Sound Navigation and Ranging

PROJECT REPORT

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Submitted in partial fulfilment of the requirements for the award of the Degree of Bachelor of Engineering in Electronics and Communication Engineering of the Bharathiar University, Coimbatore - 641046

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Certificate

Name.. *Roll No.*..........................

Register No...........................

This is the bona fide Record of the Project Work titled

"Sound Navigation and Ranging"

done by

Mr. P. SURESH. SUKUMARAN & R.K. HARIKRISHNAN

in partial fulfilment of the requirements for the award of the Degree of Bachelor of Engineering in Electronics and Communication Engineering Branch of Bharathiar University, Coimbatore during the year 1991-'92.

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Date :

Guide — *Head of the Department*

Submitted for the University Examination held on..........................

Internal Examiner — *External Examiner*

C O N T E N T S

Operation based on ultrasonic waves.

This project mainly indulges in the field of Acoustics. It utilises the property of ultrasonic waves to calculate the distance of an object from a particular point.

Clock pulse generator supplies signal for the counters operation.

A clock pulse generator is utilised which runs the counter at a frequency synchronous to the signal transmitted by the transduction element. At the instant of the transmission the counter is activated by a clock pulse of frequency 17.05 KHz.

Piezo-electric transducer excited by a Schmitt trigger circuit and operates at 40 KHz.

The transmitter is excited by a Schmitt trigger circuit. This transmitter is nothing but a piezo-electric crystal which transmits sound of frequency above audible range whenever an electric signal is applied to it. The Schmitt trigger produces oscillation of 40khz which it transmits in the form of acoustical waves called Ultra-sonics.

The receiver is also a piezo-electric transducer which resets the bistable hence counting process stops.

The time dependant sensitive sensing element picks up the sonic waves in their return part. At the instant the waves are picked up, the bistable stage gets itself reset hence stopping the counting process.

The counter shows the accurate distance of the object from the device.

The reading on the counter is the distance of the object from the meter in centimeters. The reason for this is, due to design consideration undergone on the frequency of the clock pulse. The clock frequency is 17.05 KHz and the velocity of sound is $341ms^{-1}$, it is seen that the period of the clock is equal to the time taken by the burst to travel '2cm which means 1 cm forward and 1 cm back. Thus the number of clock pulses counted between the onset of a machine of the burst and the sensing of the echo equal to the number of centimeters between the transducer and the reflecting surface.

✓Cheaper to construct. Improvement can be brought about by higher range transducers.

This device is brought to use as it is relatively cheaper than the other devices. RADAR, SODAR etc. By designing powerful transducers greater ranges and higher sensitivity can be achieved.

SOUND NAVIGATION & RANGING

(i) Privue

(ii) Transducer Characteristics

(iii) Constructional Components

(iv) Operation

(v) Accuracy

2-1 PRIVUE

Transducers are used to generate and to receive ultrasonic waves. Ships utilise them for navigation purposes.

Device used in ship's and for oceanographical research is the set up now under study. It comprises of a simple Ultrasonic transmitter which is nothing but a piezo-electric crystal and another piezo-electric crystal used as the receiver unit. The signal namely sound waves are transmitted and after reception the progress of the wave in space is noted down.

2-2 TRANDUCER CHARACTERISM

Transducers produce signals above 20 KHz when excited with electric signal and vice versa.

The piezo-electric crystal which is used as the transmitter has the property of emitting sound waves of frequency above the audible range of 40kHz when stimulated by an electric signal. The piezo-electric seusing element has the property of converting the received sound waves, which is in the form of rarifactions and compressions into its corresponding electric signal.

2-3 CONSTRUCTIONAL COMPONENTS

The whole set up comprises mainly of six major blocks namely (i) The sender unit,

(ii) the sensing unit (iii) a bistable unit, (iv) central timing unit (v) Counter (vi) Low screen. The operational details of each unit are explained clearly as we proceed through this report.

2-5 OPERATION

Signal emitted is in resonance with both transducers and counting starts.

The transduction element emits bursts of 12 pulses at a frequency of about 40kHz. This frequency is roughly identical with the resonance frequency of the two transducers, so that some sort of selectivity is obtained at the seusing element. As soon as the first burst is emitted, a bistable is actuated which enables the counter.

Time dependent sensing elements help in improving sensitivity and selectivity of the signals.

Immediately after the burst has been emitted the unit is switched to reception. The sensitivity of the receiver is a function of time. During and immediately after emission of the burst, the sensitivity is low. Crosstalk between the transduction and seusing elements has, therefore no effect on the operation of the unit. If an echo is received very soon after cersation of the emitted burst, it will be sufficiently strong to be processed by the receiver inspite of the very low sensitivity. An echo that takes a longer time to reach the sensing element will be weaker, but by then the sensitivity of the receiver has become higher. The upshot of this arrangement is that reliable measurements, unaffected by spacious reflections and crosstalk, may be made with relatively simple means.

Our reception counting is stopped and available at outpu. latch.

At the instant the echo is sensed, the bistable is reset and the counter state transferred to the output latch.

The counter reads the distance of the object as a frequency of signal clock is so designed.

Since the clock frequency is 17.05 KHz and the velocity of sound under normal atmospheric conditions may be taken as 341 ms^{-1}, the period of the clock is equal to the time taken by the burst to the time taken by the burst to travel 2cm ie., 1 cm forward and 1 cm back. This means that the number of clock pulses counted between the onset of emission of the burst and the sensing of the echo is equal to the number of centimetres between the transducers and the reflecting surface.

2-6 ACCURACY

Precision of measurement, atmospheric pressure, temperature play an important role in accuracy.

The accuracy of the measurement depends on the precision with which time is measured and on the ambient conditions. The speed of sound depends on the atmospheric pressure, the temperature, and the air density.

System itself is the main source of error.

A source of larger enors than caused by atmospheric conditions is the unit itself, mainly due to the incorrect triggering of the receiver. Partly because of the Q factor of the sensing element, it takes a finite time (upto a few periods of the 40KHz signal) before the received signal attain maximum amplitude and the receiver is triggered and a delayed period causes a measuring enor of about half a centimeter. None the less, under normal conditions, measurements made with this prototype upto a distance will be found to be accurate to within 2% ie., 2 cm/metre.

SOUND NAVIGATION & RANGING

(i) Power Supply Unit

(ii) Voltage Levelling Circuit

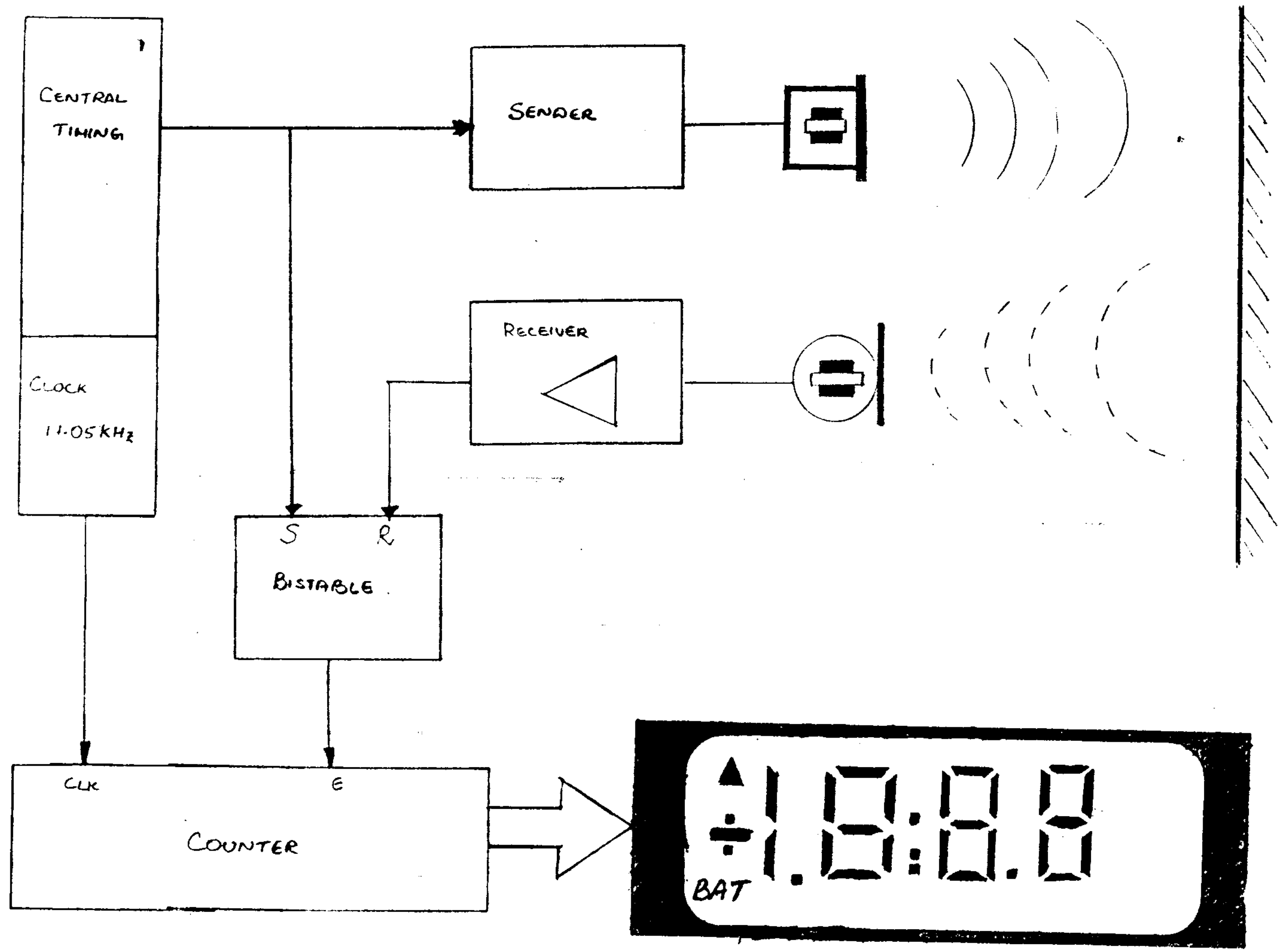
(iii) Sender Unit

(iv) Sensing Unit

(v) Reference Timing Unit

(vi) Binary Clock Unit

(vii) Bi-stable Circuit



FUNCTIONAL BLOCK OF THE RANGER

Circuit on whole uses two supplies namely a 9.v source and a constant 5.v ie., output of a voltage regulator. Weakening 9.v battery produces a signal on the LCD.

3(i) POWER SUPPLY

A 9.V battery is utilised power or input to one termin namely the inverting terminal of t comparator op-amp designated A2. The power is fed to one the terminals of the volta regulator chip ie., the 78L chip. The output of this chip is constant 5V. This 5 volts is fed a buffer amplifier designated A4. The buffer amplifier is us so as to reduce the input impeda

The buffer amplifier is a unit g non-inverting amplifier. Thus t output of the buffer will be t same 5V. This desired sampl

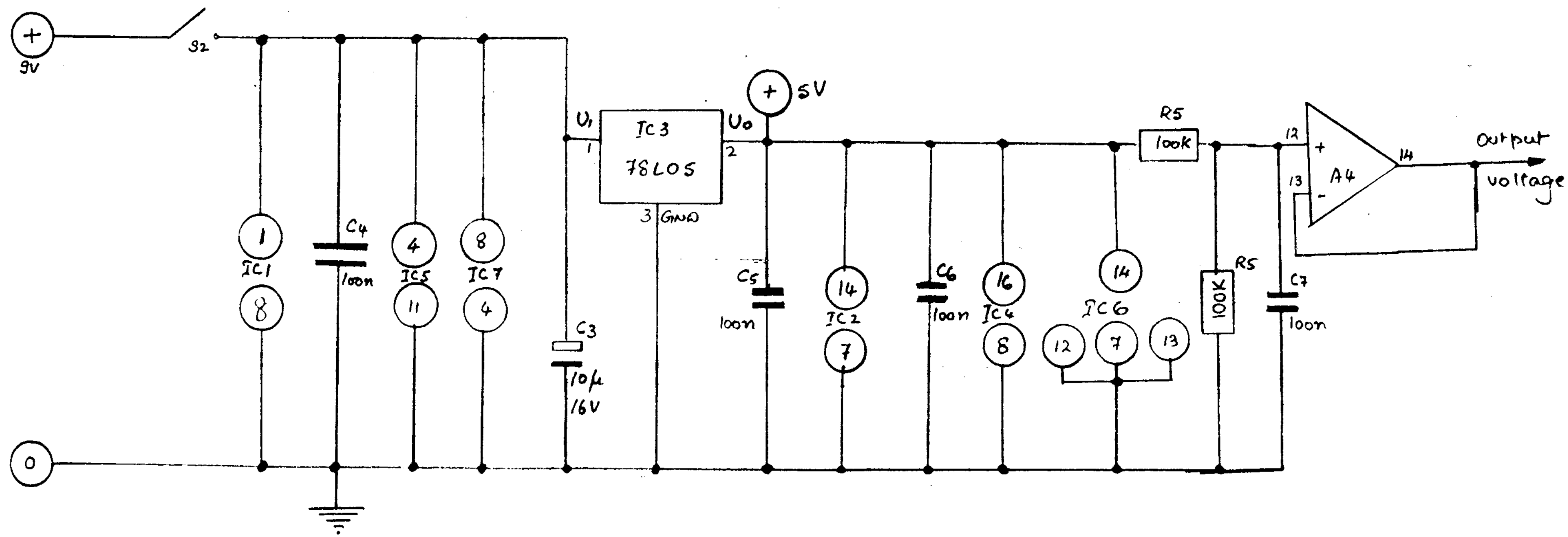


FIG: FUNCTIONAL BLOCK OF POWER SUPPLY.

voltage is supplied to the non-inverting terminal of the comparator op-amp A_2. The power input to the circuitry should never fall below 7V. Thus the battery after a long period of usage will naturally become weak. Once this happens the voltage supplied by it will become low and failure of the battery is at once indicated by the LCW display. Once this happens the battery supply, should be replaced.

3(ii) VOLTAGE LEVELLING CIRCUIT

A comparator compares the battery power with the reference and gives a signal when battery power goes low.

This circuit mainly comprises of an operational amplifier which acts as a comparator. The voltage levelling circuit is utilised for the operators information sake. It is the circuitry that enables the low - bat signal light on the LCD screen to glow when the power from the battery has dropped below requisite value, thus indicating the necessity for a replacement in the battery.

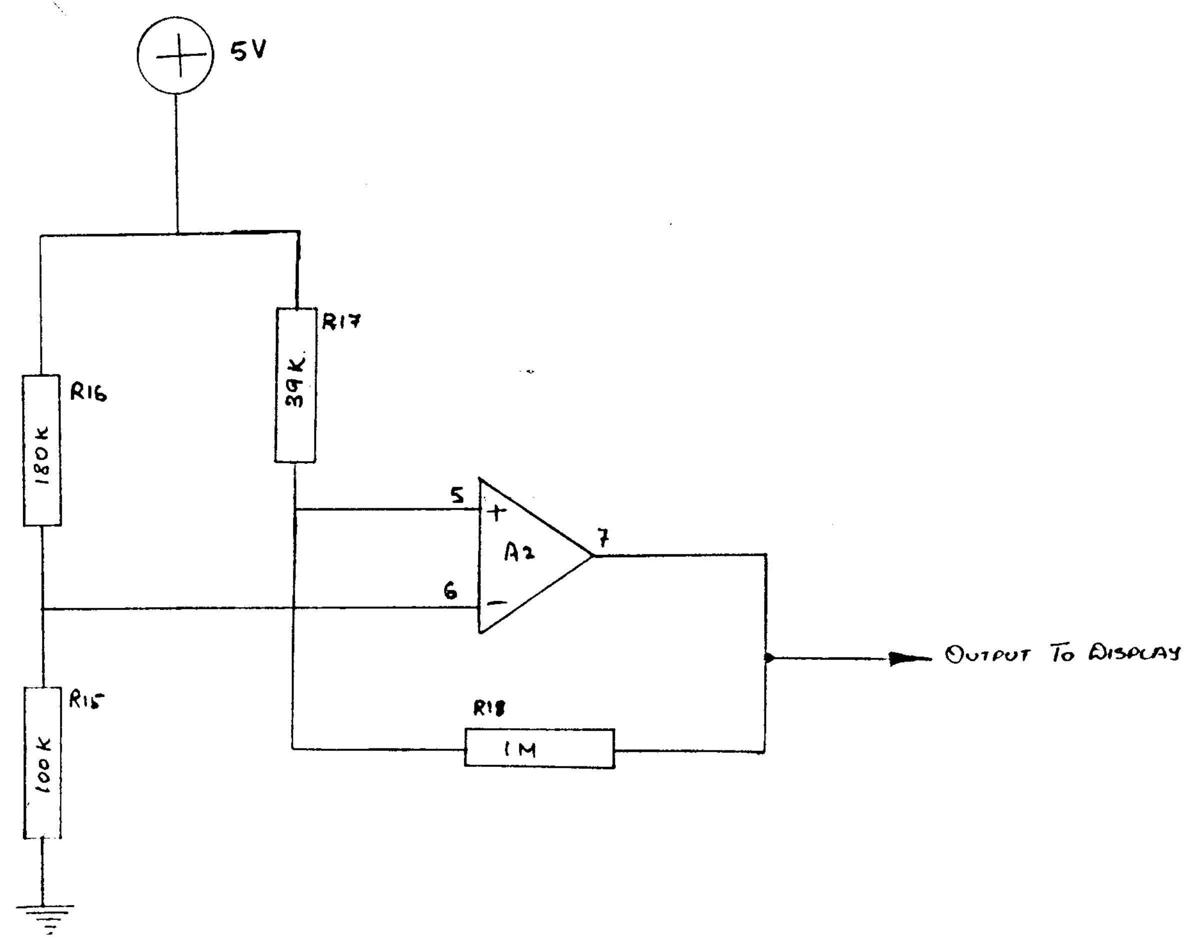


FIG: FUNCTIONAL BLOCK OF VOLTAGE LEVELLING CIRCUIT

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Comparison between the input voltage from battery and reference 5.v is compared. The output of the comparator is 0. Once the battery power goes low output changes and enables the 'low-bat' signal on the LCD.

The operation of this is simple as it takes into account the principle of comparison. The non-inverting terminal of the op.amp is connected to the output of the voltage regulator which is a constant 5V. The inverting terminal of the op.amp is connected to the supply voltage of 9V. A voltage divider circuit comprising of resistors R16 and R17 are present which drop the power's input voltage of 9V to 5V. Thus the two inputs of the comparator A2 are 5 volts and hence naturally the output of comparator will be zero. The input supply voltage is allowed to decrease upto a maximum value of 7V after which the 'low-bat' indication on the screw will glow. This is because the output of the comparator is fed to LCW screen is a nand gate which will have an output high when only both its imputs are high. As one imput input is from the 5V supply and the other is from the comparator the desired effect occurs only when the comparator output is high even this happens only when the input voltage from the battery falls from its value of 9V, but drop upto 7V is accepted after which the output goes high and hence enables the nand gali resulting in the 'low - bat' to start glowing.

3(iii) SENDER UNIT

A piezo-electric crystal transducer is put to use to produce the desired ultrasonic wave of frequency 40 KHz.

The main component of the sender unit is the transmitter element itself. A piezo-electric has the property such that when ever electrical pulses are applied to them they are stimulated. Due to this stimulation the crystal starts vibrating and produces sound like an ordinary loudspeaker. But the vibrations are of such high period that the sound produced is of very high frequency in the order of few kilo Hertz to as high as Megatiertz. When the frequency of the sound waves emitted are found to be above twenty kilo hertz we are brought into a new concept namely the field of Ultrasonics. This ultrasonic wave is nothing but sound waves above the audible range ie., 20kHz. These ultrasonic waves are highly pene-

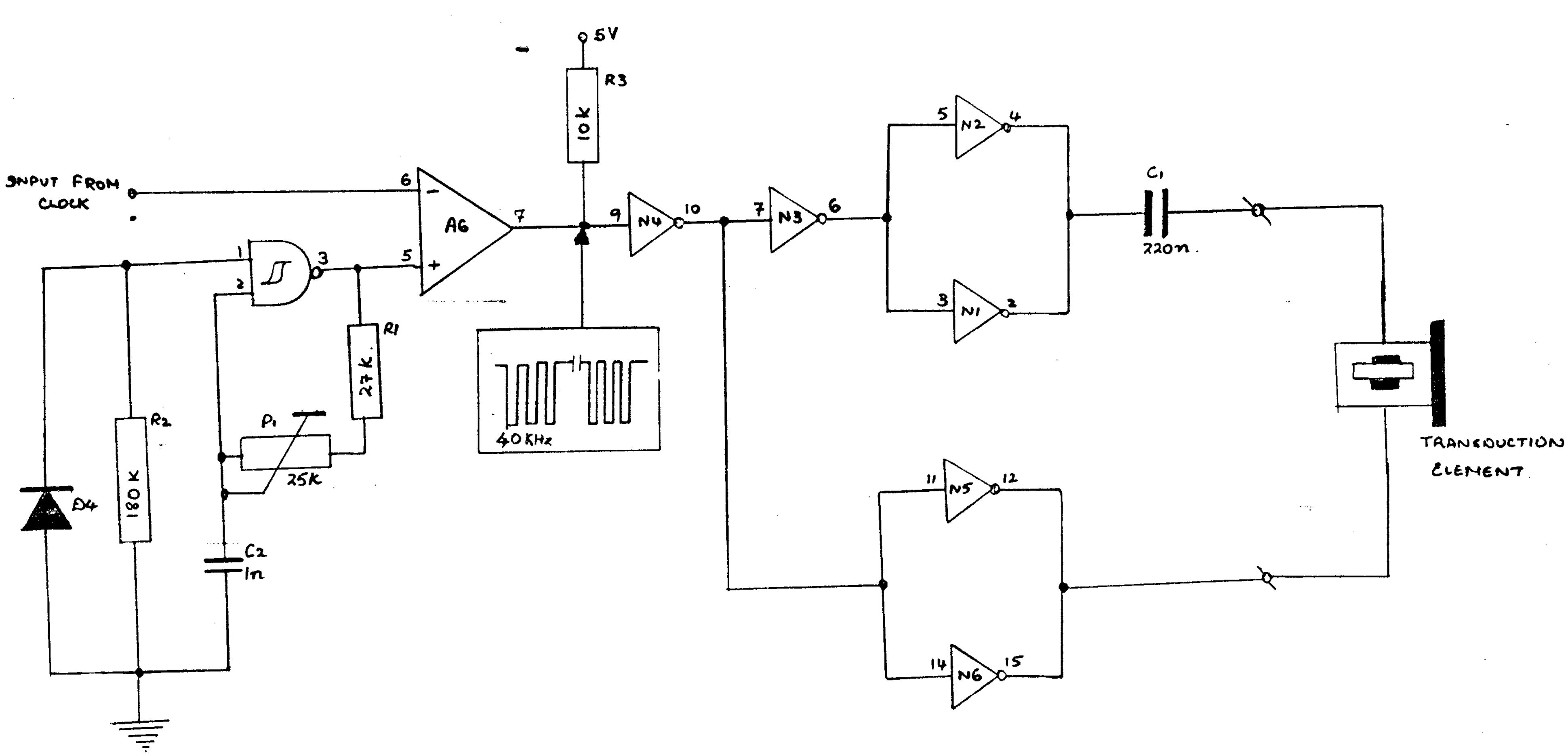


Fig: Functional Block Of Sender Unit

trative in a medium and are reflected by any material not belonging to that medium. This property of its is utilised in the project under study.

Schmitt trigger is connected to produce a signal of 40 KHz in order to excite the transducer at that frequency.

A Schmitt trigger circuit and a wave shaping circuit are used along with the piezo electric signal so as to produce a wave of desired frequency. A comparator op.amp designated by A6 is used, to whose non-inverting terminal the positive on going Schmitt trigger is connected. To the inverting terminal the input signal is applied. Hence the op.amp compares these signals fed to it and produces the desired wave whose frequency is fixed by the design parameters of P_1, which is a prest or a potentiometer whose range is 25 , and capacitor C_2 designed to 1nf. The potentiometer is hence a variable quantity and this factor is utilised in order to attain the signal of value 40KHz. This value of frequency is desired for the signal so that the transduction element will also oscillate at this frequency and

and hence will produce the ultrasonic waves of frequency 40KHz. This circuitry acts as the oscillator circuitry. The Schmitt trigger is operated at its threshold voltage. The L.T.P. points of the Schmitt trigger are varied by the use of the potentiometer. This is done so as to attain the resonance frequency.

Buffer amplifiers are used for the purpose of wave shaping the output of the transducer.

This signal shaping circuitry is made up of buffer amplifiers. It consists of four paired CMOS buffers. The output stage is actually a full bridge which causes the doubling of the effective voltage across the element. The capacitor C_1 designed as 220nt is used to block the DC component of the output signal during pauses in emission. To obtain bursts of signal by the transducer at maximum energy, IC, ie., 4049 is connected directly to the 9.V battery. The remainder of the circuit is connected to the output of the regulator and hence operates at 5V.

The transduction element will be excited at the frequency impinged onto it ie., 40 KHz, and hence produces the desired wave.

The transduction element as stated previously is a transducer made of a piezo-electric crystal. The input to the transduction element is a pulsating signal of frequency 40KHz. The transduction element has a high impedance to component and hence we make use of a pulsating signal. The crystal hence undergoes contraction and rarifaction at a period similar to the input applied to it. Thus the sound waves produced are of ultrasonic nature.

3-(iv) SENSING UNIT

The piezo-electric crystal picks up the ultrasonic signal. It has a time dependent sensitivity which enables effective reception.

The sensing unit or the receiver unit consists of another piezo-electric transducer and an amplifier designated as A3. The sensing transducer is similar to the transmitting transducer is construct but the working of it is converse to that of the transmitting antenna. Here once the ultrasound waves transmitted by the transmitter are reflected by the object they come into contact and are hence

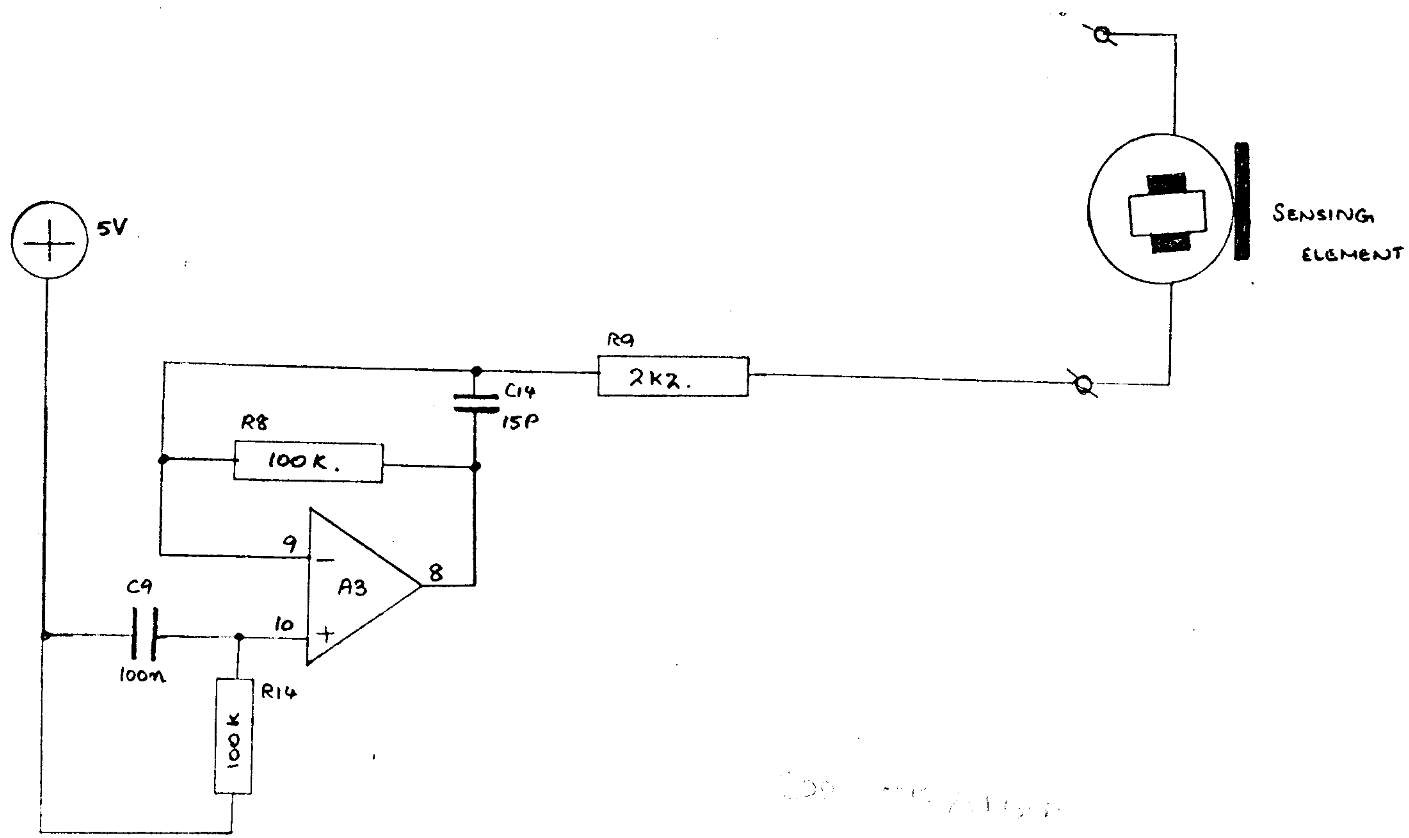


FIG: FUNCTIONAL BLOCK OF SENSING UNIT

picked up by the receiver transducer. The receiver transducer which is also a piezo-electric crystal utilises the converse principle namely that when external pressure, usually in the form of rarifaction and contractions, acts on it the transducer generates an electric signal whose value corresponds to the incident pressure wave in the form of the sound waves. The principle is similar to that of a microphone only that this transducer picks up signals of frequency in the ultrasonic range. The sensing transducer has a time dependant sensitivity. That is to say that as time elapses after the system has been operator the sensitivity of the receiving transducer increases. Thus signals which are arriving at the receiver at the shortest interval will be received with a sensing element having a minimum sensitivity. But the power of the signal will be high as it hasn't travelled much of a distance to have grown weaker in strength. The received signal which is a pulsating d.c is applied to the op.amp designated as

The gain of the amplifier is designed using the formula available.

A3. This receiver amplifier has a gain of 33dB derived from the relation.

$$\text{gain} = 20 \log \left(\frac{R8}{R9}\right) \text{dB.}$$

Where the designed values of R8 is lookr and R9 is 2k2 . This amplifier is AC coupled as it has been seen that the transducer has a very high d.c. resistance. Thus the applied input voltage thus not get amplified when the receiver is not functioning as it is blocked off by the transducer. The resistor R14 serves to minimize the off-set voltage caused by the input bias current. A minimum off set voltage at the output is necessary as it along with the input offset voltage of A5 determines the sensitivity of the transducer which has been already explained to be a time dependant quantity. The sensitivity of the transducer is matched to the ambient conditions by adjusting the potentio-meter designed to be 100M . The output of the sensing amplifier is fed to the bistable unit which sets and resets the counter by which the distance measurement is achieved.

3(v) REFERENCE TIMING UNIT

It provides a clock pulse to the counter and is considered the heart of the system.

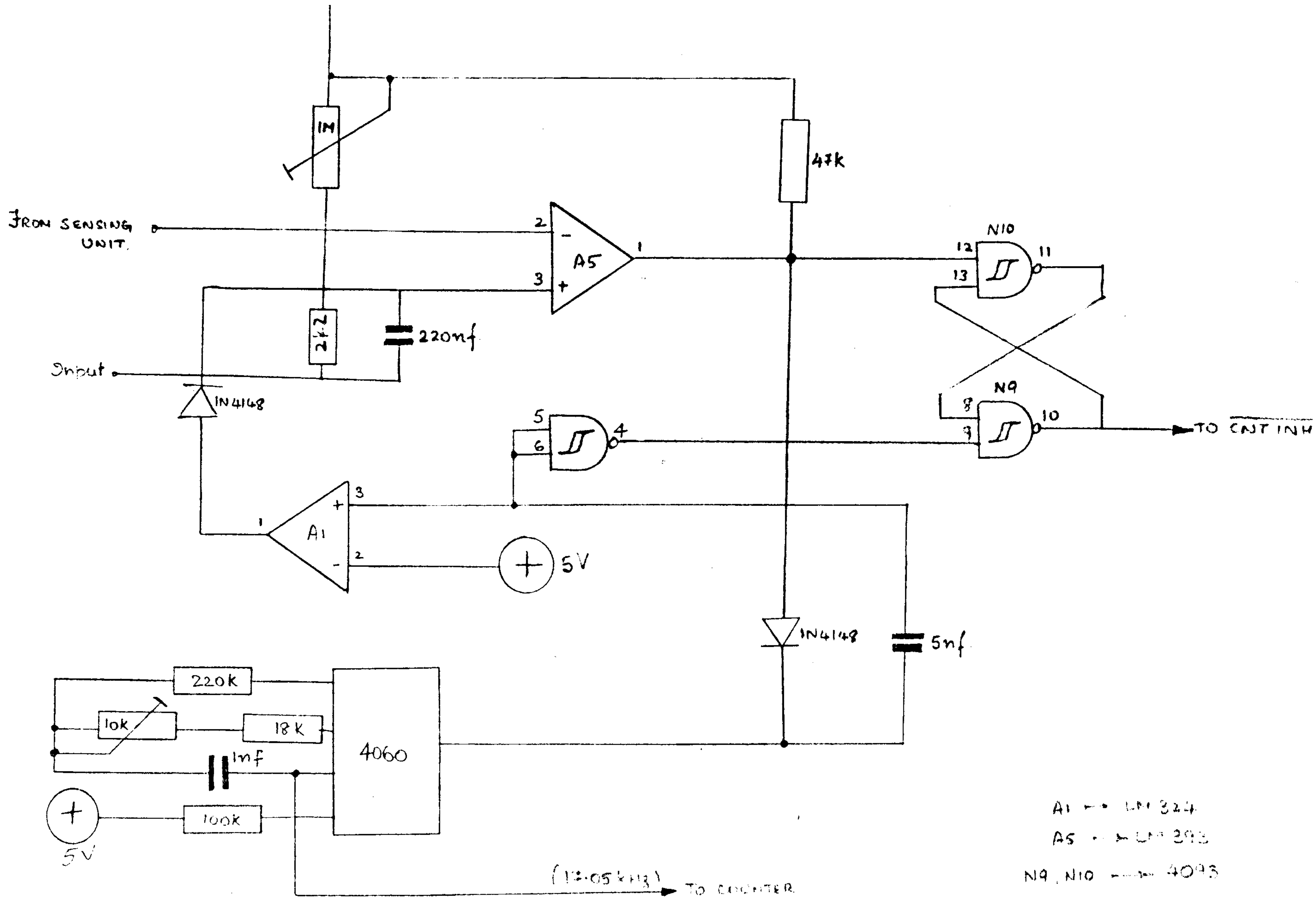
This reference timing unit is the heart of the whole system. It is at this region that the clock pulse to drive the counter and the trigger or toggling pulses are produced which are utilised to enable the counter into functioning. The reference timing unit is built up of two sections namely (i) Binary Clock Circuit

(ii) Bistable Unit.

These divisions will be explained in detail separately.

On triggering the clock pulse is fed to the counter and counting starts.

The reference timing unit is stimulated that is to say excited by the pressing by the pressing of the switch S1 which is a push-to-make button switch. Once the triggering takes place the clock pulse generator is stimulated. This unit comprises of a preset P2 which is nothing but a rheostat. This being a variable quantity is adjusted so as to attain the desired clock pulse. The signal namely clock pulse of desired



FUNCTIONAL BLOCK OF REFERENCE TIMING UNIT frequency is fed to the count pies of the counter. Thus the counter counts at the frequency of the clock pulse generated by this unit.

The output of clock circuit toggles the bistable and when the sensor picks up the signal the counter stops counting.

The output of Q12 goes high twice in a second when the switch S1 is pressed. When this Q12 goes high it gives a high on one terminal of the op.amp A1 and the terminal of the comparator A1 is the input voltage. The output of the comparator is the difference value. This value is used to toggle the bistable stage. To prevent toggling at other stages by the input signal we make use of the R6-C8 connection. This drops the voltage so that the output of A1 is only taken to consideration. The Bistable state will start the counter when the sound waves are transmitted and when the receiver picks up the waves on the return the counter is stopped. The actual working will be considered more deeply under their respective heading.

3(vi) BINARY CLOCK CIRCUIT

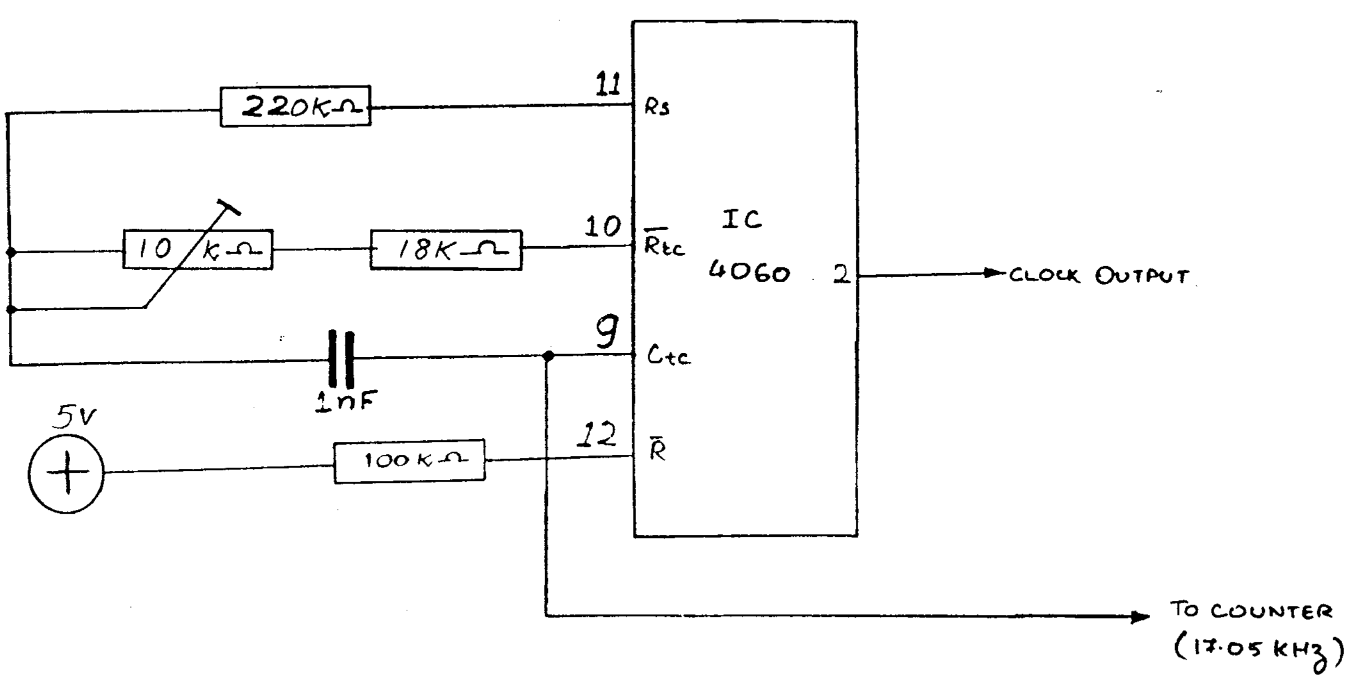
Here clock pulse for the counter is generated. Its frequency is designed using the relation provided.

This unit is the region where the clock pulse necessary for the counter to function in correspondence with the frequency of the signal being transmitted by the transducer. The binary clock circuit comprises of the chip 4060 along with a resistor, capacitor set up. The resistor used is a preset which is nothing but a rheostat. The rheostat is adjusted so that the frequency generated is of the value 17.05 KHz. The frequency designation is obtained from the formula

$$f = \frac{1}{2\pi Rc} \text{ Hz}$$

The variable quantity is the resistance which hence will give the desired frequency on proper adjustment.

As the capacitor is a constant value the frequency is varied by adjusting the rheostat so as to attain the desired value of frequency. The signal clock pulse has a time period of .3ms and hence on pressing the switch due to this period manupulation of the clock there will be a burst of twelve pulses in the

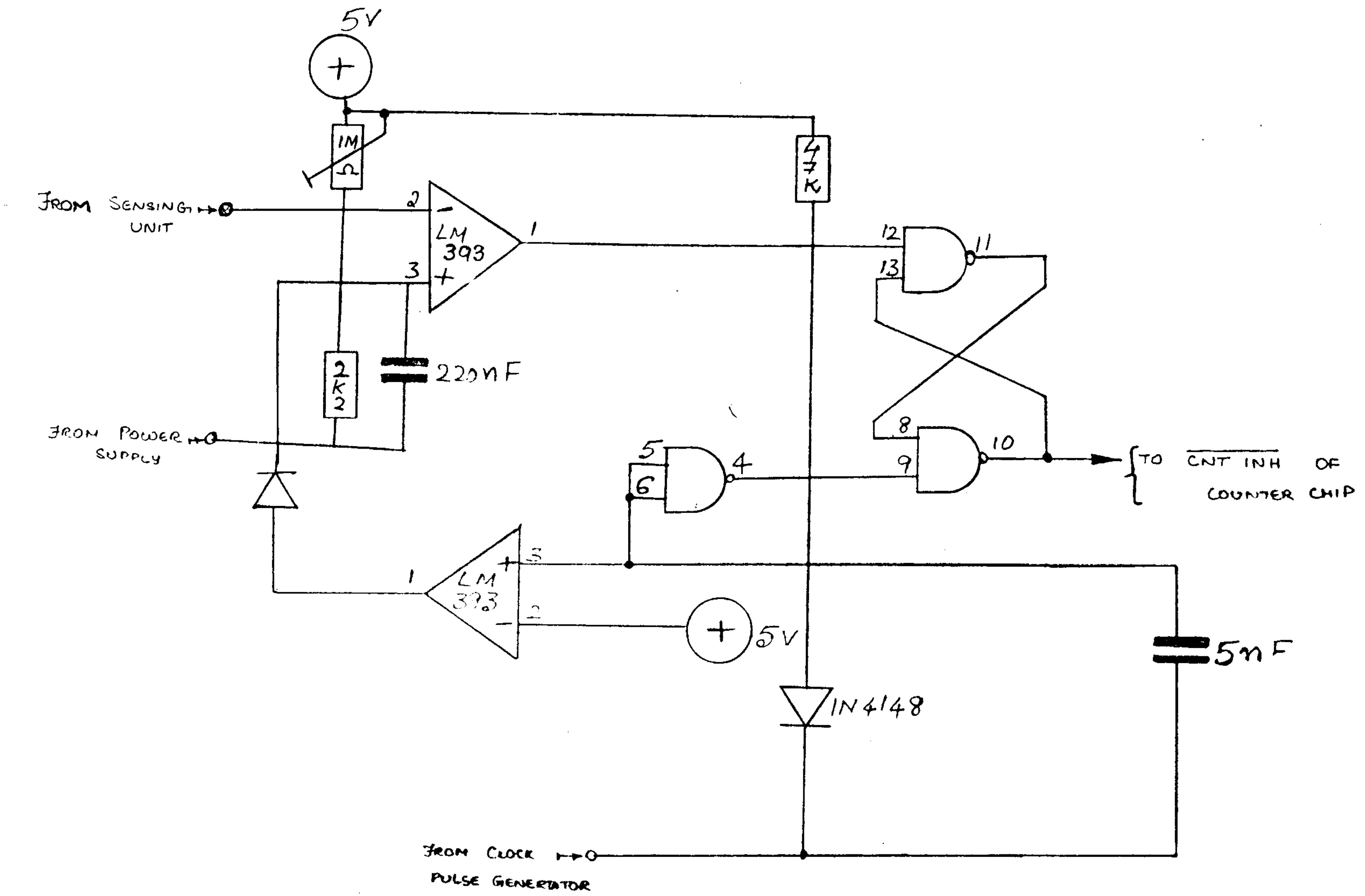


FUNCTIONAL BLOCK OF BINARY CLOCK CIRCUIT duration of 0.3ms of frequency designed as 40 KHz. Thus the binary circuits output Q12 is found to be high twice for every second. When this Q12 goes high it is seen that the output of the comparator will be of requisite value which is applied to one terminal of the amplifier A5. The inverting terminal of the same is the signal picked up by the receiving transducer and amplified by the amplifier A3. During emission, the output of A1 is high which via D1, causes the threshold of comparator A5 to be raised to a level that makes triggering by cross talk impossible.

3(vii) BISTABLE CIRCUIT

The counter get itself reset by toggling of the bistable circuitry.

This circuitry forms one block of the reference timing unit. The bistable circuit is comprised of nand gates along with an amplifier comparator, which compares the received signal after amplification with the clock pulse reference signal.



FUNCTIONAL BLOCK OF BISTABLE CIRCUIT

At the start of emission, bistable N9 and N10 is set. This disables the count inhibit input of IC8, which there upon commences counting the 17.05 Khz pulses applied to 32 by IC4.

AC coupling is used as sensing element has high impedance for DC.

The receiver input amplifier has a gain of about 33dB. The amplifier is AC coupled, because the sensing element has a virtually infinitely big DC resistance The input offset voltage is hence not amplified further (more R14 reduces the offset voltage to a minimum value which is anyway necessary as it along with the offset voltage of amplifier A1 determines the sensitivity of the transducer which is a time dependant quantity. This is realised by A1 lowering of the trigger level of A5 via time constant R6-C8. The maximum sensitivity may be matched to the ambient conditions by P3.

On reception of echo the counter gets reset and the contents are transferred to the output latch.

When an echo is received, the output of A5 goes low, which causes the bistable to be reset, and this in turn disables the clock of IC8. At the same time a short negative pulse is applied via R13-C12 and N11 to pies 34 ie., STORE, which results in the transfer of the counter state to the output latch of IC8. Gate N11 merely buffers the low impedance store input. When the Q12 output of IC4 goes low, the counter in IC8 is reset, and the circuit is ready for the next measurement of Q12 goes low in the absence of an echo, the counter is still reset, as is the bistable (via D3). The display will then read 0.00 to indicate an abortive measurement. Hence another pulse will have to be sent in order to study the distance of the desired object.

DESCRIPTION

4(i) OPERATIONAL AMPLIFIER

4(ii) VELOCITY OF ULTRASOUND IN AIR

4(iii) COUNTER

4(iv) GENERATION AND CHARACTERISTICS OF ULTRASONICS

4(v) LCD

4(i) OPERATIONAL AMPLIFIERS

BACKGROUND

The operational amplifier is today the most widely used analog subassembly. It is safe to say that its basic properties and applications are sufficiently understood by most circuit designers and builders.

SELECTION PRINCIPLES

To properly choose an operational amplifier for any given set of requirements, the designer must have:

1) A complete definition of the design objectives. Signal levels, accuracy desired, bandwidth requirements, circuit impedance, environmental conditions and other factors must be well defined

2) Firm understanding of what the manufacturer means by the numbers published for the parameters. Frequently, any two manufacturers may have comparable published specifications, which may have been arrived at using differing measurement techniques. This creates a pitfall in op amp selection. To avoid these difficulties, the designer must know what the published specifications mean and how these para-meters are measured.

There are three fundamental aspects to the rational selection of an operational amplifier for a given application: (1) Establishing the circuit architecture, (2) defining the performance levels, and (3) choosing the amplifier(s).

DEFINITIONS OF SPECIFICATIONS

Absolute Maximum Differential Voltage

Under most operating conditions, feedback maintains the error voltage between inputs to nearly zero volts. However, in some applications such as voltage comparators, the voltage between the inputs can become large. This specification defines the maximum voltage which can be applied between inputs without causing permanent damage to the amplifier.

Common Mode Rejection

An ideal operational amplifier responds only to the difference voltage between inputs ($e^+ - e^-$) and produces no output for a common mode voltage, that is, when both inputs are at the same potential. However, due to slightly different gains between the plus and minus inputs, or variations in offset voltage as a function of common-mode level, common-mode input voltage are not eliminated at the output. If the output error voltage, due to a known magnitude of common mode voltage, is referred to the input (dividing by the closed loop gain), it reflects the equivalent common mode error voltage (CME) between the inputs. Common mode rejection ratio (CMRR is defined as the ratio of common mode voltage to the resulting common mode error voltage. Common mode rejection is often expressed logarithmically. CMR(indB)=20 $\log_{10}$ (CMRR).

Common-Mode Voltage, Maximum

For differential input amplifiers, the voltage at both inputs can swing about ground (power supply common) level. Common mode voltage is defined as any voltage is defined as any voltage (above or below ground) that could be observed at both inputs. The maximum common-mode voltage is defined as that voltage which will produce less than a specified value of common-mode error.

Drift vs Supply

Offset voltage, bias current, and difference current vary as supply voltage is varied. Usually, do errors due to this effect are negligible compared to drift with temperature. No inference may be drawn from this low frequency specification.

Drift vs Temperature

Offset voltage, bias current, and difference current all change, or "drift", from their initial values with temperatures. This is by far the most important source of error in most precision applications. The temperature co-efficients (tempcos) of those parameters are all defined as the average slope over a specified temperature range. Drift can be a nonlinear function of temperature, the slopes generally are greater at the extremes of temperature than around normal ambient (+25°C),which generally means that for small temperature excursions in the vicinity of +25°C, the specification is conservative.

Drift vs Time

Offset voltage, bias current, and difference current change with time as components age. It is important to realize that drift with time is random, and rarely - if ever accumulates linearly for healthy devices. A convenient rule of thumb for extrapolation is to divide the drift for a stated interval by the square root of its ratio to any other interval interest.

Full-Power Response

The large signal and small signal response characteristics of operational amplifiers differ substantially. An amplifier's output will not respond to large signal changes as fast as the small signal bandwidth characteristics would predict, primarily because of slew-rate limiting in the outputs stages. Full-power response is specified in two ways; full linear response and full peak response. Full linear response is specified in terms of the maximum frequency at unity closed loop gain, for which a sinusoidal input signal will produce full output at rated load without exceeding a pre-determined distortion level.

The other frequency response is the maximum frequency at which full output swing may be obtained, irrespective of distortion. This is termed **"full peak response"**.

Initial Bias Current

Bias current is defined as the current required at either input from an infinite source impedance to drive the output to zero (assuming zero common mode voltage). For differential amplifiers, bias current is present at both the negative and the positive input. All Analog devices specifications pertain to the larger of the two, not the average. For single ended amplifiers (i.e., chopper types), bias current refers to the current at the input terminal.

Initial Difference Current

Difference current is defined as the difference between the bias currents as the two inputs. The input circuitry of differential amplifiers is generally symmetrical, so that bias currents at both inputs tend to be equal and tend to track with changes in temperature and supply voltage. Therefore, difference current is often about 0.1 times the bias current at either input, assuming that initial bias current has not been compensated at the input terminals. For amplifiers in which bias currents track, it is often possible to reduce voltage errors due to bias current and its variations by the use of equal resistance loads at hoth inputs.

Input Impedance

Differential input impedance is defined as the impedance between the two input terminals at +25°C, assuming that the error voltage is nulled or very near zero volts. To a first approximation, dynamic impedance can be represented by a capacitor in parallel with a resistor.

Common mode impedance, expressed as a resistance in parallel with a capacitance, is defined as the impedance between each input and power supply common, specified at +25°C. Common mode impedance is a nonlinear function of both temperature and common mode voltage. For FET-input amplifiers, common-mode resistance is reduced by a factor of two for each 10° of temperature rise.

Input Offset Voltage

Offset voltage is defined as the voltage required at the input from zero source impedance to drive the output to zero; its magnitude is measured by closing the loop (using low values of resistance) to establish a large fixed gain, measuring the amplified error at the output, and dividing the measured value by the gain.

The initial offset voltage is specified at +25°C and rated supply voltage. In most amplifiers, provisions are made to adjust initial offset to zero with an external trim potentiometer.

Input Noise

Input voltage and current nose characteristics can be specified and analyzed in much the same way as offset-voltage and bias current characteristics. In fact, long-term drift can be considered as nose which occurs at very low frequencies. The primary difference is that, when evaluating nose performance bandwidth must be considered. Also rms noise from different sources is summed by root-sum-of-squares, rather than linear addition. Depending on the amplifier design, noise may have differing characteristics as a function of frequency, being dominated by "1/f noise", resistor noise, or junction noise, at various frequencies.

Several noise specifications are given. Low frequency noise in the band 0.01 to 1Hz (or 0.1 to 10Hz) is specified as peak-to-peak, with a 3.30 uncertainty, signifying that 99.9% of the observed peak-to-peak excursions will fall within the specified limits. Wideband noise is specified as rms. For some types, spectral density plots or **"spot-noise"**, at specific frequencies, in aV/ Hz or pA Hz, are Provided.

Open-Loop Gain

✓ Open-loop gain is defined as the ratio of a change of output voltage to the voltage applied between the amplifier inputs to produce the change. Gain is specified at dc. In many applications, the frequency dependence of gain is important; for this reason, the typical open-loop gain as a function of frequency is published for each amplifier type.

Overload Recovery

✓ Overload recovery is defined as the time required for the output voltage to recover to the rated output voltage from a saturated condition caused by a 50% overdrive. Publised specifications apply for low impedances and contain the assumption that overload recovery is not degraded by stray capacitance in the feedback network.

Rated Output

✓ Rated output voltage is the minimum peak output voltage which can be obtained at rated current or a specified value of resistive load before clipping or out-of-spec nonlinearity occurs. Rated output current is the minimum guaranteed value of current supplied at the rated output voltage lor other specified voltage). Load impedances less than the specified (or implied) value can be used, but the maximum output voltage will decrease, distortion may increase, and the open-loop gain will be reduced.

Settling Time

✓ Settling time is defined as the time elapsed from the application of a perfect step input to the time when the amplifier output has entered and remained within a specified error band symmetrical about the final value. Settling time, therefore, includes the time required: for the signal to propagate through the amplifier, for the amplifier to slew from the initial value, recover from slew-rate limited overload (if it occurs) and settle to a given error in the linear range. It may also include a **"long tail"** due to the time required to reach thermal equilibrium, or the settling time of compensation circuits. Settling time is usually specified for the condition of unity gain, relatively low impedance levels, and no (or a specified value of) capacitive loading, and any specified compensation. A full scale unipolar step input is used, and both polarities are tested.

Slewing Rate

The slewing rate of an amplifier, usually in volts per micro second (V/us) defines the maximum rate of change of output voltage for a large input step change.

Unity-Gain Small Signal Response

Unity-gain small-signal response is the frequency at which the open-loop gain falls to IV/V, or OdB under a specified compensation condition. **"Small signal"** indicates that, in general, it is not possible to obtain large output voltage swing at high frequencies because of distortion due to slew-rate limiting or signal rectification.

4(ii) VELOCITY OF SOUND IN AIR

The velocity of sound, v, in a gas, such as air, for frequencies above 200 Hz is given as,

V= (VP/e)

where f- adiabalic bulk modulus of the gas (1.4 for air)

P- Pressure of the gas in Pa (air pressure at sea level is $(1.01325x10^6$ Pa)

I- density of the gas in kgm^{-3}

(of air= 1.29 kgm^{-3})

If a mole of air has a mass M and a volume V the density is M/V and the velocity of round V is,

V= (VP/I = (PV/M)

but PV=RT where R is the molar constant and T is the absolute temperature.

Therefore, V = (RT/M)

Since V,M and R are constants for a given gas, it follows that the velocity of sound in a gas is independant of the pressure if the temperature remains constant. It also follows that the velocity of sound is proportional to the square root of its absolute temperature. Thus if the velocity at room temperature, 20°C=293K is calculated from,

V = 291/273

= 342.91 MS^{-1}

GENERAL DESCRIPTION OF COUNTERS

The ICM 7224 and ICM 7225 devices constitute a family of high-performance CMOS 4 1/2 digit counters, including decoders, output latches, display drivers, count inhibit leading zero blanking, and reset circuitry.

The counter section provides direct static counting, gauranteed from DC to 15 MHz, using a 5v + or - 10% supply over the operating temperature range. At normal ambient temperatures, the devices will typically count upto 25 MHz. The COUNT input is privided with a schmitt trigger to allow operation in noisy environments and correct counting with slowly changing inputs. These devices also provide count inhibit, store and reset circuitry, which allow a direct interface with an ICM 7207/A, to implement a low cost, low power frequency counter with a minimum component count.

These devices also corporate several features intended to simplify cascading four digit blocks. The carry out put allows the counter to be cascaded, while the leading zero blanking input and output allows correct leading zero blanking between four decade blocks. The back plane driver of the LCD devices may be disabled, allowing the segments to be slaved to another back plane signal necessary when using an 8 or 12 digit single backplane display.

DESCRIPTION OF OPERATION

The LCD devices in the family (ICM 7224 and ICM 7224 A) provide outputs suitable for driving conventional 4½ digits by seven segments LCD displays, including twenty nine individual segment drivers, backplane driver, and a self contained oscillator and divided chain to generate the back plane frequency.

The segment and back plane drivers each consists of a CMOS inverter, with a n- and p channel devices ratioed to provide identical on resistances, and thus equal rise and fall times. This eluminates any DC component which could arise from differing rise and fall times, and ensures maximum display life.

The backplane output devices can be disabled by connecting the oscillator input to ground. This synchronises the twenty nine segments outputs directly with a single input a BP terminal and allows cascading of several slave devices to the backplane output of one master device. The backplane may also be derived from an external source. This allows the use of displays of characters in multiples of four and single backplane. A slave device will represent a load of approximately two hundred pF. The limitation on the number of devices that can be slaved to one master device backplane driver is the additional load represented by a larger backplane of more than four digits, and the affect of that load on the back plane rise and fall time. A good rule of thumb to observe inorder to minimize power consumption is to keep the rise and fall times less than about 5 micro seconds. The backplane driver devices of one device should handle the backplane to a display of 16 1-½-inch characters without the rise and fall times exceeding five micro seconds. It is recommended that if more than four devices are to be slaved together, that the backplane signal be derived externally and all the ICM 7224 devices be slaved to it.

This external signal should be capable of driving very large capasitive loads with short rise and fall times. The maximum frequency for a backplane signal should be about 150 Hz, although this may be too fast for optimum display response at lower display temperatures, depending upon the display used.

The onboard oscillator is designed to free one at approximately 19 Khz at micro amphier power levels. The oscillator frequency is divided by 128 to provide the backplane frequency, which will be approximately 150 Hz with the oscillator free running. The oscillator frequency may be reduced by connecting an external capacitor between the oscillator terminal and the V+.

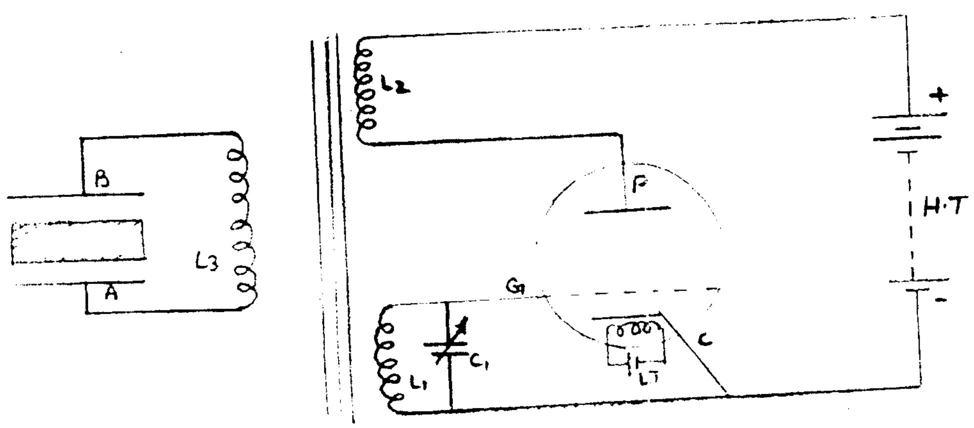
The oscillator may also be over driven if desired, although care must be taken to ensure that the backplane driver is not disabled during the negative portion of the over driving signal. This can done by driving the oscillator input between the positive supply and a level out of the range where the backplane disable is sensed about one fifth of the supply voltage above the negative supply. Another technique for overdriving the oscillator is to skew the duty cycle after overdriving signal such that the negative portion has a duration shorter than about one micro second. The backplane disable sensing circuit will not respond to signals of this duration.

4(iv) GENERATION AND CHARACTERISTICS OF ULTRASONICS

Sound waves of high frequencies usually above 20,000 KHz are called ultrasonics. Ultrasonics are generated by the following methods. (i) Galton whistel (ii) Magnetostriction oscillator (iii) Piezo electric oscillator. The last method is the one used and hence is the only one explained.

PIEZO ELECTRIC OSCILLATOR

In the piezo-electric effect, if one pair of opposite faces of a crystal is subjected to pressure, the other pair of opposite faces develop opposite electric charges. The sign of the charges changes when the faces are subjected to tension instead of pressure.



The converse of piezo-electric effect is also true. According to this, if alternating voltages are applied to one pair of faces, the corresponding changes in the dimensions of the other pair of faces of the crystal are produced.

Thus, when the two opposite faces of a quartz crystal, their faces being cut perpendicular to the optic axis, are subjected to alternating voltage, the other pair of opposite faces experiences stresses and strains. The quartz crystal will continuously contract and expand. Elastic vibrations are set up in the crystal.

When the frequency of the alternating voltage is equal to the natural frequency of vibration of the crystal or its simple higher multiples, the crystal is thrown into resonant vibrations and the amplitude will be large. These vibrations are longitudinal in nature. The frequency of vibrations is,

n = P/2l* sqrt (y/)

where P=1,2,3, etc.

Y is the elasticity and is the density of the crystal.

The velocity of longitudinal waves in the crystal,

v = sqrt (Y/)

DETECTION OF ULTRASONIC WAVES

Ultrasonic waves propagated to a medium can be detected in number of waves. Some of them are,

1) Kundt's tube method

2) Sensitive flame method

3) Thermal detectors

4) Quartz crystal method

Again as the last is the one in use its operation is only explained here.

This method is based on the prinple on piezo-electric. When one pair of opposite faces of a Quartz crystal is exposed to the ultra sonic waves the other pair of opposite faces develop opposite charges. These charges are amplified and detected using an electronic circuit.

APPLICATIONS OF ULTRASONIC WAVES

Ultrasonic waves have a large number of practical applications.

1) **Depth of Sea**

Ultrasonic waves of high frequency are used to determine the depth of the sea. A Piezo-electric quartz oscillator is used. The crystal is placed between two metal plates and the plates are connected to a spark oscillator, producing damped oscillations. The frequency of damped oscillator is tuned to the natural frequency of the quartz crystal which itself acts as a transmitter and a receiver of the ultrasonic waves. These waves are transmitted towards the bed of the sea. These waves are reflected back by the bed and echo is detected by the crystal itself. The time interval between the emitted signal and the echo is determined with the help of the oscillograph. Using the known values of velocity and the time interval the depth of sea is calculated as,

$$h = \frac{(V* t)}{2}$$

2) **Signalling**

Ultrasonic waves are used for directional signalling. The frequency of ultrasonic waves is higher than the audible waves. Therefore the wave length is small. Due to this factor they can be sent in the form of short beams. If a crystal, in the form of a disc of various r, is used the angle of cone containing these waves is given by

$$\sin O = \frac{0.61}{r}$$

For small wave lengths O.

3) **Heating Effects**

When a beam of ultrasonic wave is passed through a substance it gets heated. If ultrasonic waves pass through water at 0°c, the water can be made to boil.

4) **Mechanical Effects**

Ultrasonic waves are used to bore holes in steam and other metals of their alloys. Here the drill oscillates with ultrasonic frequency and can bore many hard metal.

5) **Crack in Metals**

Ultrasonic waves can be used to detect tracks or discontinuity in metal structures. In this case, an emitter and detector of ultrasonic waves are used. The beam is directed towards the metal and the reflected beam is detected by the detector. If there is a crack or discontinuity, there will be a rise rise in energy received by the detector.

6) **Formation of alloys**

Alloys are uniform composition are obtained by subjecting the constituents to an ultrasonic beam. The two constituents are well mixed by the ultrasonic wave even though they differ in density.

7) **Chemical Effect**

Ultrasonic waves act like catalytic agents and accelerate chemical reactions. They bring about a number of chemical changes.

8) **Soldering**

Aluminium which cannot be soldered by ordinary soldering is soldered by using ultrasonic waves in addition to the solder.

9) **Medical Applications**

Ultrasonic waves have a large number of applications in the field of medicine. Some of the important are as follows:

a) Neuralgic pain: The affected portion of the body is exposed to ultrasonic waves which produce a soothing massage action and relieves the pain.

b) Arthritis: A small metal head vibrating the frequency of more than 10^6 hertz is moved over the skin of the patient. These vibrations after passing through the tissues, produce a deep massage action. The patient is relieved of the pain.

c) Broken teeth: Ultrasonic waves are used by dentists for the proper extraction of broken teeth.

d) Bloodless surgery: Ultrasonic waves are used in blood surgery. Here the waves are focussed on a sharp instrument and the tissues are destroyed without any loss of blood. Such instruments are used for bloodless brain operations.

10) **Sterlization**

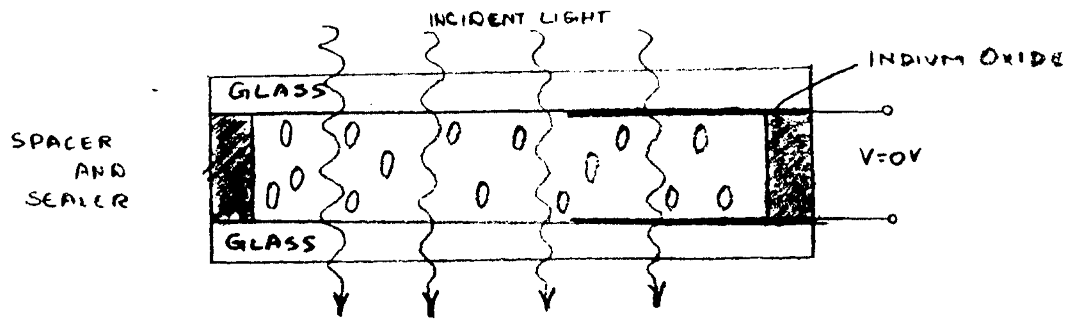
Ultrasonic waves can destroy unicellular organisms. They are used in the sterlization of water and milk.

Ultrasonic waves are having more and more practical applications in all fields. Active research work is still in progress to study the effect of ultrasonic waves in mechanical, biological, chemical, physical and industrial fields.

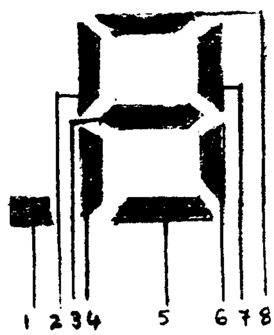
4(v) LIQUID CRYSTAL DISPLAYS

The liquid crystal display has a distinct advantage of having a lower power requirement than the LED. It is typically in the order of microwatt compared to the milli watts for LEDs. It does however require an external or internal light source, and are limited to a temperature range of 0° to 60°c.

A liquid crystal is a material that will flow like a liquid but whose molecular structure has some properties normally associated with solids. The greatest interest is in nematic liquid crystal. The individual molecules have a rod like appearance. The indium oxide conducting surface is transparent and the incident light will simply pass through the crystal and hence appear clear. If a voltage usually between 6 and 20v is applied across the conducting surfaces the molecular arrangements is disturbed, with the result that regions will be established with different indices of refraction. The incident light is therefore reflected in different directions at the interface between regions of different indices of refraction with the result that the scattered light has frosted glass appearance.



A digit on LCD display may have the segmented appearance. The black area is actually are cleared conducting surface connected to the terminals below for external control. If the number 2 were required the terminals 8,7,3,4,and 5 would be energised and only those regions would be frosted while the other areas will remain clear.



The field effect are twisted nematic LCD has the same segment appearance and thin layer of encapsulated liquid crystal, but its mode of operation is very different. Similar to the dynamic scattering LCD, the field affect can be operated in the reflective or transmissive mode with an internal source. The internal light source is on the right and the viewer is on the left. Only the vertical component of the entering light on the right can pass through the vertical light polarizer on the right. In the field effect LCD, either the clear conducting surface to the right is chemically etched or an organic film is applied to orient the molecules in the liquid crystal in the vertical plane, parallel to the cell wall. The opposite conducting surface is also treated to ensure that the molecules are 90° outer face in the direction shown (horizontal) but still parallel to the cell wall. In between the two walls of the crystal there is a general drift from one polarization to the other. The left hand light polarizer is also such that it permits the passage of only the vertically polarized incident light. If there is no applied voltage to the conducting surfaces, the vertically polarized light enters the crystal region and follows the 90° bending of the molecular structure. Its horizontal polarization is attenuated and the viewer sees a uniformly dark pattern. When a treshold voltage is applied the rod like molecules alligned themselves with the field and the light passes directly through without the shift. The vertical incident light can then pass through the second vertically polarized screen and the light area is seen. Through proper excition of the segments of each digit the pattern will appear. If there is no applied voltage, there is a uniformly lit display. The application of voltage results in a vertically incident light encountering a horizontally polarized filter at the left which will not be able to pass through and be reflected. A dark area results on the crystal.

Field affect LCDs are normally used when a source of energy is prime factor since they absorb considerably less power than the light scattering types. The cost is typically higher for field effect units, and their height is limited to about 2" while light scattering units are available upto 8" in height. LCDs are characteristically much lower than LED. There is a great range of colour choice in LCD units.

The printed circuit board is fitted snuggly in the chosen case. Note that two corners must be removed to allow passage of the screws that fasten the front & rear of the case.

Mounting of LCD should be done carefully. Proper screening between LCD and transducer to prevent cross talk.

Many wire links are required and these should, has a general rule, be soldered in place before any population after bored takes place. Make sure that the LCD is mounted at the correct height to fit snuggly in the window provided in the case. The distance between the top of the display and the board must be 25mm. To prevent crosstalk of the LCD drive pulses to the receiver, it is essential to fit a tin or brass screen between the upper row of LCD pins and the transducers. This screen is fitted between the two solder pins provided.

Proper seperation between the transduction and the sensing elements.

A seconds screen is required to cover the shaded area. It should be soldered to the first screen near C13, and kept in place with the aid of few drops of super glue or apoxy resin.

The transducer may be fitted on to the solder pins provided on the board or outside the case, for instance, in the bumpers of a car. On the board, there will be located towards the front of the case, in which two 16mm diameter holds must be drilled. If mounted externally they are connected to the board by two way individually screened cable.

A good multimeter is essential; an oscilloscope and/or frequency meter is useful.

Oscillator frequency matched with resonance frequency of transducers. Oscillator frequency tuned by preset P1.

The frequency of the 40 KHz oscillator must be matched to the resonance frequency of the transducers. Connector temporary wire link between pins 1 and 14 of IC 2: this will cause a transduction element to operate continuously. Turn P1 fully anti-clock wise. Measure the current drawn from the battery with the multimeter and turn P1 slowly clock-wise until the current is a maximum. The oscillator is then said to currect frequency. Note that when P1 is turned further there is a second current peak, that is not the required point. The Motorola version has a smaller hysteresis and this may necessitate an increase in the value of C2 to 2n2. The National Semiconductor version, has a higher hysteresis, so that the value of C2 may have to be reduced to 470p.

Remove the wire links from pins 1 and 14 IC2. Press S1 and make sure that the transduction element produces a short click twice a second.

The clock frequency is adjusted with preset P2.

Next, P2 must be adjusted until the oscillator in IC4 operates at 17.05 KHz. In the absence of a frequency meter, place the unit in a position where the distance between the front of the transducer and a good reflecting surface is exactly 1m. Press S1 and turn P2 until the display reads 1.00. If the reading is not stable or just 0.00 turn P3 slightly until a correct, stable reading is obtained.

Sensitivity of a sensing element tuned by preset P3.

Adjustment of P3 (sensitivity) depends largely on the circumstances of use. In quiet surroundings, the control may be set fully anti-clock wise. If, however, the display gives a spurious readings, the sensitivity is too high: ; the meter then detects its own clock. This obviated by turning P3 slightly clock wise.

Sensitivity is reduced for noisy surroundings. Take into consideration absorbing properties of materials.

If the unit is used in noisy surroundings, reduce the sensitivity even further, so that it does not respond to spurious sounds. Note, however, that the maximum measureable distance is then reduced. Which should be born in mind that absorbent surfaces, such as furniture, dressed people, and so on cannot be reliably be detected. This is because the echo from them is too weak to trigger the receiver. It pays, however, to experiment. The sensitivity of the receiver may be increased by reducing the value of

R6. Further more, the time dependency

of the sensitivity may be altered by changing the value of time constant R6-C Reducing that value makes the meter more sensitive over shorter distances.

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SOUND NAVIGATION & RANGING

PARTS LIST

Resistors

R1=27K

R2,R16=180K

R3=10K

R4,R5,R7,R8,R13-R15, ¼ R20=100K

R6,R9= 2K2

R10=47K

R11=18K

R12=220K

R17=39K

R18= 1m.

R19=1K.

P1=25K

P2=10K

P3= 1m

Capacitors

C1,C8=220n

C2=1m

C3=10micro, 16v

C4-C7,C9=100n

C10=1n0

C11=5n6

C12=270p

C13=1 micro, 6.3v

C14=15p

Semi Conductors

D1-D4=1N4148

IC1=4049

IC2=4093

IC3=78L05

IC4=4060

IC5=LM324

IC6=4030

IC7=LM393

IC8=ICM7224

Miscellaneous

U1=MA40A5S Ultrasonic Transmitter

U2=MA40A5R Ultrasonic receiver

3½-digit LC display

S1=push to make button.

S2=miniature SPDT switch

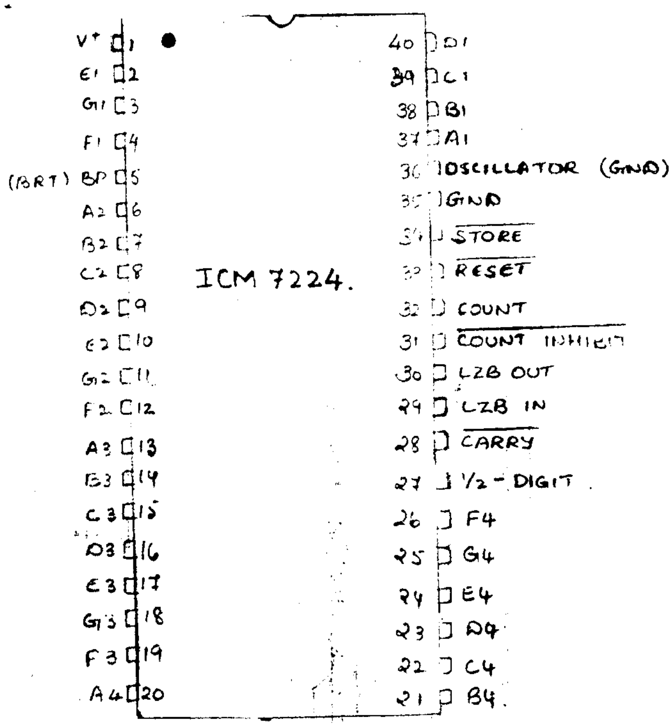


FIG: PIN CONFIGURATION OF ICM 7224.

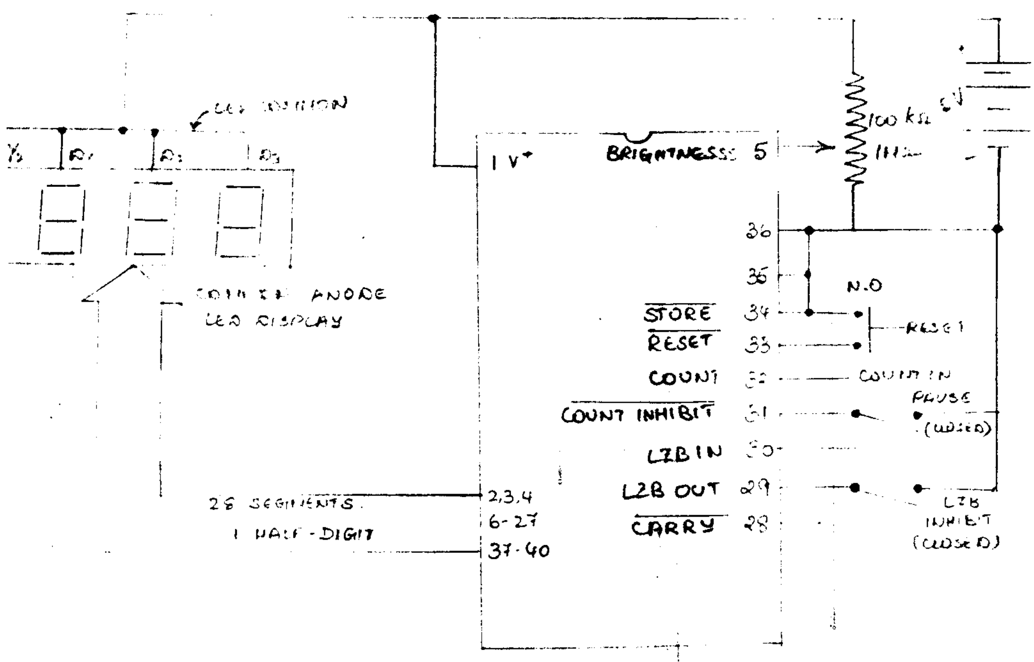
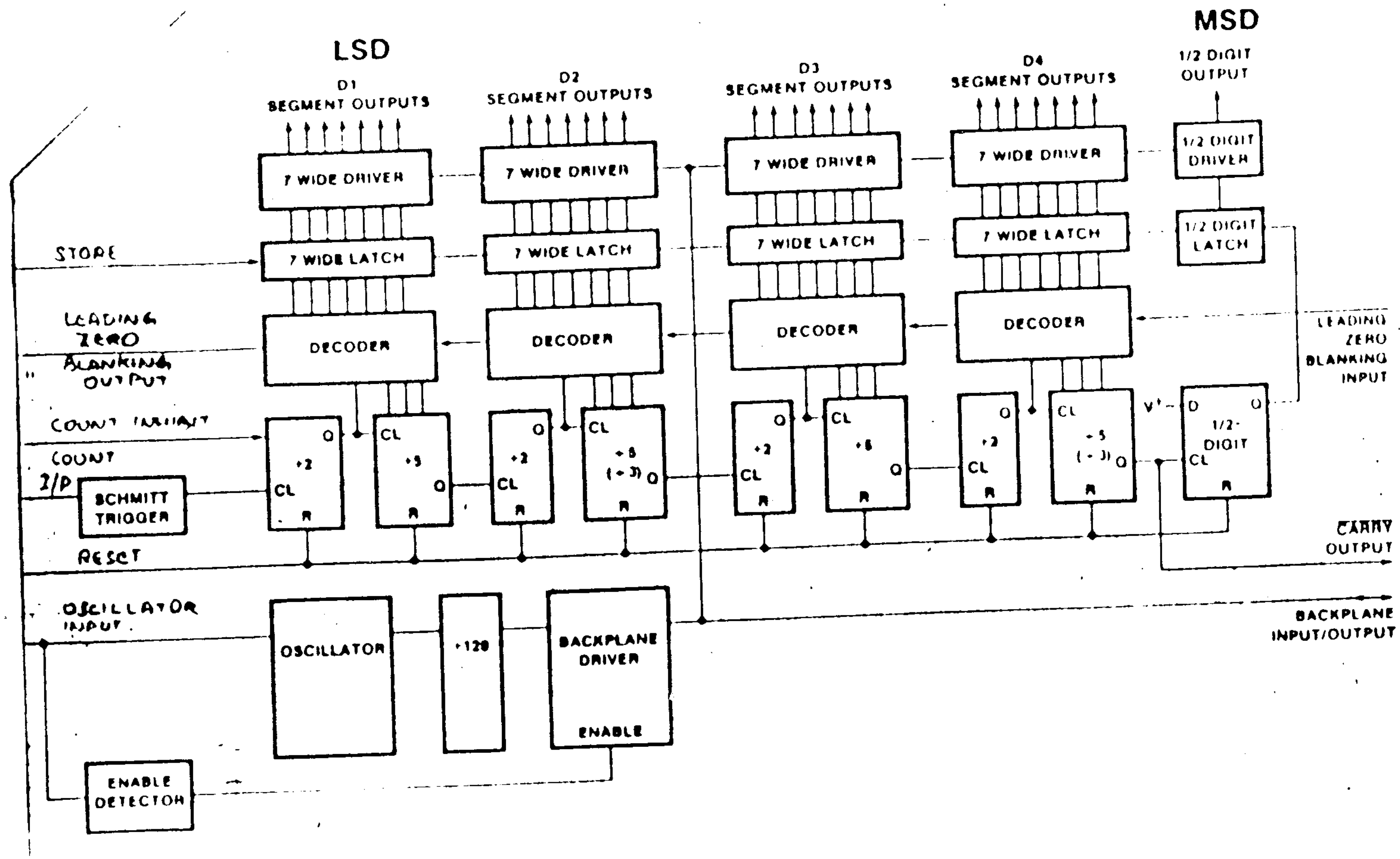
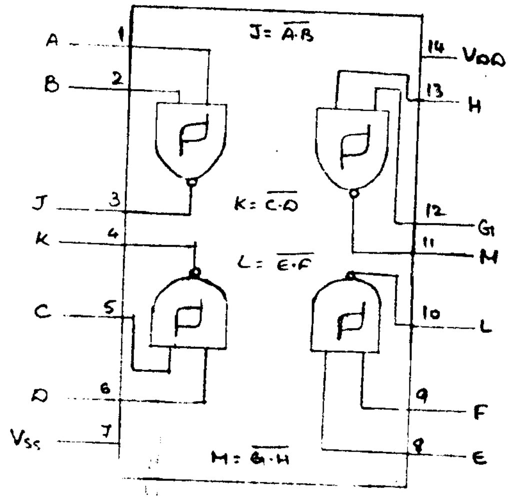
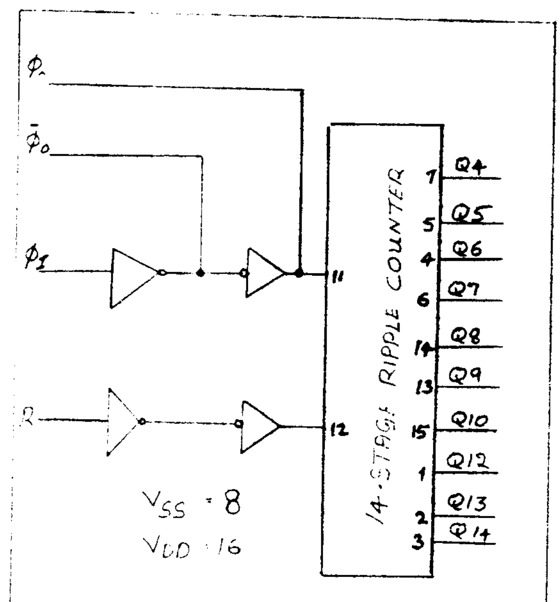


FIG: TYPICAL APPLICATION (UNIT COUNTER).

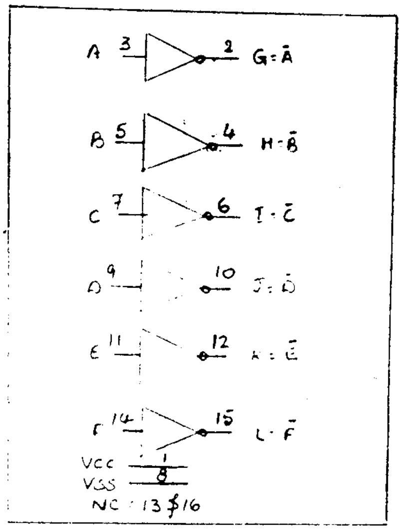

LSD
MSD
D1
SEGMENT OUTPUTS
D2
SEGMENT OUTPUTS
D3
SEGMENT OUTPUTS
D4
SEGMENT OUTPUTS
1/2 DIGIT
OUTPUT
7 WIDE DRIVER
7 WIDE LATCH
DECODER
1/2 DIGIT DRIVER
1/2 DIGIT LATCH
STORE
LEADING ZERO BLANKING OUTPUT
COUNT INHIBIT
COUNT I/P
SCHMITT TRIGGER
RESET
OSCILLATOR INPUT
OSCILLATOR
÷120
BACKPLANE DRIVER
ENABLE
ENABLE DETECTOR
LEADING ZERO BLANKING INPUT
CARRY OUTPUT
BACKPLANE INPUT/OUTPUT
1/2-DIGIT
CL
R
Q
D
V+
÷2
÷5
÷6
(÷3)



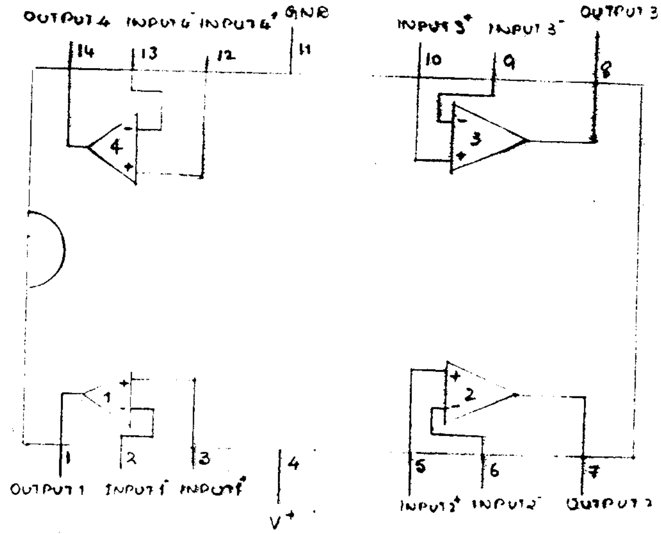
4093 PIN SPECIFICATIONS



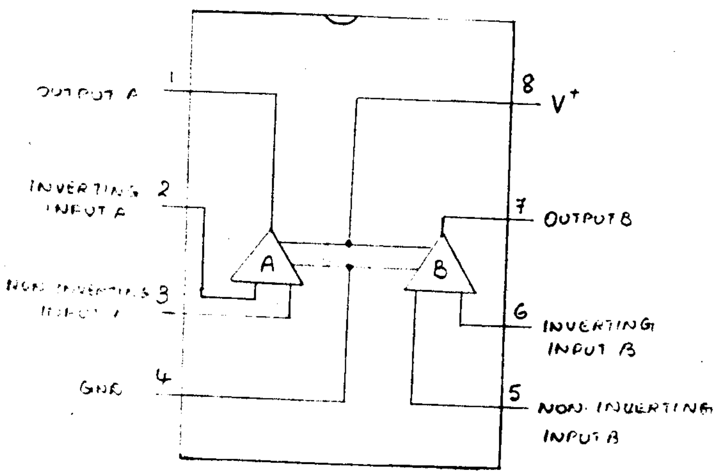
CD 4060 FUNCTIONAL DIAGRAM.



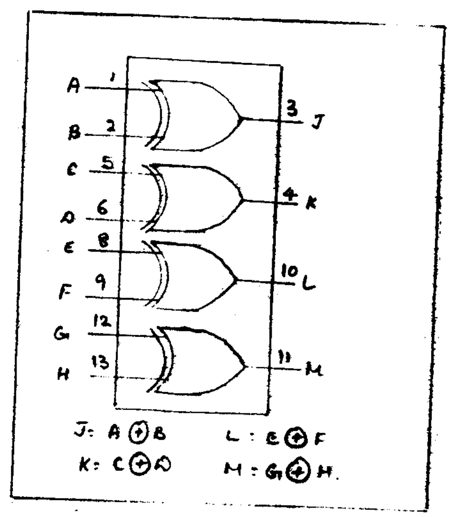
Functional diagram of 4049.



PIN CONFIGURATION OF LM324



PIN CONFIGURATION OF LM 393.



PIN CONFIGURATION OF 4030