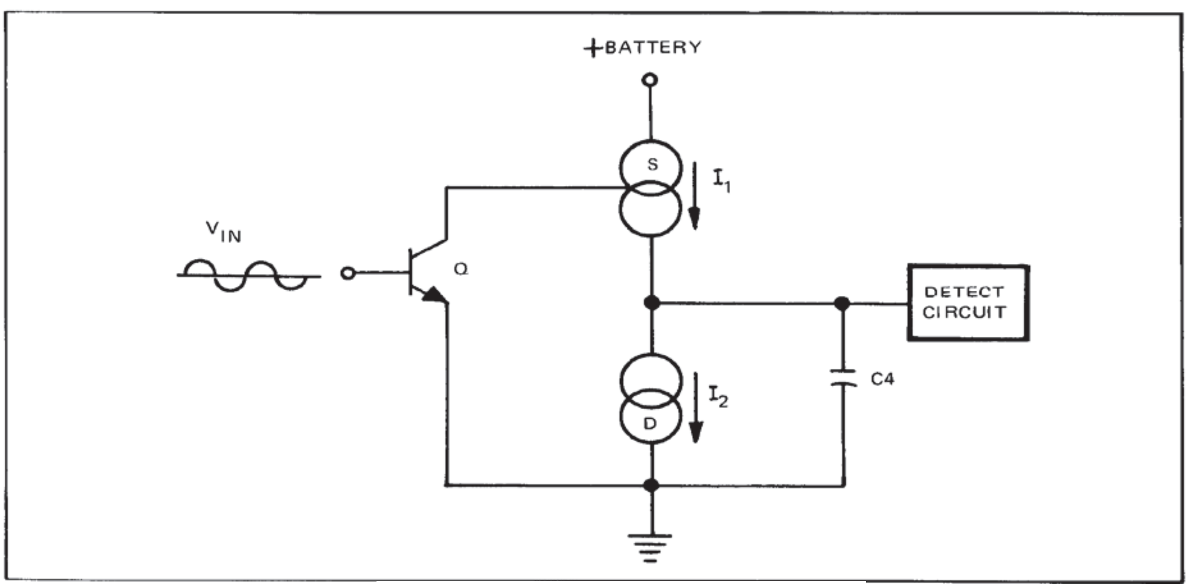


FIGURE 4-12 DETECTION CIRCUIT

The input circuit is modeled as shown in Figure 4-13. The impedance of this circuit is:

$$Z_{INPUT\ CKT} = \frac{L_S C(R_S R_P)S^2 + [C(R_S R_P + R_S R_L + R_L R_P) + L_S]\,S + R_P R_L)}{L_s C S^2 + C(R_P + R_L)S}$$

Where C_T = Transducer Capacitance
C_S = 2200 pf Storage Capacitor
R_S = 150 ohm Limiting Resistor
R_P = Resistance Of Secondary
L_S = Inductance Of Secondary
R_L = Resistance Of Load Across Secondary (To Lower Q)

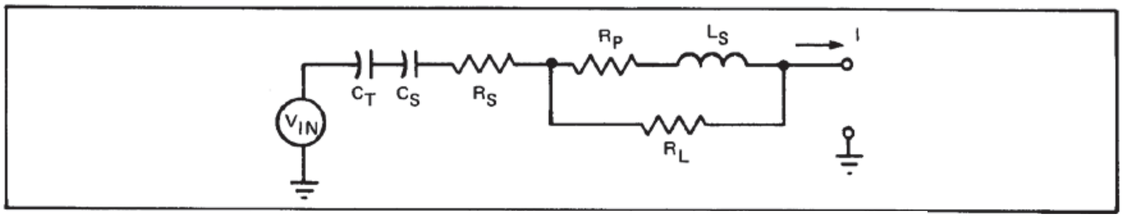


FIGURE 4-13 MODEL OF INPUT CIRCUIT

The tuned circuit is modeled as shown in Figure 4-14:

$$Z_{TUNED\ CKT} = \frac{R_P L_S = R_P R_C}{(R_P CL)S^2 + (R_P R_C C + L)S + (R_P + R_C)}$$

Where $R_P(t)$ = $R \| R_0(t)$
R = a fixed external resistor in parallel with the tuned circuit.
L = the inductance of the ferrite - enclosed coil
R_C = the resistance of the coil (~3 ohms)
C = the capacitance
$Ro(t)$ = the A.C. resistance which is a function of the D.C. current flowing through diodes inside the analog chip. This resistance follows the relation:

$$R_{A.D.} = \frac{KT/q}{|I_{D.C.}|}$$

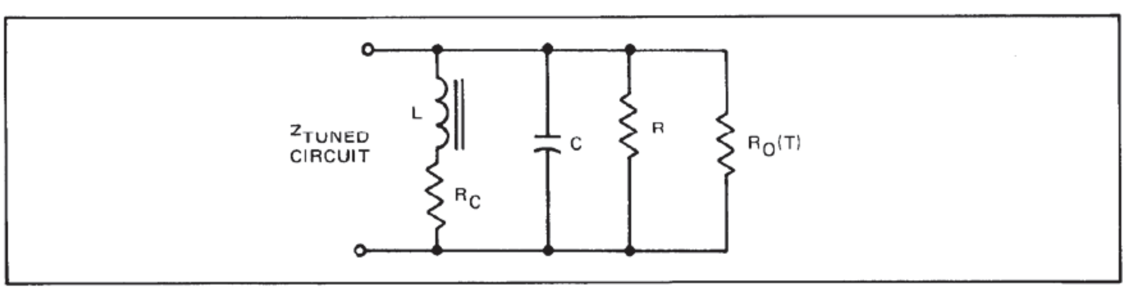


FIGURE 4-14 MODEL OF L-C TANK CIRCUIT

6. Receiver Buffer Amplifier

This amplifier (Figure 4-15) consists of a differential amplifier input and emitter-follower output. It provides a voltage gain of approximately 20 db and prevents the tuned circuit from being loaded by subsequent stages.

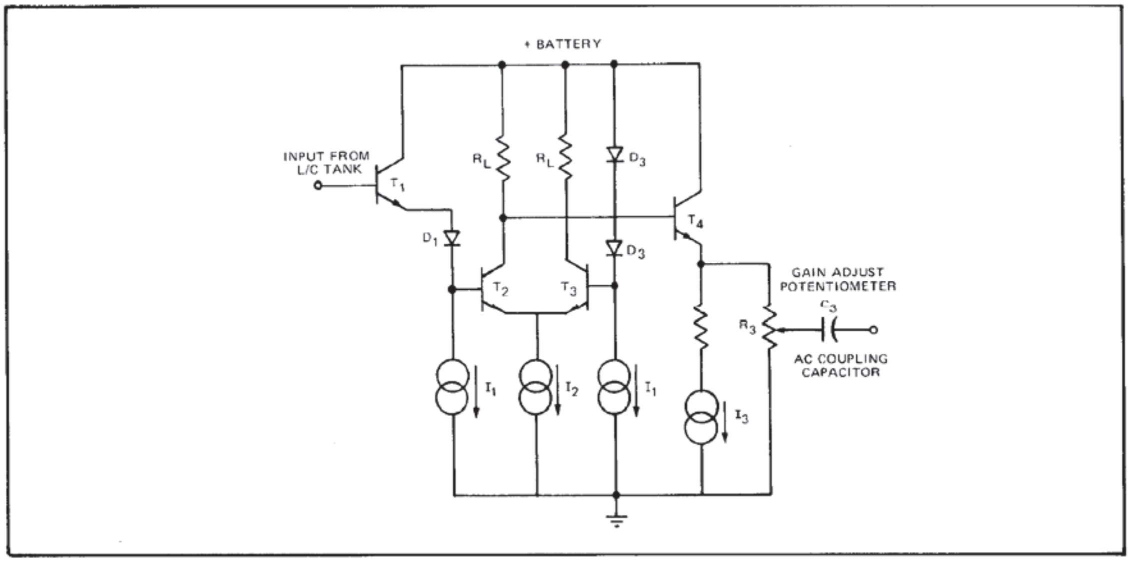


FIGURE 4-15 RECEIVER BUFFER AMPLIFIER

7. Receiver Gain 2 Amplifier

This amplifier (Figure 4-16) is AC coupled to the potentiometer. It consists of a basic multiplier circuit followed by a current-to-voltage converter. The gain of this stage is varied by changing the bias current (I_B), in eight discrete increments (steps 9-16 on graph 1).

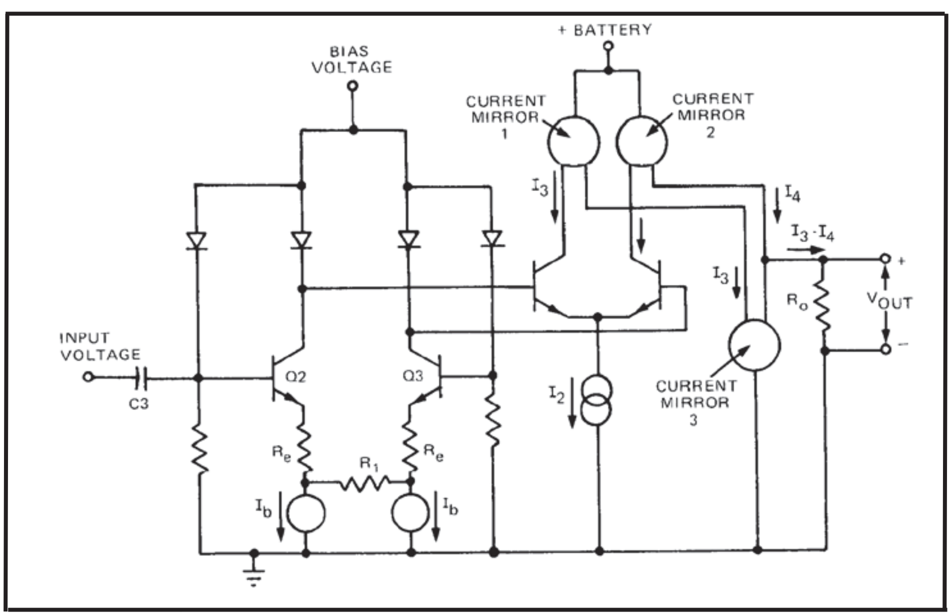


FIGURE 4-16 SECOND AMPLIFIER STAGE - MULTIPLIER

The gain is defined by:

$$\frac{V_{OUT}}{V_{IN}} = \frac{R_O I_2}{I\,(R_L + 2r_e)}$$

where r_e is the emitter resistance of transistors Q2 and Q3. Current lb is generated by an exponential amplifier connected to the summing mode of the digital-to-analog converter shown in Figure 4-17.

I_a and l_b are a function of gain control lines A, B, and C. Because of the difficulty in process control, the magnitudes of these currents will vary from circuit to circuit. However, the gain curve can be shifted by changing $R_{FEEDBACK.}$ This ensures that at least at one distance, all devices will exhibit similar gain.

E. Ranging Module Gain

Four logic signals control the system gain and bandwidth as a function of time. The timing and performance relationships between the logic signals, gain and bandwidth are shown in Figure 4-18

The gain controlling logic can be observed at the following points (Figure 4-18):

GCA at pin 14 of U1
GCB at pin 13 of U1
GCC at pin 12 of U1
GCD at pin 15 of U1

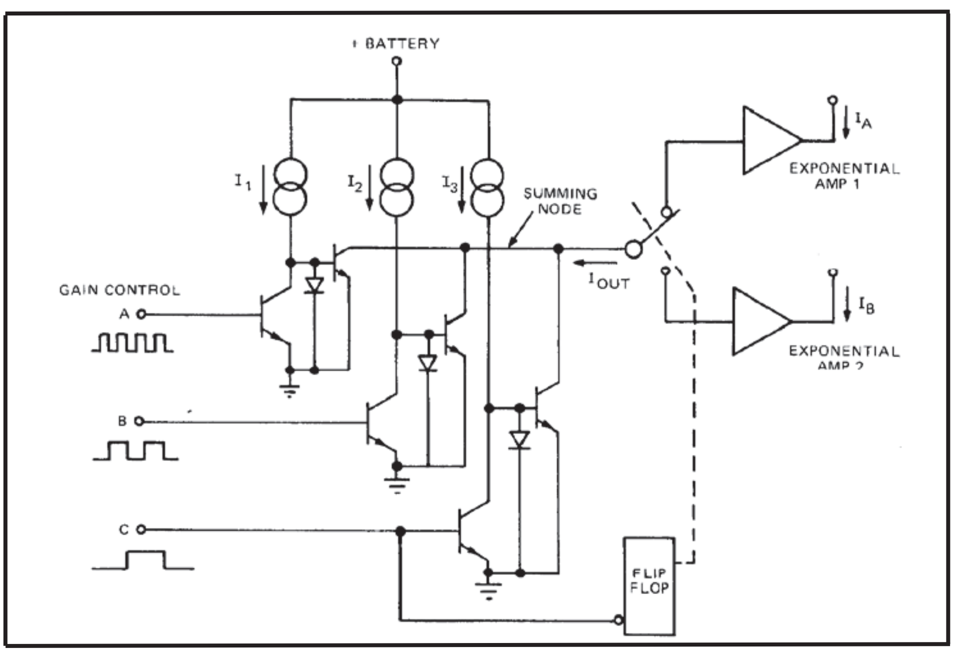


FIGURE 4-17 D /A CONVERTER

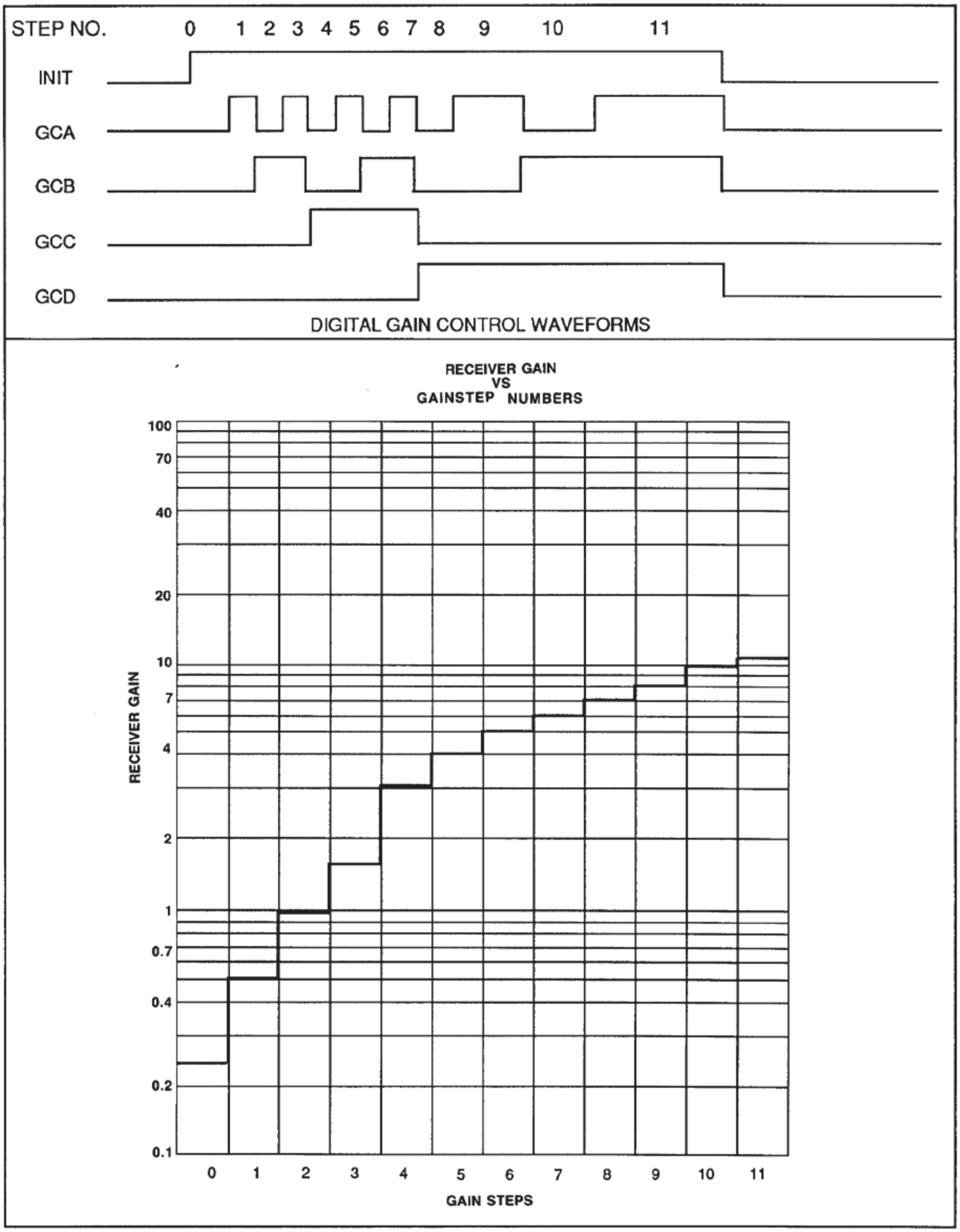


FIGURE 4-18 GAIN CONTROL

PID# 606782 – Series 600 Environmental Grade OEM Kit

- Two (2) – Series 600 Environmental Grade Electrostatic Transducers (PID# 607281)
- Two (2) – Series 6500 SMT Sonar Ranging Modules (PID# 615088)
- Four (4) – Female Transducer Clips (PID# 735714A) **
- Two (2) – Flexible Ribbon Cables with Connectors (PID# 1B0579A/1B0580A)
- One (1) – Plastic Storage Tray (PID# 746380)
- One (1) – OEM Kit Systems Manual (PID# 61010x)

PID# 606783 – Series 600 Instrument Grade OEM Kit

- Two (2) – Series 600 Instrument Grade Electrostatic Transducers (PID# 604142)
- Two (2) – Series 6500 SMT Sonar Ranging Modules (PID# 615088)
- Four (4) – Female Transducer Clips (PID# 735714A) **
- Two (2) – Flexible Ribbon Cables with Connectors (PID# 1B0579A/1B0580A)
- One (1) – Plastic Storage Tray (PID# 746380)
- One (1) – OEM Kit Systems Manual (PID# 61010x)

PID# 606784 – Series 600 Open Face OEM Kit

- Two (2) – Series 600 Open Face Electrostatic Transducers (PID# 604144)
- Two (2) – Series 6500 SMT Sonar Ranging Modules (PID# 615088)
- Four (4) – Female Transducer Clips (PID# 735714A) **
- Two (2) – Flexible Ribbon Cables with Connectors (PID# 1B0579A/1B0580A)
- One (1) – Plastic Storage Tray (PID# 746380)
- One (1) – OEM Kit Systems Manual (PID# 61010x)

PID# 606785 – Series 7000 OEM Kit

- Two (2) – Series 7000 Electrostatic Transducers (PID# 604565)
- Two (2) – Series 6500 SMT Sonar Ranging Modules (PID# 615088)
- Four (4) – Female Transducer Clips (PID# 735714A) **
- Two (2) – Flexible Ribbon Cables with Connectors (PID# 1B0579A/1B0580A)
- One (1) – Plastic Storage Tray (PID# 746380)
- One (1) – OEM Kit Systems Manual (PID# 61010x)

PID# 606790 – Series 9000 Piezoelectric OEM Kit

- Two (2) – Series 9000 Piezoelectric Transducers (PID# 618417)
- Two (2) – Series 9000 SMT Sonar Ranging Modules (PID# 615085)
- Two (2) – Flexible Ribbon Cables with Connectors (PID# 1B0579A/1B0580A)
- One (1) – Plastic Storage Tray (PID# 746380)
- One (1) – OEM Kit Systems Manual (PID# 61010x)

****** The 6500 Sonar Ranging Module comes with a 2-wire cable with these clips already installed for connecting to the Electrostatic Transducers. The Female Transducer clips (PID# 735714A) are included with the kit as spare connectors if you wish to assemble your own cable, such as for longer length, etc.

A. Suggested User-Supplied Drive Circuits for Initiate (INIT)

Although there may be other methods for driving the Ultrasonic Ranging Unit, these circuit configurations have been tested and found to perform well while being simple to construct. In addition, they will enable you to quickly use and evaluated the ultrasonic ranging module.

The primary components in the following configurations are CMOS devices (74C14 Hex triggers) which work quite well as drive circuits.

1. Symmetrical Drive Circuit

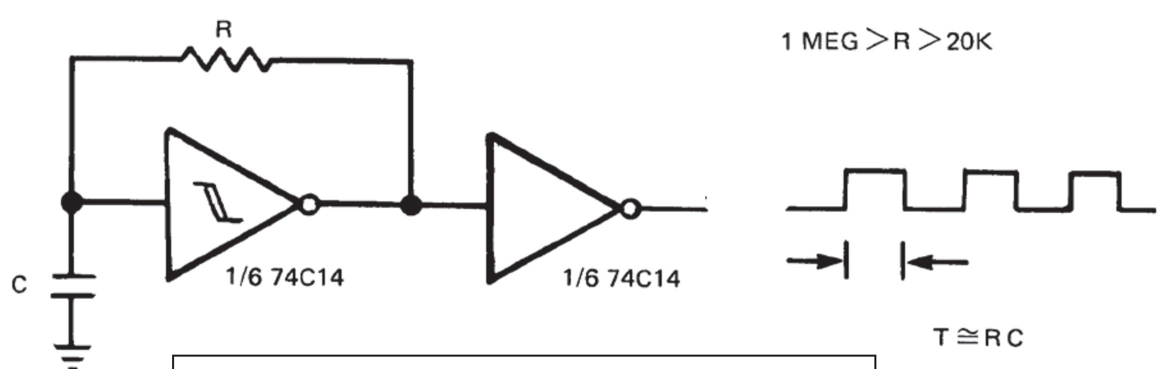


FIGURE B-1 SYMMETRICAL DRIVE CIRCUIT

Figure B-1 is a symmetrical drive circuit, suitable for generating 1 to 5 repetitions per second (rps). Both pulse duration and off-time are approximately equal to T = R x C.

2. Asymmetrical Drive Circuit

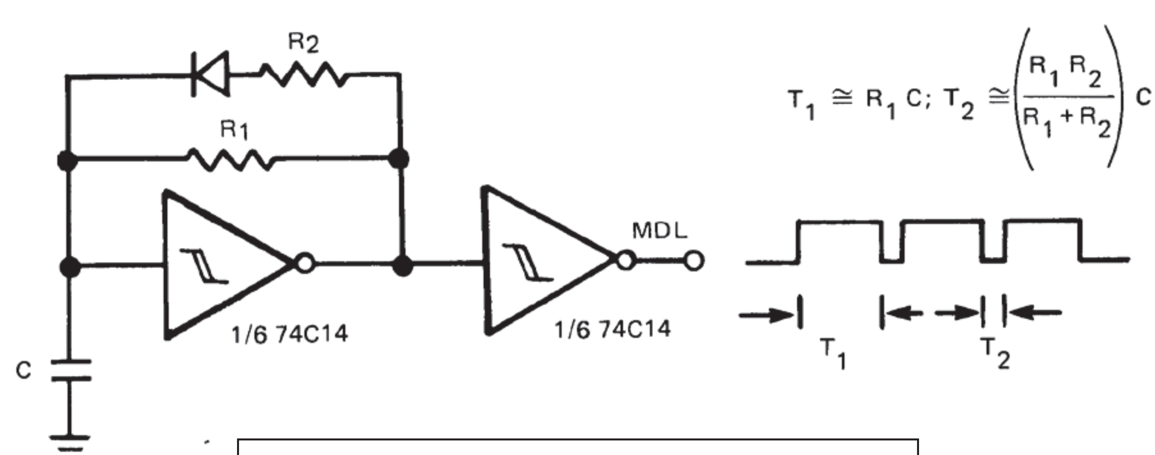


FIGURE B-2 ASYMMETRICAL DRIVE CIRCUIT

Figure B-2 is an asymmetrical drive, capable of providing up to 10 rps with long "on" symmetry. As above, pulse duration is approximately equal to T1 = R1C; however, the off time is approximately equal to T2 = (R1R2/R1+R2) x C.

3. Slow Asymmetrical Drive Circuitt

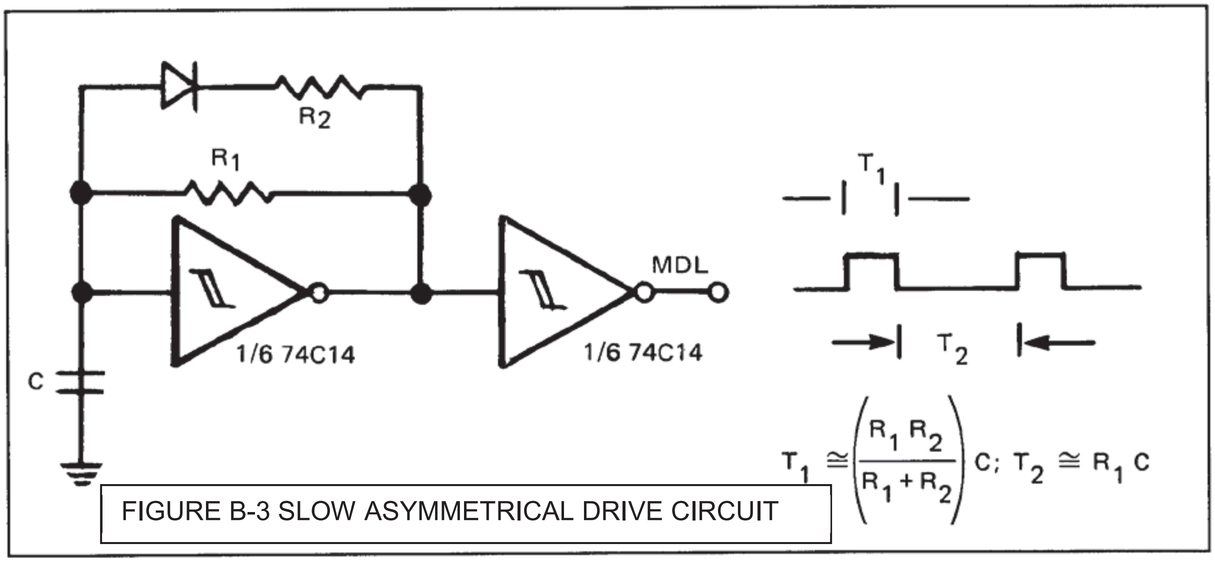


FIGURE B-3 SLOW ASYMMETRICAL DRIVE CIRCUIT

Figure B-3 is also an asymmetrical drive; however, it is designed to provide as little as 4 repetitions per minute with long "off" symmetry. Pulse duration is approximately equal to:

$$T1 = (R1R2/R1+R2) \times C$$

and pulse off time is approximately equal to:

$$T2 = R1 \times C$$

A. Suggested User-Supplied Application and Demonstration Circuits

The circuits in this Appendix are provided for reference only. There are many other methods for driving the Ultrasonic Ranging System. These circuit configurations may help to enable you to quickly use and evaluate the Ultrasonic Ranging Module.

The primary components in the following configurations are CMOS devices which work quite well as drive circuits.

1. Multiple Systems Support

Figure C-1 is included here for its application value rather that as a general drive circuit. It is a method of cycling several systems in sequence repeatedly so that they do not interfere with each other.

This circuit is a digital system utilizing a symmetrical drive. (All components are identified on the drawing.) Very slow repetition rates can be achieved with this circuit, and it can be used to drive up to eight modules in sequential order.

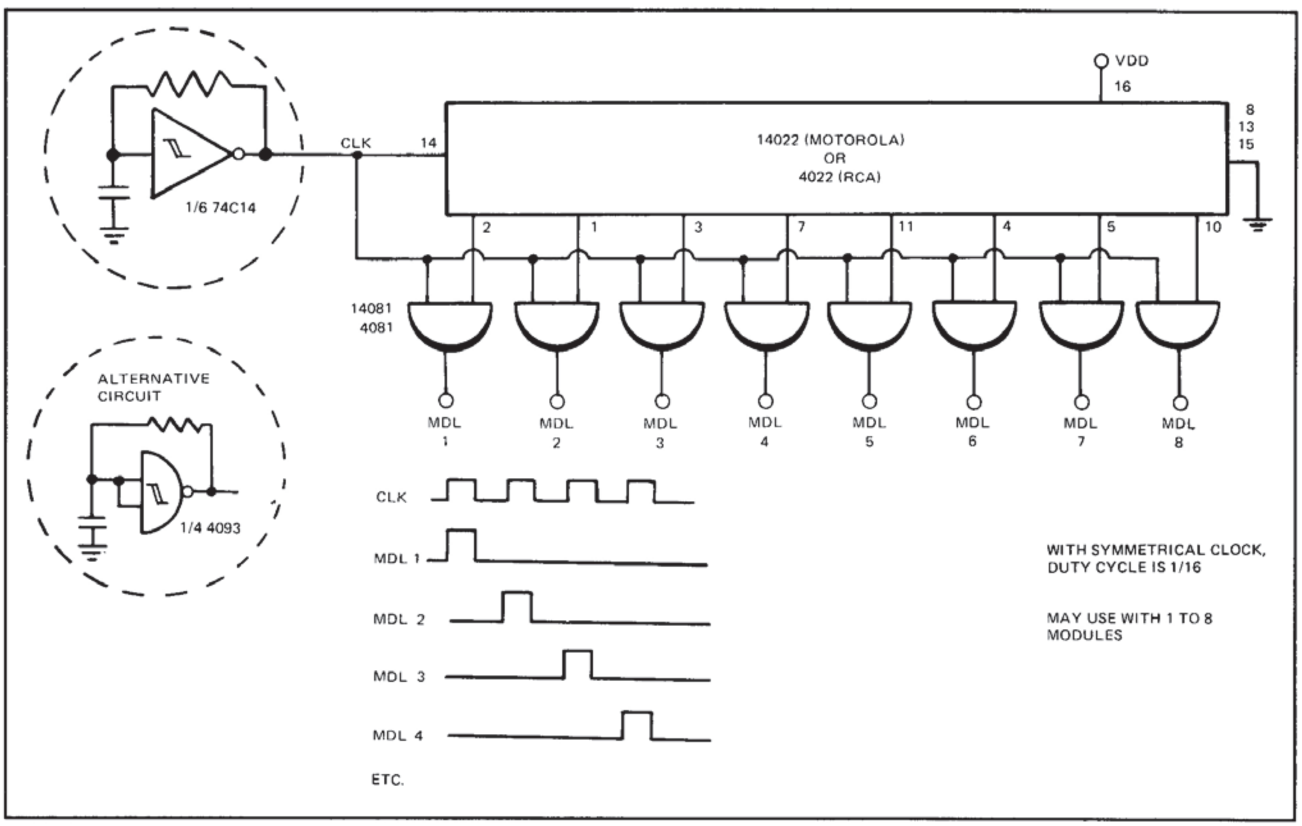
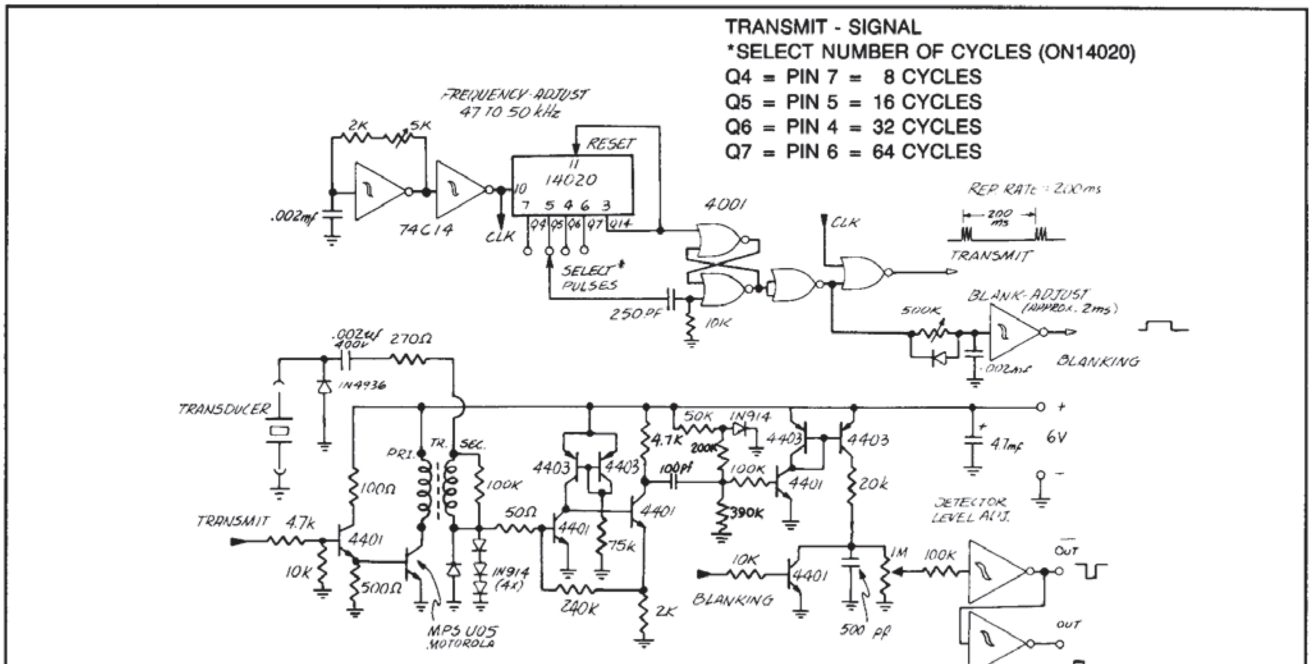


Figure C-1 MULTIPLE SYSTEMS SUPPORT

2. Fixed Gain Tester Circuit

Figure C-2 is a fixed-gain test circuit. It is a simple circuit that may be built from readily available parts. The circuit produces a single frequency transmit burst of 8, 16, 32 or 64 cycles and repeats at regular intervals of about 20 milliseconds. It features adjustable blanking, a fixed gain amplifier, a detector and complementary, buffered, echo-detect outputs. The transmit frequency is adjustable by means of a potentiometer. This circuit is intended as a starting point in arriving at a system design where the sophistication of the Ultrasonic circuit board is not needed.



NOTE: TR can be either:

1. Ferroxcube 1107 A250 core wound with Primary = 5 turns #32 copper wire, Secondary = 220 turns #38 copper wire or
2. Ferrite Rod 3/4" long by 5/32" diameter wound with Primary = 30 turns of #28 copper wire, Secondary = 1000 turns of #44 copper wire or
3. Polaroid Transformer part No. 614096

FIGURE C-2 FIXED GAIN TESTING CIRCUIT

SensComp, Inc.
36704 Commerce Rd.
Livonia, MI 48150   USA
Telephone: (734) 953-4783
Fax: (734) 953-4518
www.senscomp.com

Series 600 Instrument Grade Ultrasonic Sensor

SensComp's Series 600 Instrument Grade Electrostatic Ultrasonic Sensor is specifically intended for operation in air at ultrasonic frequencies. The assembly comes complete with a perforated protective cover.

Features

50 kHz Electrostatic Ultrasonic Sensor
Beam Angle of 15° at -6 dB
Ranges from 6” to 35’
Excellent Receive Sensitivity
Integral Perforated Protective Cover.
Specifically Intended for Operation in Air at Ultrasonic Frequencies

Part No.

*PID# 604142 – Series 600 Instrument Grade Ultrasonic Sensor

*RoHS Compliant

Benefits

Able to Range from 6” to 35’
Excellent Receive Sensitivity

Applications

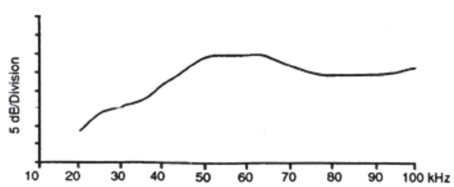
Level Measurement, Proximity Detection, Presence Detection, Robotics, Educational Products

Specifications

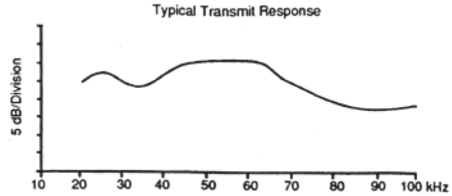
Description

The Series 600 ultra-sensitive ultrasonic sensors feature ranging capability from 2.5 cm to 15.2 m when used with SensComp drive electronics. They are ideally suited for demanding applications where the most sensitivity possible is the highest priority. These ultrasonic sensors are among the best available when detecting soft targets. They have a broad band frequency response.

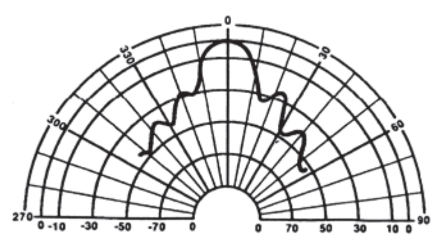
Transmit/Receive Response & Beam Pattern



Typical Transmit Response



Typical Free Field Receive Response



Typical Beam Pattern At 50 kHz

Note: dB normalized to on-axis response.
Note: Curves are representative only. Individual responses may differ.

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Series 600 Instrument Grade Specifications

Usable Frequency Range
- **Transmitting** .... See Graph
- **Receiving** .... See Graph

Beam Pattern .... See Graph
Typical: 15° at -6dB

Transmitting Sensitivity .... 110 dB min
at 50.0 kHz; 0dB re 20 μPa at 1 meter
(300 VAC_{PP}; 150 VDC bias)

Receiving Sensitivity .... -42 dB min
at 50.0 kHz; 0dB = 1 volt/ Pa
(150 VDC bias)

Distance Range .... 0.15 to 10.7 M (0.5 to 35 feet)

Resolution (± 1% over entire range) .... ± 3mm to 3m (± 0.12 to 10 ft)

Weight .... 8.2 gm (0.29 oz)

Suggested DC Bias Voltage 200V

Suggested AC Driving Voltage .... 200V peak

Combined Voltage .... 400V max

Capacitance at 1 kHz (typical) .... 400–500 pf
(at 150 VDC bias)

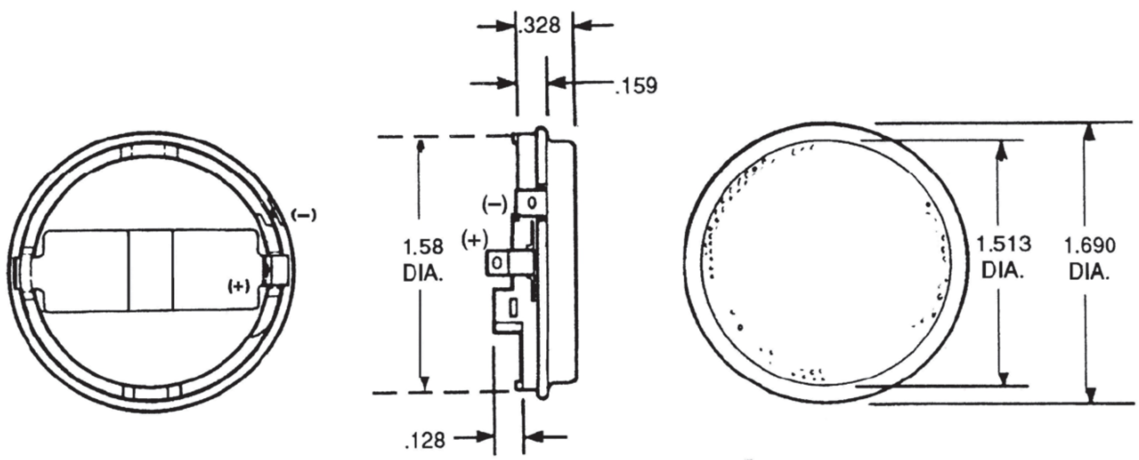
Operating Temperature .... -40 to +85° C (-40 to 185° F)

Relative Humidity (non-condensing) ..... 5% - 95%

Dimension
- **Thickness** .... 0.46 inch
- **Diameter** .... 1.69 inch

Standard Finish
- **Foil** .... Gold
- **Housing** .... Satin Black Painted 304 Stainless Steel

Notes:
[1] Lines which may occasionally appear in foil have no effect on product functionality or performance.
[2] Variations in die depth may result in minor variations of tolerances.



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SensComp, Inc.
36704 Commerce Rd.
Livonia, MI 48150 USA
Telephone: (734) 953-4783
Fax: (734) 953-4518
www.senscomp.com

Series 600 Environmental Grade Ultrasonic Sensor

SensComp's Series 600 Environmental Grade Electrostatic Ultrasonic Sensor is specifically intended for operation in air at ultrasonic frequencies. This ultrasonic sensor is identical to the Series 600 Instrument Grade Ultrasonic Sensor except that the outer housing is made of 304 stainless steel for harsh environments.

Features

50 kHz Electrostatic Ultrasonic Sensor
Beam Angle of 15° at -6 dB
Ranges from 6” to 35’
Excellent Receive Sensitivity
Better Suited for Harsh Environments
Stainless Steel Housing, Perforated Protective Cover.
Specifically Intended for Operation in Air at Ultrasonic Frequencies

Part No.

*PID# 607281 – Series 600 Environmental Grade Ultrasonic Sensor
*RoHS Compliant

Benefits

Able to Range from 6” to 35’
Excellent Receive Sensitivity

Applications

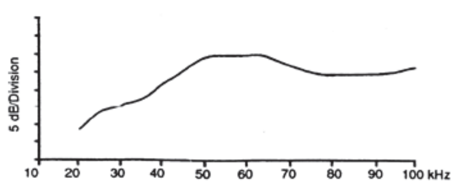
Level Measurement, Proximity Detection, Presence Detection, Robotics, Educational Products
Operation in Outdoor Environments

Specifications

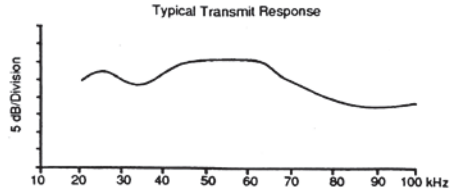
Description

The Series 600 ultra-sensitive ultrasonic sensors feature ranging capability from 2.5 cm to 15.2 m when used with SensComp drive electronics. They are ideally suited for demanding applications where the most sensitivity possible is the highest priority. These ultrasonic sensors are among the best available when detecting soft targets. They have a broad band frequency response.

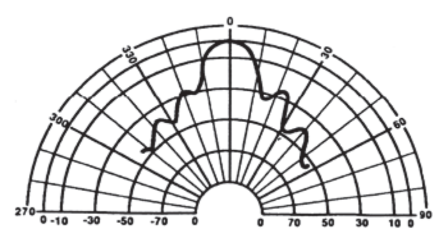
Transmit/Receive Response & Beam Pattern



Typical Transmit Response



Typical Free Field Receive Response



Typical Beam Pattern At 50 kHz

Note: dB normalized to on-axis response.
Note: Curves are representative only. Individual responses may differ.

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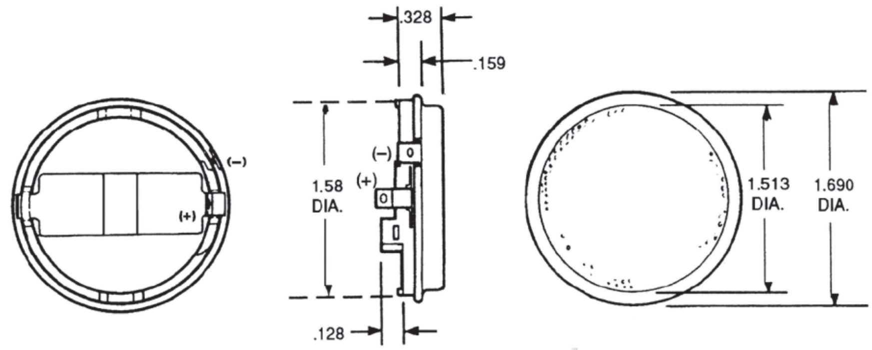


Specifications

Usable Frequency Range
- **Transmitting** .... See Graph
- **Receiving** .... See Graph

Beam Pattern .... See Graph
Typical: 15° at -6dB

Transmitting Sensitivity .... 110 dB min
at 50.0 kHz; 0dB re 20 µPa at 1 meter
(300 VAC_{PP}; 150 VDC bias)

Receiving Sensitivity .... -42 dB min
at 50.0 kHz; 0dB = 1 volt/Pa
(150 VDC bias)

Distance Range .... 0.15 to 10.7 M (0.5 to 35 feet)

Resolution (± 1% over entire range)....... ± 3mm to 3m (± 0.12 to 10 ft)

Weight .... 8.2 gm (0.29 oz)

Suggested DC Bias Voltage.................. 200V

Suggested AC Driving Voltage .... 200V peak

Combined Voltage .... 400V max

Capacitance at 1 kHz (typical) .... 400–500 pf
(at 150 VDC bias)

Operating Temperature .... -40 to +85° C (-40 to 185° F)

Storage Temperature............................. -40 to 120° C (-40 to 250° F)

Relative Humidity (non-condensing) ..... 5% - 95%

Dimension
- **Thickness** .... 0.46 inch
- **Diameter** .... 1.69 inch

Standard Finish
- **Foil** .... Gold
- **Housing** .... 304 Stainless Steel

Notes:

[1] Lines which may occasionally appear in foil have no effect on product functionality or performance.

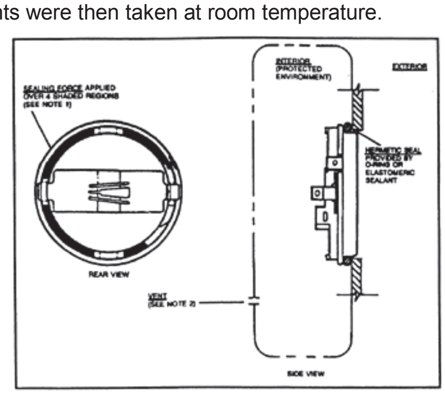
[2] Variations in die depth may result in minor variations of tolerances.

Environmental Characteristics & Exposures

Note: The following tests were performed in an environmentally controlled test facility with the ultrasonic sensor housed in a custom designed test enclosure. The test enclosure protects the ultrasonic sensor sides and back from exposure to any foreign matter. The rear of the ultrasonic sensor is vented to atmosphere pressure.

After each test, the ultrasonic sensors were cleaned and dried as necessary. Measurements were then taken at room temperature.

- Storage Temperature.................. -40 TO 120° C (-40 to 250 ° F)
- Salt Spray Exposure (96 hours)... 5% salt spray solution at 95 °
- Shock and Vibration.................... 50 G peak in each direction along 3 perpendicular axes, pulse duration: 6.5 ms; 6 G's RMS 20-2000 Hz for 6 minute.
- Water Immersion (24 hours) .... (vent hole sealed)
- Freeze/Thaw Cycle (4 cycles) ..... Spray with water, drain, expose to -20° F (-30° C) for 20 minutes, allow to warm to room temperature.
- Chemical Exposure..................... Gasoline, acetone, sulphur dioxide. Samples sprayed with/ exposed to chemical, then placed in120° F (49° C) / 90% relative humidity environment for 24 hours.



No claims are made for performance without an enclosure providing protection equal to or better than the test enclosure described above. Similarly, no claim is made for performance in any other environments or under any other condition than those controlled conditions described herein.

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www.senscomp.com

Series 600 Open Face Ultrasonic Sensor

SensComp's Series 600 Open Face Electrostatic Ultrasonic sensor is specifically intended for operation in air at ultrasonic frequencies. This ultrasonic sensor extends the range of applications for electrostatic ultrasonic sensor technology, is Parylene coated, and the outer housing is made of 304 stainless steel for harsh environments.

Features

Open Face Construction
Parylene Coated
50 kHz Electrostatic Ultrasonic sensor
304 Stainless Steel Housing
Narrow Beam Angle of 15° at -6 dB
Low Ring Characteristics

Part No.

*PID# 604144 – Series 600 Open Face Ultrasonic Sensor
*RoHS Compliant

Benefits

Improved Performance In:
- Dusty Environments
- Harsh Chemical Environments

Splash and Moisture Resistant
Resistant to Organic and Inorganic Solvents
Excellent Receive Sensitivity
Able to Range from 6” to 35’

Applications

Level Measurement in Tanks
Proximity Detection in Harsh Industrial and Agricultural Environments

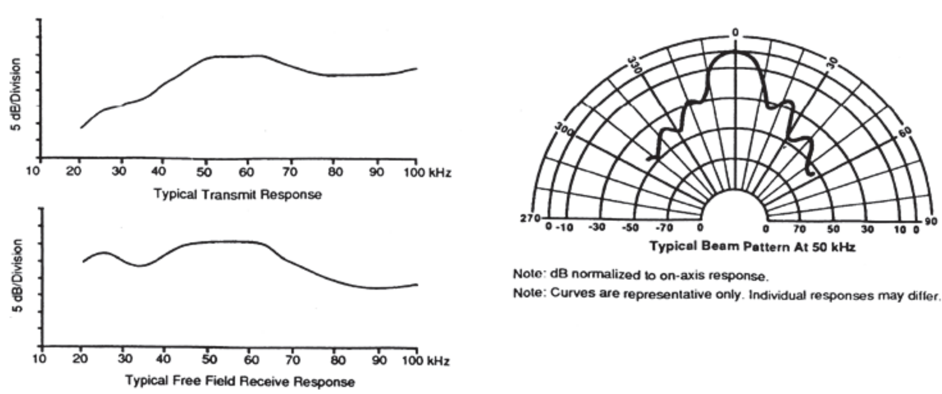
Specifications

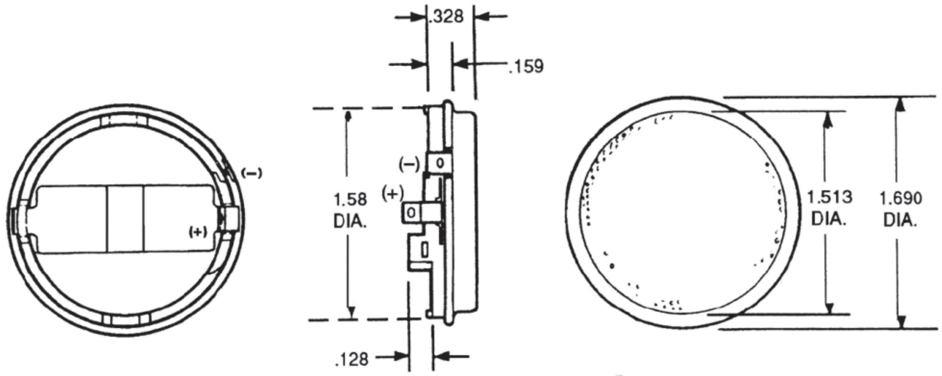
Description

The open face construction of SensComp’s Series 600 Ultrasonic sensor minimizes the potential of dust and powdered material collecting on the front face of the ultrasonic sensor.

The added protection of the Parylene conformal coating makes this ultrasonic sensor splash resistant and able to operate more efficiently in harsh chemical environments containing organic and inorganic solvents. Additionally, the Parylene coating provides extended protection against corrosion and mechanical abrasion.

Transmit/Receive Response & Beam Pattern





Specifications

Usable Frequency Range
Transmitting .... See Graph
Receiving .... See Graph
Beam Pattern .... See Graph
Typical: 15° at -6dB
Transmitting Sensitivity .... 110 dB min
at 50.0 kHz; 0dB re 20 μPa at 1 meter
(300 VAC_{PP}; 150 VDC bias)
Receiving Sensitivity .... -42 dB min
at 50.0 kHz; 0dB = 1 volt/Pa
(150 VDC bias)
Distance Range .... 0.15 to 10.7 M (0.5 to 35 feet)
Resolution (± 1% over entire range)....... ± 3mm to 3m (± 0.12 to 10 ft)
Weight .... 8.2 gm (0.29 oz)

Suggested DC Bias Voltage.................. 200V
Suggested AC Driving Voltage .... 200V peak
Combined Voltage .... 400V max
Capacitance at 1 kHz (typical) .... 400–500 pf
(at 150 VDC bias)
Operating Temperature .... -40 to +85° C (-40 to 185° F)
Storage Temperature............................. -40 to 120° C (-40 to 250° F)
Relative Humidity (non-condensing) ..... 5% - 95%
Dimension
Thickness .... 0.46 inch
Diameter .... 1.69 inch
Standard Finish
Foil .... Gold
Housing .... 304 Stainless

Notes:

[1] Lines which may occasionally appear in foil have no effect on product functionality or performance.

[2] Variations in die depth may result in minor variations of tolerances.

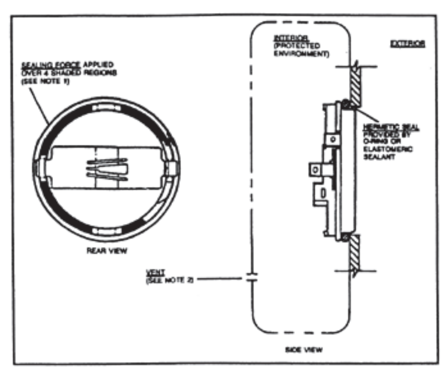
Environmental Characteristics & Exposures

Note: The following tests were performed in an environmentally controlled test facility with the ultrasonic sensor housed in a custom designed test enclosure. The test enclosure protects the ultrasonic sensor sides and back from exposure to any foreign matter. The rear of the ultrasonic sensor is vented to atmosphere pressure.

After each test, the ultrasonic sensors were cleaned and dried as necessary. Measurements were then taken at room temperature.

Storage Temperature -40 TO 120° C (-40 to 250 ° F)

- Salt Spray Exposure (96 hours)... 5% salt spray solution at 95 °
- Shock and Vibration..................... 50 G peak in each direction along 3 perpendicular axes, pulse duration: 6.5 ms; 6 G's RMS 20-2000 Hz for 6 minute.
- Water Immersion (24 hours) .... (vent hole sealed)
- Freeze/Thaw Cycle (4 cycles) ..... Spray with water, drain, expose to -20° F (-30° C) for 20 minutes, allow to warm to room temperature.
- Chemical Exposure...................... Gasoline, acetone, sulfur dioxide. Samples sprayed with/ exposed to chemical, then placed in120° F (49° C) / 90% relative humidity environment for 24 hours.



No claims are made for performance without an enclosure providing protection equal to or better than the test enclosure described above. Similarly, no claim is made for performance in any other environments or under any other condition than those controlled conditions described herein.

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www.senscomp.com

Series 7000 Ultrasonic Sensor

SensComp's Series 7000 Electrostatic Ultrasonic sensor is specifically intended for operation in air at ultrasonic frequencies. The assembly comes complete with a perforated protective cover.

Features

50 KHz Electrostatic Ultrasonic sensor
Beam Angle of 17° at -3 dB
Ranges from 6” to 35’
Excellent Receive Sensitivity
Perforated Plastic Protective Cover.
Specifically Intended for Operation in Air at Ultrasonic Frequencies

Part No.

*PID# 612366 – Series 7000 Ultrasonic sensor (with electrical connecting clips)
*PID# 614565 – Series 7000 Ultrasonic sensor (without electrical connecting clips)
*RoHS Compliant

Benefits

Able to Range from 6” to 35’
Excellent Receive Sensitivity

Applications

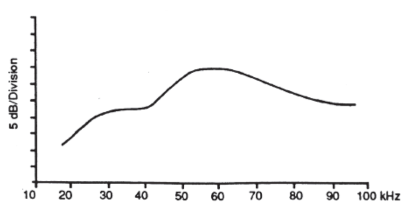
Level Measurement, Proximity Detection, Presence Detection, Robotics, Educational Products

Specifications

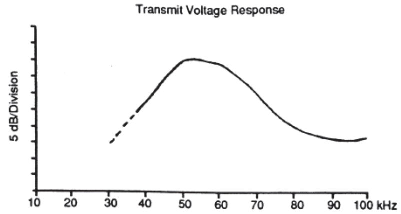
Description

The Series 7000 ultra-sensitive ultrasonic sensors feature ranging capability from 2.5 cm to 15.2 m when used with SensComp drive electronics. They are ideally suited for demanding applications where the most sensitivity possible is the highest priority. These ultrasonic sensors are among the best available when detecting soft or small targets.

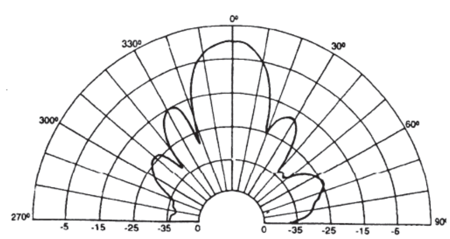
Transmit/Receive Response & Beam Pattern



Transmit Voltage Response



Receive Voltage Response



Typical Beam Pattern At 50 kHz

Note: dB normalized to on-axis response.
Note: Curves are representative only. Individual responses may differ.

Series 7000 Specifications

Usable Frequency Range
- **Transmitting** .... See Graph
- **Receiving** .... See Graph

Beam Pattern .... See Graph
Typical: 17° at -3dB

Transmitting Sensitivity .... 106.9 dB min
at 50.0 kHz; 0dB re 20 μPa at 1 meter
(300 VAC_{PP}; 150 VDC bias)

Receiving Sensitivity .... -43.4 dB min
at 50.0 kHz; 0dB = 1 volt/Pa
(150 VDC bias)

Distance Range .... 0.15 to 10.7 M (0.5 to 35 feet)

Resolution (± 1% over entire range)....... ± 3mm to 3m (± 0.12 to 10 ft)

Weight .... 4.7 gm (0.15 oz)

Suggested DC Bias Voltage.................. 200V

Suggested AC Driving Voltage .... 200V peak

Combined Voltage .... 400V max

Capacitance at 1 kHz (typical) .... 600-700 pf
(at 150 VDC bias)

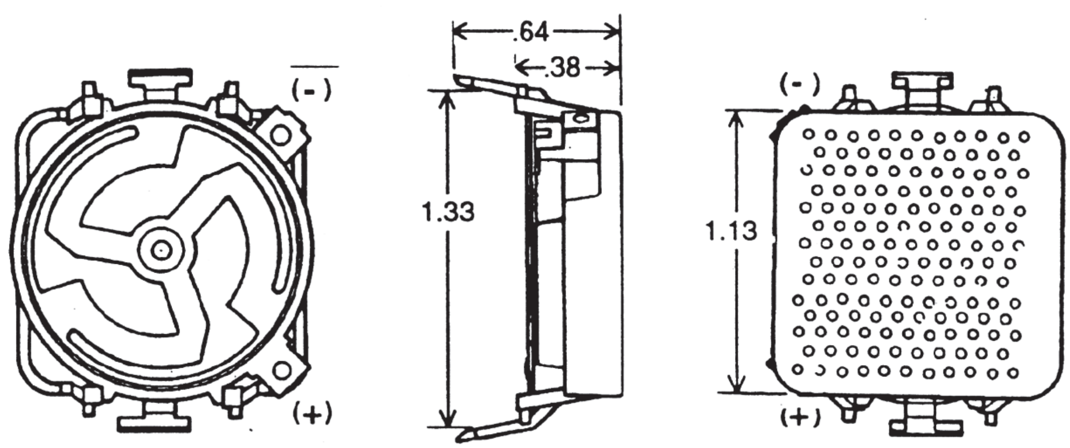
Operating Temperature .... -40 to +85° C (-40 to 185° F)

Relative Humidity (non condensing) .... 5% - 95%

Dimension
- **Thickness** .... 0.41 inch
- **Square Size** .... 1.13 inch

Standard Finish
- **Foil** .... Gold
- **Housing** .... Flat Black Plastic

Notes:
[1] Lines which may occasionally appear in foil have no effect on product functionality or performance.
[2] Variations in die depth may result in minor variations of tolerances.



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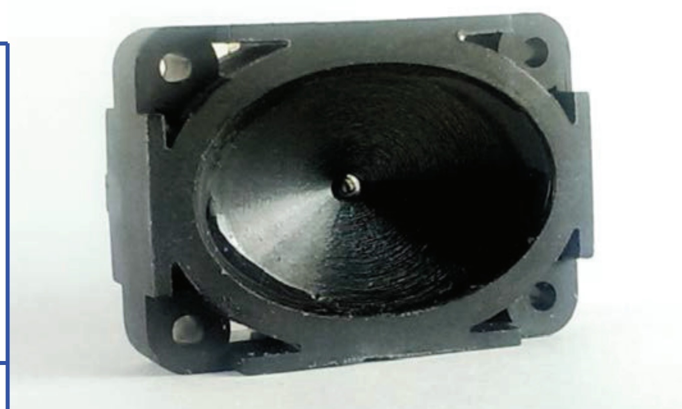
Series 9000 Transducer

SensComp's Series 9000 Piezoelectric transducer is specifically intended for operation in air at ultrasonic frequencies.

Features

48 kHz Piezoelectric Transducer
Asymmetrical Beam Angle of 18° by 30° (typ.)
Rugged Construction
Suited for Harsh Environments
Specifically Intended for Operation in Air at Ultrasonic Frequencies



Part No.

*PID# 618417LF – Series 9000 Transducer

*RoHS Compliant

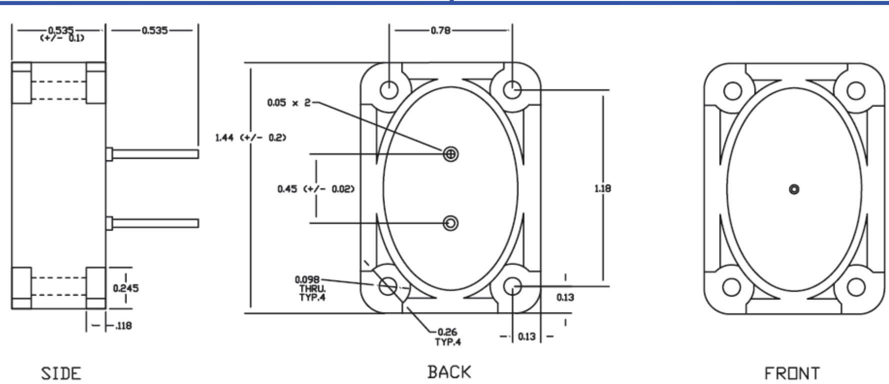
Benefits

Meets or Exceeds SAE Specification J1455 for Heavy-duty Trucks
Withstands Demands of Automotive Exteriors

Level Measurement, Proximity Detection, Presence Detection, Robotics, Educational Products
Operation in Outdoor Environments

Description

The Piezoelectric based Series 9000 transducer is specifically intended for operation in air at ultrasonic frequencies. Its rugged construction and unique asymmetrical beam pattern make it an ideal choice to withstand the rigorous demands of the automotive exterior and other harsh environments. This transducer design is intended to meet or exceed the guidelines set forth in SAE specification J1455 for heavy-duty trucks.



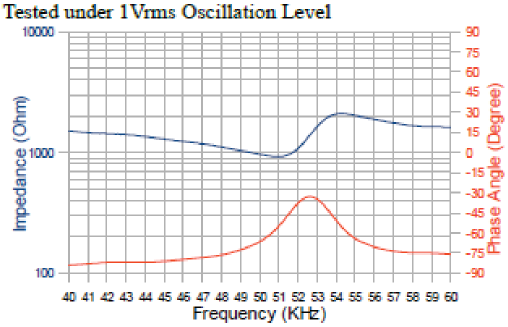
Series 9000 Specifications

Operating Frequency..........................48 KHz ±2 kHz
Ringing ....1.2 mS max.
Bandwidth (100dB) Transmitter..............15 kHz
(-80dB) Receive..................15 kHz
Transmitting Sound Pressure Level.......100 dB min
0dB re 0.0002 µbar at 30 cm,
10 Vrms, at 48 kHz
Receiving Sensitivity ....-80 dB min
at 48 kHz; 0dB = 1 volt/µbar
Total Beam Angle.................................. ...See Graph
Asymmetrical........................18° typ. x 30° typ.
Suggested AC Driving Voltage 10-120Vp-p
Driving Voltage (10% duty cycle) ....140Vp-p max
Impedance ....1000 ohms ±10%
at resonant frequency 48 kHz
Capacitance at 1 KHz ±20% ....2400 pF
Construction
Outer Housing....................................Valox Plastic
Cone...............................Anodized Aluminum
Dimensions in inches.........................See Drawing

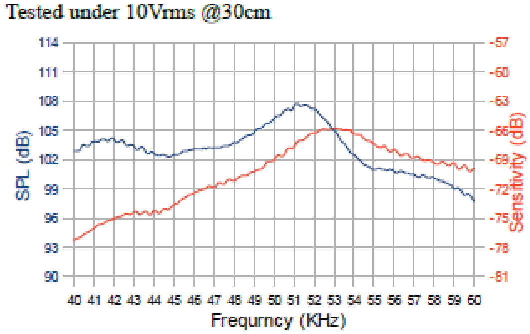
All specifications are taken @ 25°C typ.

Operating Temperature...........................-30 to +70°C
Storage Temperature ....-40 to +80°C
Relative Humidity (non condensing) ....98% at 38°C
Salt Spray ....5% @ 95% Rh
Altitude Operating ....12,000 feet
Non-Operating.....................40,000 feet
Dust, Sand, Gravel Bombardment ....
1 quart #50 Abrasive Sand, 3.6 ft. drop,
(20) Repetitions
Mechanical Vibration
10 G Random Triaxial Vibration,
50 Hz – 2 KHz for 1 hour
Mechanical Shock
Survives a 3 foot drop on concrete floor
Steam Cleaning
Input Pressure
4.5 bf/in^2 min at 200° F
Pressure Wash
102 lb/ in^2 at 104° F at 150 gal/minute
Chemical Exposure
Gasoline, Solvent, Cleaners, Lubricants

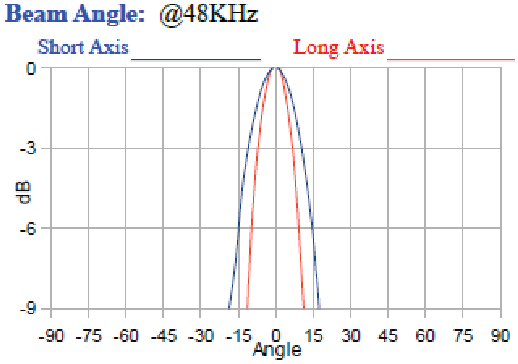
Impedance/Phase Angle vs. Frequency
Tested under 1Vrms Oscillation Level



Sensitivity/Sound Pressure Level
Tested under 10Vrms @30cm



Beam Angle: @48KHz



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SMT 6500 Ranging Modules

SensComp 6500 Ranging Modules provide the drive electronics for SensComp Electrostatic Ultrasonic sensors

Features

Accurate Sonar Ranging from 6 inches to 35 feet

Drives a 50 kHz Electrostatic Ultrasonic sensor without an Additional Interface

Operates from a Single Power Supply Source

Accurate Clock Output Provided for External Use

Selective Echo Exclusion

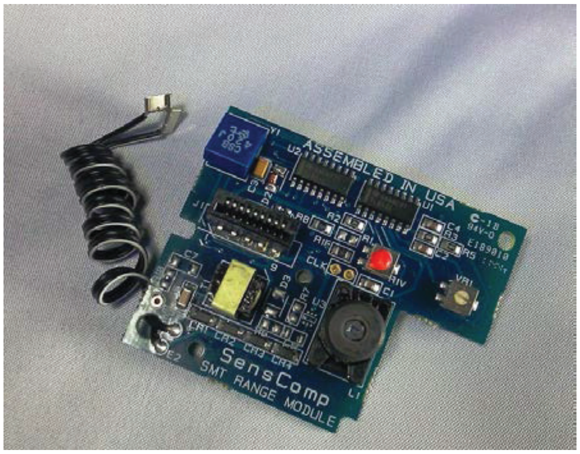
TTL Compatible

Multiple Measurement Capability

Integrated Ultrasonic sensor Cable

Variable Gain Control Potentiometer

Specifications



Part No.

*PID# 615078LF – SMT 6500 Ranging Module

*PID# 615079LF – SMT 6500E Ranging Module, Enhanced (Includes Pull-up Resistors and an Internal Oscillator for Repetitive Operation)

*PID# 615080LF – SMT 6500NC Ranging Module Without Connector (J1)

*RoHS Compliant

Description

The SMT 6500 series are economical sonar ranging modules that can drive all SensComp electrostatic ultrasonic sensors. This module, with a simple interface, is able to measure distances from 6 inches to 35 feet. The typical accuracy is +/- 1% of the reading over the entire range.

This module has an external blanking input that allows selective echo exclusion for operation on a multiple-echo mode. The module is able to differentiate echos from objects that are only three inches apart. The digitally controlled gain, variable bandwidth amplifier minimizes noise and side-lobe detection in sonar applications.

The module has an accurate ceramic resonator controlled 420 kHz time base generator. An output based on the 420 kHz time base is provided for external use. The sonar transmit output is 16 cycles at a frequency of 49.4 kHz.

The 6500 Series module operates over a DC power supply range from 4.5 volts to 6.8 volts (5 volts nominal) and is characterized for operation from 0° C to 70° C

Absolute Maximum Ratings over Operating Free-air temperature range

Voltage from any pin to ground (see Note 1) .... 7 VDC
Voltage from any pin except XDCR to V_{CC} (see Note 1) .... -7 VDC to 0.5 VDC
Operating free-air temperature range .... 0° C to 70° C
Storage temperature range............ -40° C to 85° C

NOTE 1: The XDCR pin may be driven from -1 volt to 400 volts typical with respect to ground.

Recommended Operating Conditions

		MIN	MAX	UNIT
Supply Voltage, Vcc		4.5	6.8	V
High-level Input Voltage, VIH	BLNK, BINH, INIT	2.1		V
Low-level Input Voltage, VIL	BLNK, BINH, INIT		0.6	V
ECHO and OSC Output Voltage			6.8	V
Delay Time, Power Up to INIT High		5		ms
Recycle Period		80		ms
Operating Free-air Temperature, T_A		0	70	°C

Electrical Characteristics over Recommended Ranges of Supply Voltage And Operating Free-Air Temperature

PARAMETER		TEST COND.	MIN	TYP	MAX	UNIT
Input Current	BLNK, BINH, INIT	V_I = 2.1 V			1	mA
High-level Output Current, I_{OH}	ECHO, OSC	V_{OH} = 5.5V			100	µA
Low-level Output Voltage, V_{OL},	ECHO, OSC	I_{OL}= 1.6 mA			0.4	V
Ultrasonic sensor Bias Voltage		T_A = 25° C		200		V
Ultrasonic sensor Output Voltage (peak to peak)		T_A = 25° C		400		V
No. of Cycles for XDCR Output to Reach 400V		C = 500 pF			7	
Internal Blanking Interval				2.38†		ms
XMIT Drive Signal Duration				1.1†		ms
Frequency During 16-pulse Transmit Period	OSC output			49.4†		kHz
	XMIT output			49.4†		kHz
Frequency After 16-pulse Transmit Period	OSC output			93.3†		kHz
	XMIT output			0		kHz
Supply Current, Icc	During transmit period				2000	mA
	After transmit period				100	mA

† These typical values apply for a 420 kHz ceramic resonator

Operation With SensComp Electrostatic Ultrasonic Sensors

There are two basic modes of operation for the 6500 Series Sonar Ranging Modules: Single-echo mode and multiple-echo mode. The application of power (V_{CC}), the application of the initiate (INIT) input, and the resulting transmit output, and the use of the Blanking Inhibit (BINH) input are basically the same for either mode of operation. After applying power (V_{CC}) a minimum of 5 milliseconds must elapse before the INIT signal can be taken high. During this time, all internal circuitry is reset and the internal oscillator stabilizes. When INIT is raised to a high level, drive to the ultrasonic sensor (XDCR) output occurs. Sixteen pulses at 49.4 kHz with an amplitude of 0 volts to 400 volts peak to peak will excite the ultrasonic sensor as transmission occurs. At the end of the 16 transmitted pulses, a 200 VDC bias remains on the ultrasonic sensor (as recommended) for optimum receiving operation.

In order to eliminate ringing of the ultrasonic sensor from being detected as a return signal, the Receive (REC) input of the ranging control IC is inhibited by internal blanking for 2.38 milliseconds after the initiate signal. If a reduced blanking time is desired, then the BINH input can be taken high to end the blanking of the Receive input any time prior to internal blanking. This may be desirable to detect objects closer than 1.33 feet (corresponding to 2.38 milliseconds) and may be done if ultrasonic sensor damping is sufficient so that ringing is not detected as a return signal.

In the single-echo mode of operation (Figure 1), all that must be done next is to wait for the return of the transmitted signal, traveling at approximately 0.9 milliseconds per foot out and back. The returning signal is amplified and appears as a high logic level echo output. The time between INIT going high and the Echo (ECHO) output going high is proportional to the distance of the target from the ultrasonic sensor. If desired, the cycle can now be repeated by returning INIT to a low logic level and then taking it high when the next transmission is desired.

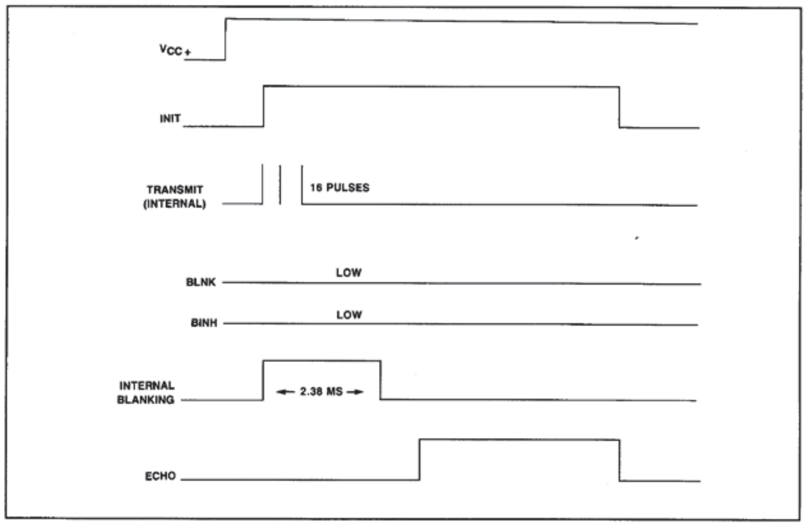


FIGURE 1: EXAMPLE OF A SINGLE-ECHO-MODE CYCLE WITHOUT BLANKING INPUT

If there is more than one target and a single transmission detects multiple echos, then the cycle is slightly different (Figure 2). After receiving the first return signal which causes the ECHO output to go high, the Blanking (BLNK) input must be taken high then back low to reset the ECHO output for the next return signal. The blanking signal must be at least 0.44 milliseconds in duration to account for all 16 returning pulses from the first target and allow for internal delay times. This corresponds to the two targets being three inches apart.

During a cycle starting with INIT going high, the receiver amplifier gain is increased at discrete times (Figure 3) since the transmitted signal is attenuated with distance. At approximately 38 milliseconds, the maximum gain is attained. Although gain can be increased by varying R1 (see Component Layout), there is a limit to which the gain can be increased for reliable module operation. This will vary from application to application. The modules are “kitted” prior to their final test during manufacture. This is necessary because the desired gain distribution is much narrower than the module gain distribution if all were kitted with one value resistor. As kitted, these modules will perform satisfactorily in most applications. As a rule of thumb, the gain can be increased up to a factor of four, if required, by increasing R1 correspondingly. Gain is directly proportional to R1.

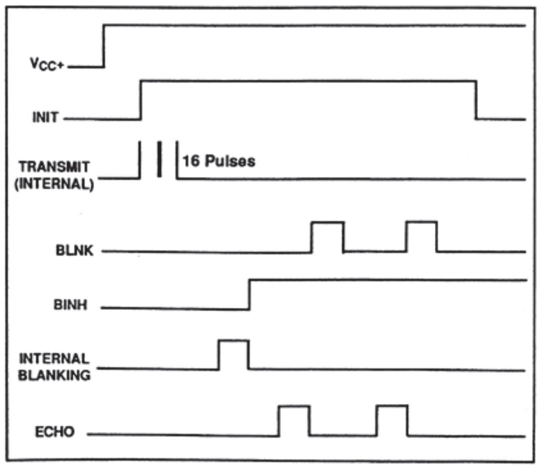


FIGURE 2: EXAMPLE OF A MULTIPLE-ECHO-MODE CYCLE WITH BLANKING INPUT

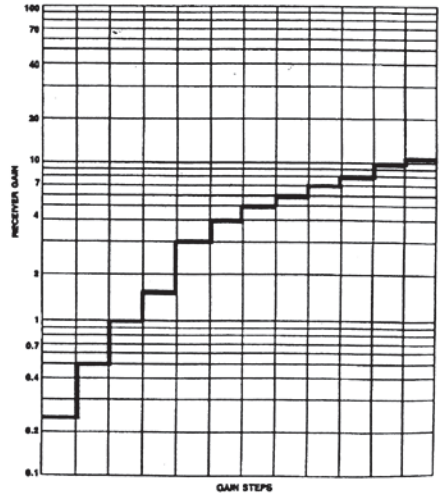


FIGURE 3: RECEIVER GAIN VS GAINSTEP NUMBERS

Input/Output Schematic Notes:

The ECHO and OSC outputs are open collector NPN transistor outputs (Figure 4) requiring 4.7 K ohm pull-up resistors between V_{CC} and the output.

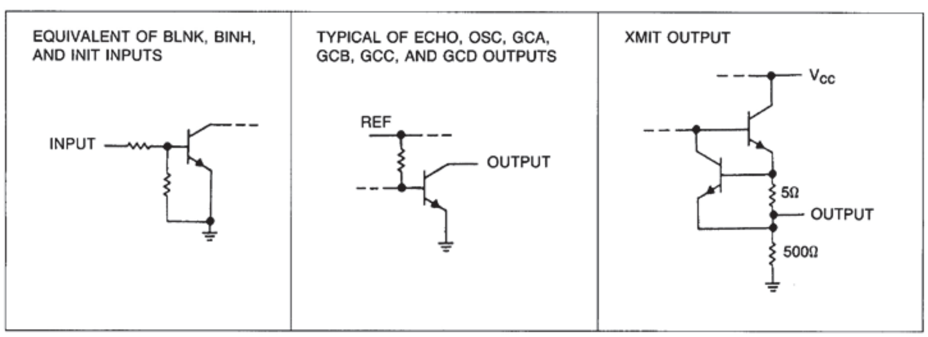
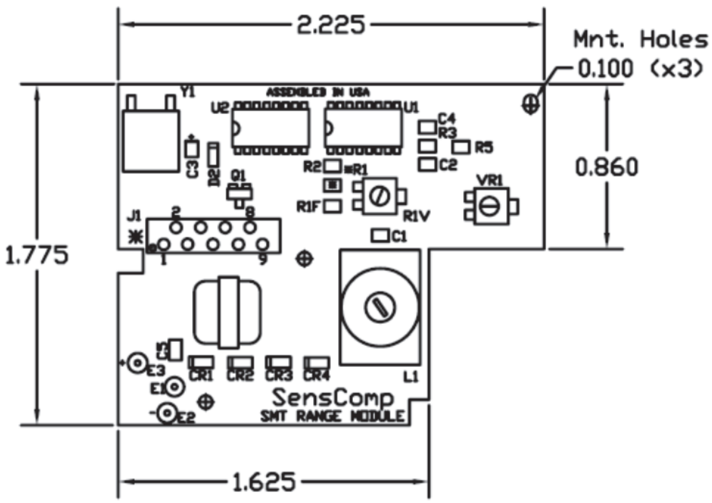


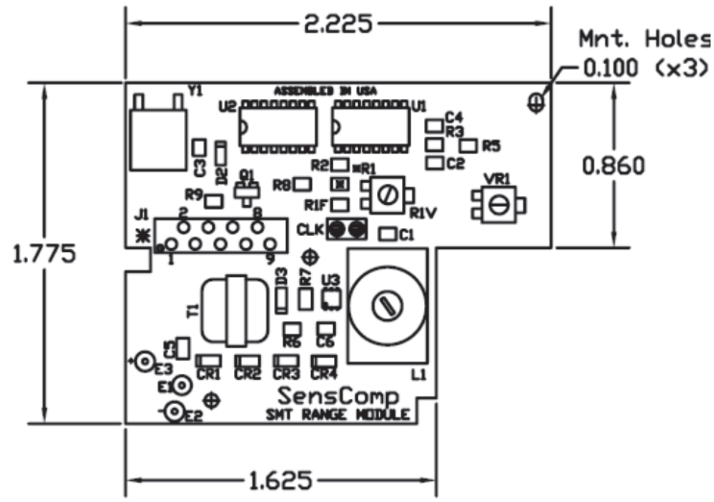
FIGURE 4: SCHEMATIC EQUIVALENT CIRCUITS OF BOARD INPUTS/OUTPUTS

Component Layouts



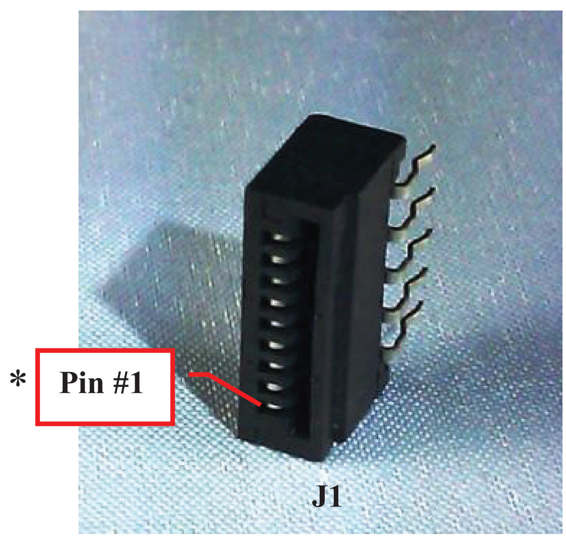
SMT Series
6500 Ranging Module

(PID#615078LF, #615080LF)



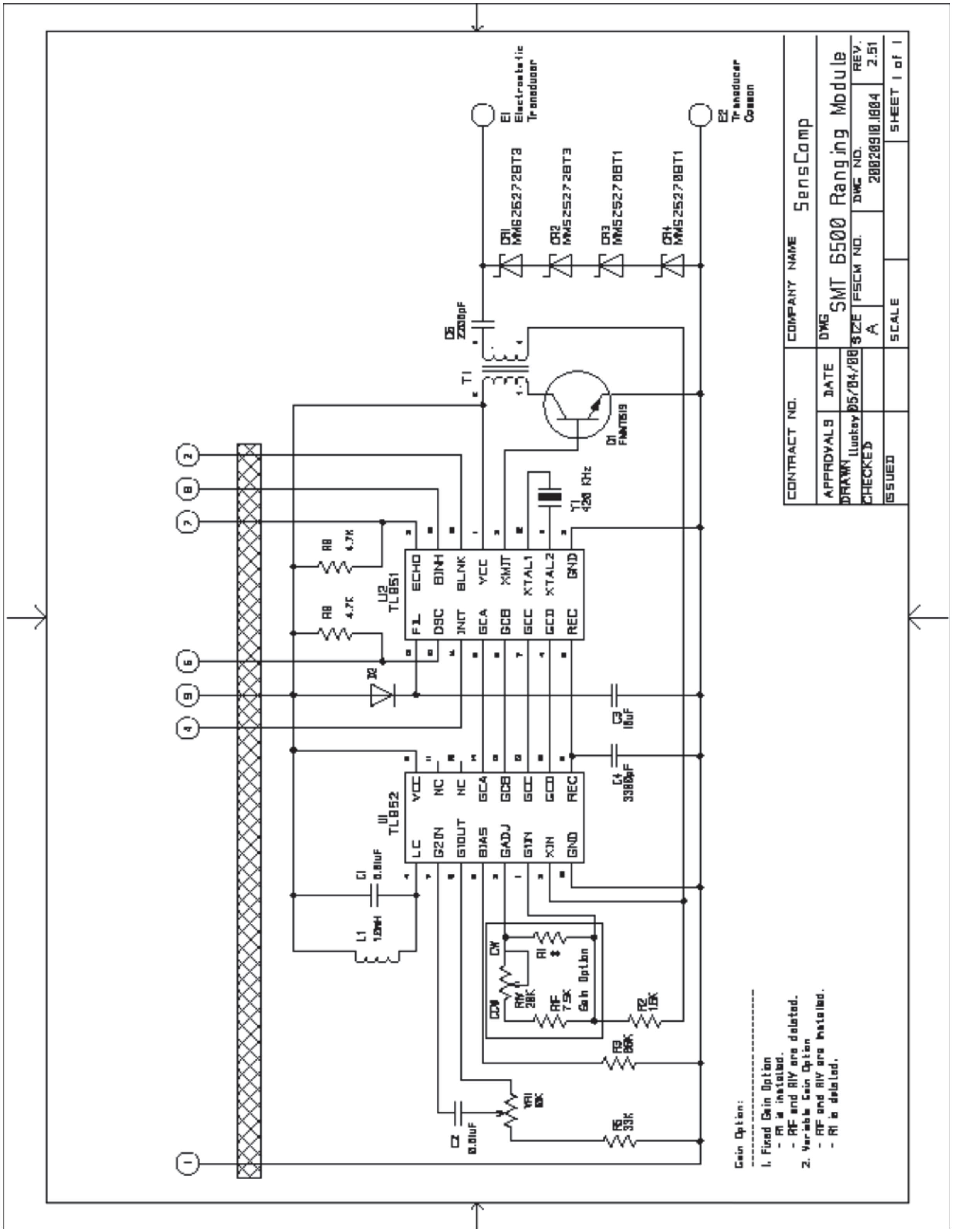
SMT Series
6500E Ranging Module

(PID#615079LF)

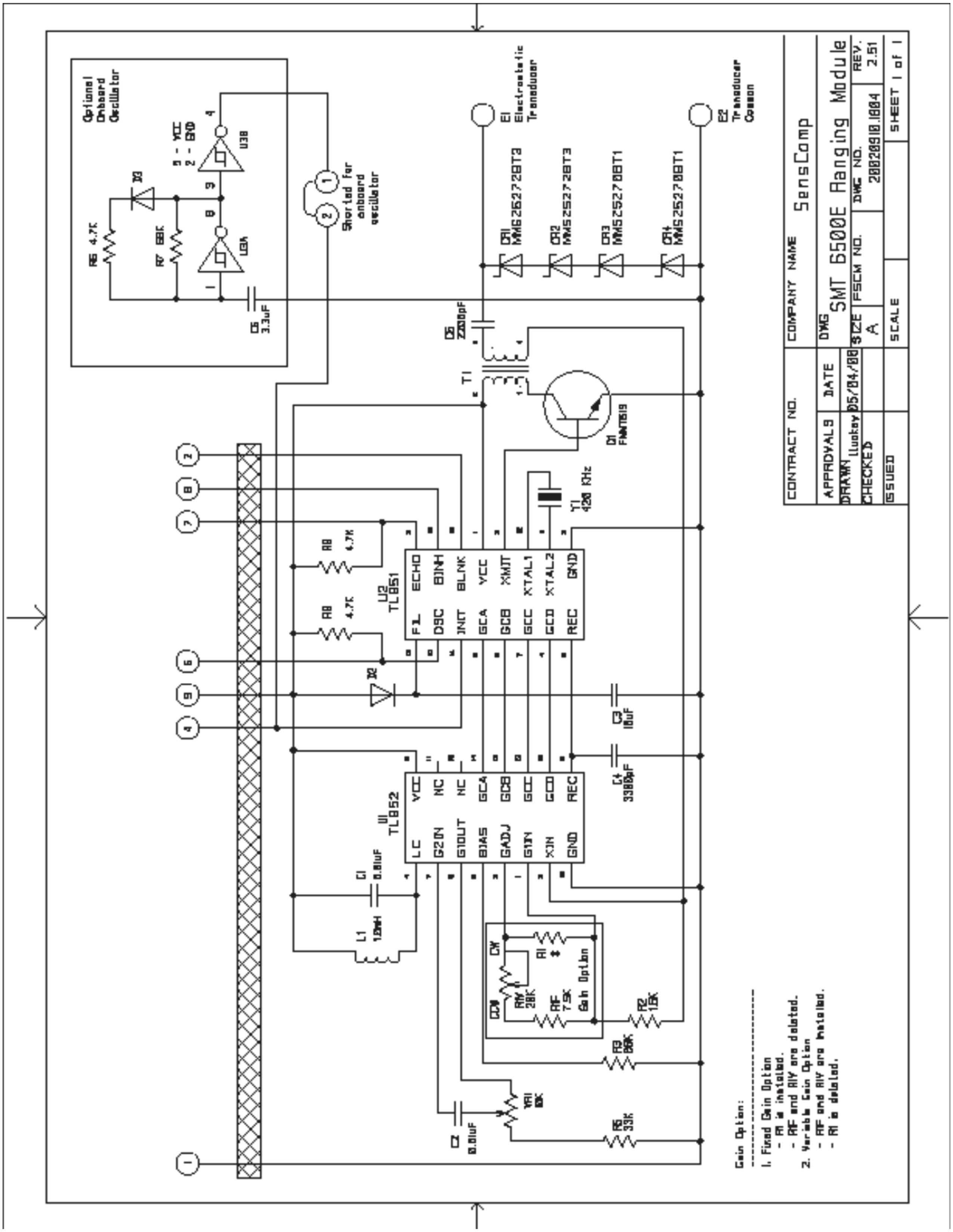


***NOTE:** J1 internal contacts only make connection on one side of the connector; pin 1 position may change on mating connector.

Schematic –SMT 6500 Ranging Module



Schematic – SMT 6500E Ranging Module



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SMT Series 9000 Ranging Modules

SensComp's Ranging Modules provide the drive electronics for SensComp Series 9000 Ultrasonic Sensors

Features

- Accurate Sonar Ranging from 12 inches to 18 feet
- Drives a 45 kHz Series 9000 Piezoelectric Ultrasonic sensor Without an Additional Interface
- Operates from a Single Power Supply Source
- Accurate Clock Output Provided for External Use
- Selective Echo Exclusion
- TTL Compatible
- Multiple Measurement Capability
- Integrated Ultrasonic sensor Cable
- Variable Gain Control Potentiometer

Part No.

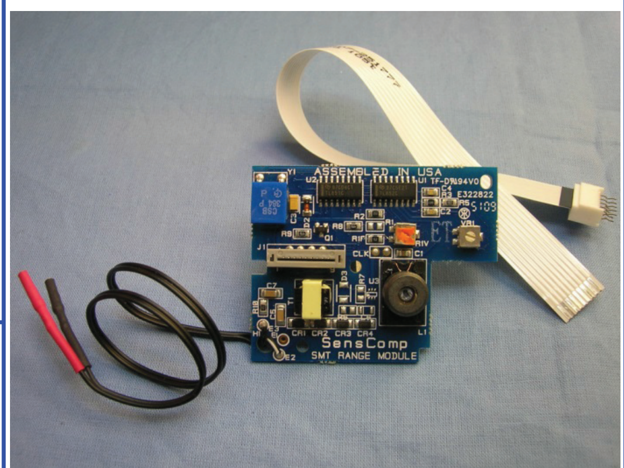
PID# 615085 – SMT Series 9000 Ranging Module

*PID# 615086 – SMT Series 9000E Ranging Module, Enhanced (Includes Pull-up Resistors and a Cycle Oscillator for Repetitive Operation)

PID# 615087 – SMT Series 9000NC Ranging Module without Connector (J1)

*RoHS Compliant

Specifications



PID#615085 Shown

Description

The SMT Series 9000 is an economical sonar ranging module that can drive SensComp's Series 9000 Piezoelectric Ultrasonic sensor. This module, with a simple interface, is able to measure distances from 12 inches to 18 feet. The typical accuracy is ±1% of the reading over the entire range.

This module has an external blanking input that allows selective echo exclusion for operation on a multiple-echo mode. The module is able to differentiate echoes from objects that are only three inches apart. The digitally controlled gain and variable bandwidth amplifier minimizes noise and side-lobe detection in sonar applications.

The module has an accurate ceramic resonator controlled 384 kHz time base generator. An output based on the 384 kHz time base is provided for external use. The sonar transmit output is 16 cycles at a frequency of 45 kHz.

The Series 9000 module operates over a DC power supply range from 4.5 volts to 6.8 volts (5 volts nominal) and is characterized for operation from 0° C to 70° C.

Absolute Maximum Ratings over Operating Free-Air Temperature Range

Voltage from any pin to ground (see Note 1) .... 7 VDC
Voltage from any pin except XDCR to V_{CC} (see Note 1) .... -7 VDC to 0.5 VDC
Operating free-air temperature range .... 0° C to 70° C
Storage temperature range .... -40° C to 85° C

NOTE 1: The XDCR pin may be driven from -1 volt to 400 volts typical with respect to ground.

Recommended Operating Conditions

		MIN	MAX	UNIT
Supply Voltage, Vcc		4.5	6.8	V
High-level Input Voltage, VIH	BLNK, BINH, INIT	2.1		V
Low-level Input Voltage, VIL	BLNK, BINH, INIT		0.6	V
ECHO and OSC Output Voltage			6.8	V
Delay Time, Power Up to INIT High		5		ms
Recycle Period		80		ms
Operating Free-Air Temperature, T_A		0	70	°C

Electrical Characteristics over Recommended Ranges of Supply Voltage and Operating Free-Air Temperature

PARAMETER		TEST COND.	MIN	TYP	MAX	UNIT
Input Current	BLNK, BINH, INIT	V_I = 2.1 V			1	mA
High-level Output Current, I_{OH}	ECHO, OSC	V_{OH} = 5.5V			100	µA
Low-level Output Voltage, V_{OL},	ECHO, OSC	I_{OL}= 1.6 mA			0.4	V
Ultrasonic sensor Output Voltage (peak to peak)		T_A = 25° C		120		V
No. of Cycles for XDCR Output to Reach 120V		C = 500 pF			7	
Internal Blanking Interval				2.38†		ms
XMIT Drive Signal Duration				1.1†		ms
Frequency During 16-Pulse Transmit Period	OSC Output			45†		kHz
	XMIT Output			45†		kHz
Frequency After 16-Pulse Transmit Period	OSC Output			83.3†		kHz
	XMIT Output			0		kHz
Supply Current, Icc	During Transmit Period				2000	mA
	After Transmit Period				100	mA

† These typical values apply for a 384 kHz ceramic resonator

Operation With SensComp Series 9000 Ultrasonic Sensors

There are two basic modes of operation for the Series 9000 Sonar Ranging Modules: Single-echo mode and multiple-echo mode. The application of power (V_{CC}), the application of the initiate (INIT) input, and the resulting transmit output, and the use of the Blanking Inhibit (BINH) input are basically the same for either mode of operation. After applying power (V_{CC}) a minimum of 5 milliseconds must elapse before the INIT signal can be taken high. During this time, all internal circuitry is reset and the internal oscillator stabilizes. When INIT is raised to a high level, drive to the ultrasonic sensor (XDCR) output occurs. Sixteen pulses at 45 kHz, with a 0 to 120 volts peak to peak amplitude, will excite the ultrasonic sensor as transmission occurs. At the end of the 16 transmitted pulses, the sonar ranging module switches to the receive mode.

In order to eliminate ringing of the ultrasonic sensor from being detected as a return signal, the Receive (REC) input of the ranging control IC is inhibited by internal blanking for 2.38 milliseconds after the initiate signal. If a reduced blanking time is desired, then the BINH input can be taken high to end the blanking of the Receive input any time prior to internal blanking. This may be desirable to detect objects closer than 1.33 feet (corresponding to 2.38 milliseconds) and may be done if ultrasonic sensor damping is sufficient so that ringing is not detected as a return signal.

In the single-echo mode of operation (Figure 1), all that must be done next is to wait for the return of the transmitted signal, traveling at approximately 0.9 milliseconds per foot out and back. The returning signal is amplified and appears as a high logic level echo output. The time between INIT going high and the Echo (ECHO) output going high is proportional to the distance of the target from the ultrasonic sensor. If desired, the cycle can now be repeated by returning INIT to a low logic level and then taking it high when the next transmission is desired.

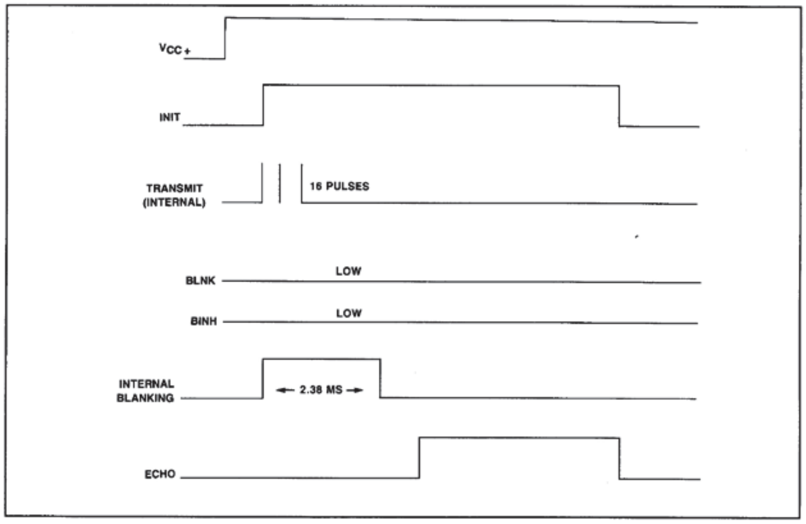


FIGURE 1: EXAMPLE OF A SINGLE-ECHO-MODE CYCLE WITHOUT BLANKING INPUT

If there is more than one target and a single transmission detects multiple echoes, then the cycle is slightly different (Figure 2). After receiving the first return signal which causes the ECHO output to go high, the Blanking (BLNK) input must be taken high then back low to reset the ECHO output for the next return signal. The blanking signal must be at least 0.44 milliseconds in duration to account for all 16 returning pulses from the first target and allow for internal delay times. This corresponds to the two targets being 3 inches apart.

During a cycle starting with INIT going high, the receiver amplifier gain is increased at discrete times (Figure 3) since the transmitted signal is attenuated with distance. At approximately 38 milliseconds, the maximum gain is attained. Although gain can be increased by varying R1 (see Component Layout), there is a limit to which the gain can be increased for reliable module operation. This will vary from application to application. The modules are “kitted” prior to their final test during manufacture. This is necessary because the desired gain distribution is much narrower than the module gain distribution if all were kitted with one value resistor. As kitted, these modules will perform satisfactorily in most applications. As a rule of thumb, the gain can be increased up to a factor of 4, if required, by increasing R1 correspondingly. Gain is directly proportional to R1.

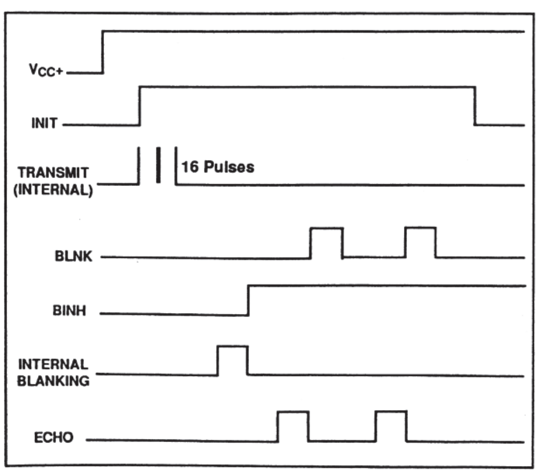


FIGURE 2: EXAMPLE OF A MULTIPLE-ECHO-MODE CYCLE WITH BLANKING INPUT

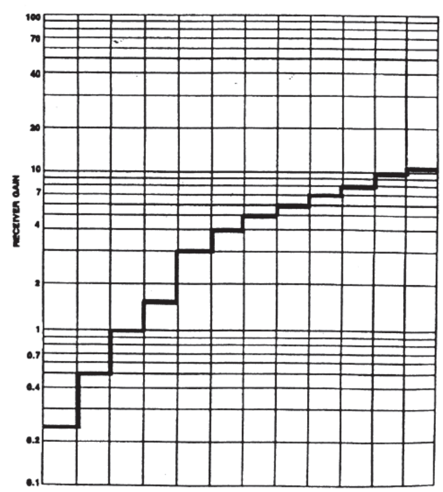


FIGURE 3: RECEIVER GAIN VS GAINSTEP NUMBERS

Input/Output Schematic Notes:

The ECHO and OSC outputs are open collector NPN transistor outputs (Figure 4) requiring 4.7K ohm pull-up resistors between V_{CC} and the output.

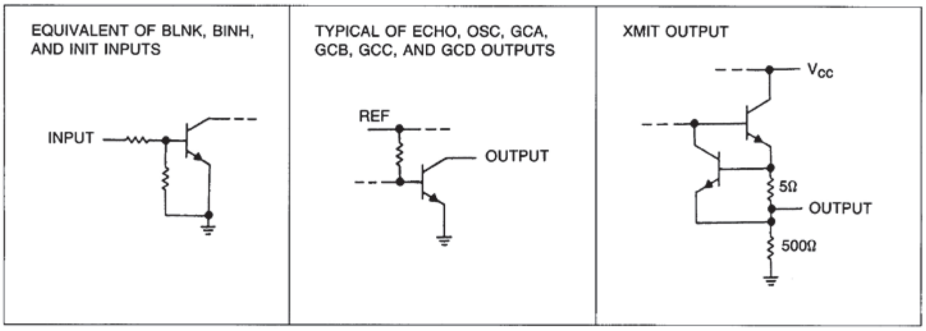
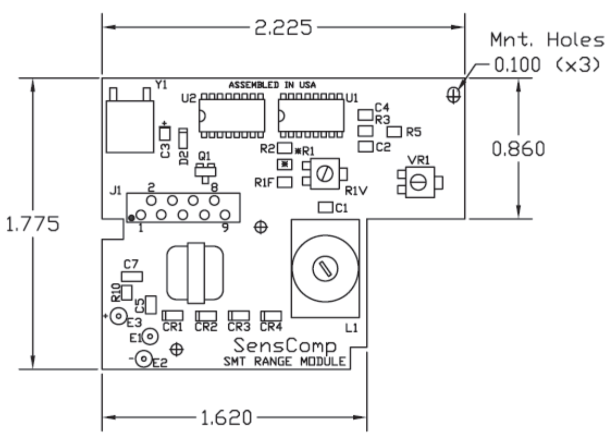


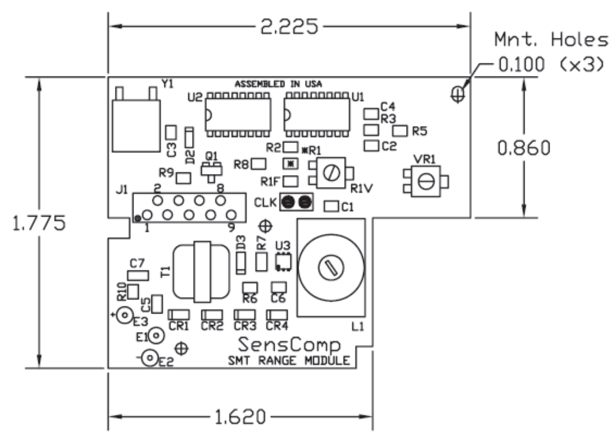
FIGURE 4: SCHEMATIC EQUIVALENT CIRCUITS OF BOARD INPUTS/OUTPUTS

Component Layouts



SMT Series
9000 Ranging Module

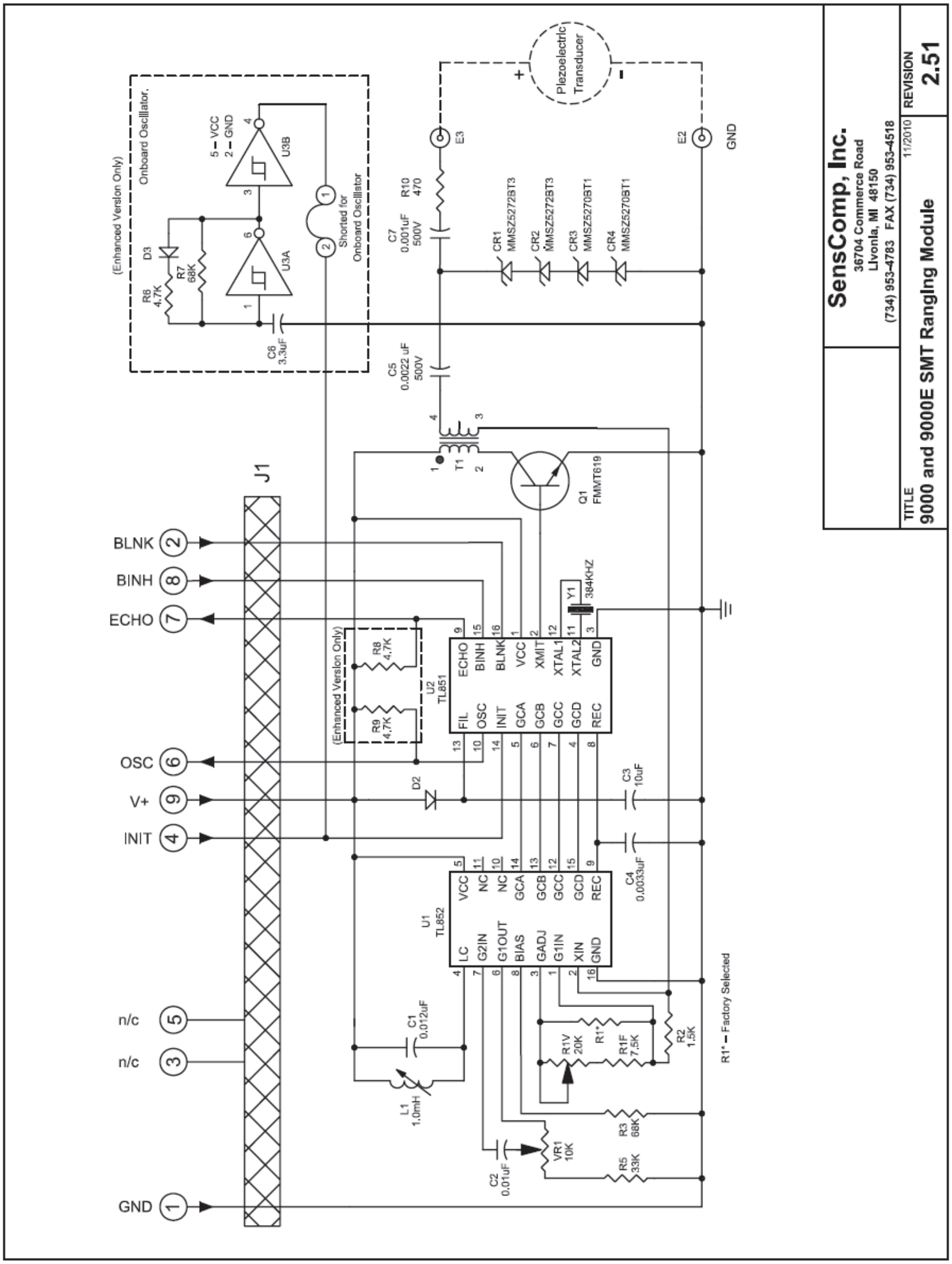
(PID#615085)



SMT Series
9000E Ranging Module

(PID#615068)

Schematic – 9000(E) SMT Ranging Module



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