Domestic Powerline Communication

P_1350

PROJECT WORK

Submitted by

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M E., M.I.S.T.E.,

1998-1999

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

Department of Electronics and Communication Engineering

Kumaraguru College of Technology

COIMBATORE - 641 006.

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ACKNOWLEDGEMENT

First and foremost, we would like to thank our respected principal **Dr.K.K. Padmanabhan, B.Sc., (Engg), and M.Tech., Ph.D.** who has given his consent to our project and has extended his goodwill by allowing us to utilize all the college facilities.

We would like to express our heart felt gratitude to our beloved Head of the Department **Prof. M. Ramasamy, M.E., MIEEE (USA), MIE, MISTE, C.Eng. (I) MBMESI**., who has encouraged us right through our project period and our respected **Prof. K.Ramprakash M.E.,MISTE** who was a constant source of inspiration.

It is our privilege to have worked under the guidance of our discerning guide **Mrs. H. Mangalam, M.E., MISTE**, without whom the project wouldn't have seen the light of the day.

Our special thanks are reserved for **Mr. Muthuswamy** Asst. manager and **Mr. Sugathakumar** Supervisor of Mfg. Engg. Dept. TATAFONE, Palakkad, who helped us a lot by providing us technical guidance.

We are very grateful to all the staff members who have readily rendered their helping hand towards the project.

We would be failing in our duties if we do not thank our lab technicians who have always co-operated with us for the completion of the project.

- Authors

SYNOPSIS

This project entitled " **DOMESTIC POWERLINE COMMUNICATIONS**" is marily aimed at transmitting telephone signals through the AC powerlines that exist in domestic household which are serving only as power carriers so far. The idea is unique l will transform any ordinary household into a fully networked house enabling the user transform any of his power outlet plug points as an extension outlet for his phone, hout affecting the normal functioning of the power supply, in any way.

The user with this facility is able to connect his telephone anywhere in his building hout having to worry about the additional costs involved in laying extension lines all r the building.

The telephone line and the telephone set are connected to the powerline through ple interfaces, which do not affect the performance of the telephone line, or the erline in any way. The telephone signals are all transmitted in a suitable way so that common user finds no difference in using the phone. Thus a normal telephone can connected directly through the interface without any alterations on it.

Our project is developed using common and low cost circuits that will be useful in ing the product reach the market.

1. INTRODUCTION TO TELEPHONE LINE COMMUNICATION

Of the various available communication systems , the telephone is the most widely used. The necessary control signals and speech signals are transmitted using telephone cables. Our project aims at sending these signals via powerlines. Such a technique will tremendously reduce the cost of telephone communication and hence is highly feasible in the commercial point of view.

Before stepping in depth into powerline communication, the basic building blocks and the operation of the basic telephone are dealt with in brief.

The given block diagram (fig 1.1) illustrates the interconnection of various main components of the subscriber's equipment.

The handset consists of two sections-the receiver and the transmitter. The transmitter is a microphone, which converts the speech signals into electrical signals for the purpose of transmission over the line. The receiver

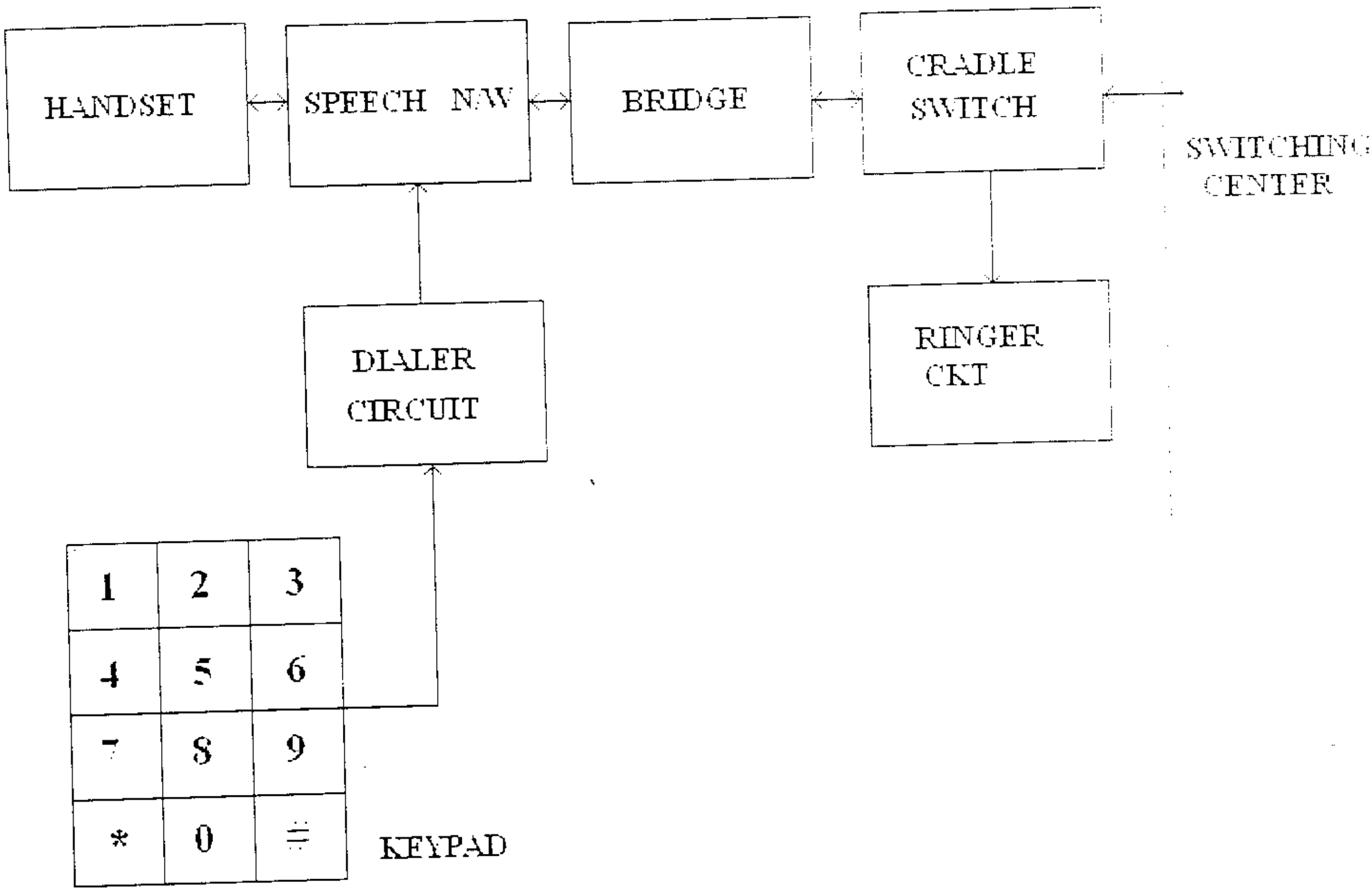


FIG 1.1 BASIC BLOCK DIAGRAM OF A TELEPHONE

converts the electrical signals received from the local switching center into sound. The speech sound consists of frequencies ranging from 100Hz to 3000Hz.But the range, which is being transmitted, is 500-2500Hz so that the telephone system is simplified in construction and cost. The signal at the receiver also consists of attenuated feedback from the transmitter called the sidetone. This function is done by the speech network. The speech network also does the work of separating the transmitted and the received signals at the subscriber's set. The cradle switches may be in either of two positions-on hook and off hook. When the handset is on the cradle switch, it is said to be in on hook position. At this position, there is a DC voltage drop of 48V across the telephone lines.

When the handset is lifted up, the switch is said to be in off-hook position. There are logic circuits at the switching center to detect the off hook position of the handset. The voltage across the telephone lines has now dropped to –10V.

The hookswitch connects the telephone line to the ringer in the on hook position and to the speech network in the off hook position. Thus when the subscriber receives a call, he is intimated of the arriving call by a ringing current. This is an electrical signal of about 75V RMS at a frequency of 25-60Hz, which activates the ringer at the subscriber set. When the handset is off hook, the ringing signal is cut off.

When the subscriber is placing the call, the switching center prepares to accept dial signals. The two methods of transmitting the dialing information to the switching center are pulse generation and tone generation.

Pulses are generated either by electronic pulse dialers or rotary type dialers. The latter has almost become extinct. These dialers generate a series of pulses that transmit the dialed number to the switching center. Fig1.2 shows the pulse train generated when the number 3 is dialed.

The dialed number is identified by the switching center by counting the number of breaks in the pulse train. Thus the time taken to transmit a number / digit depends on the value of the digit. The bridge rectifier provides the dialer with the proper polarity of the DC line bias and hence prevents damage of dialer due to line reversal.

The second method of sending dialing information is by tone

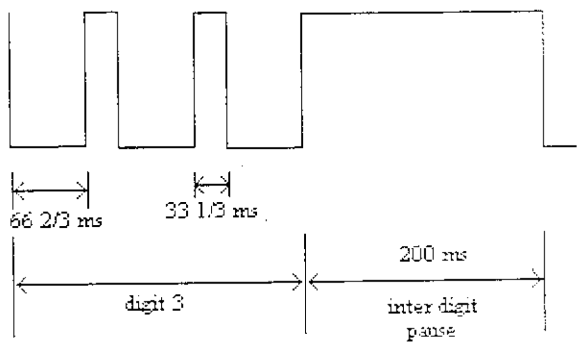
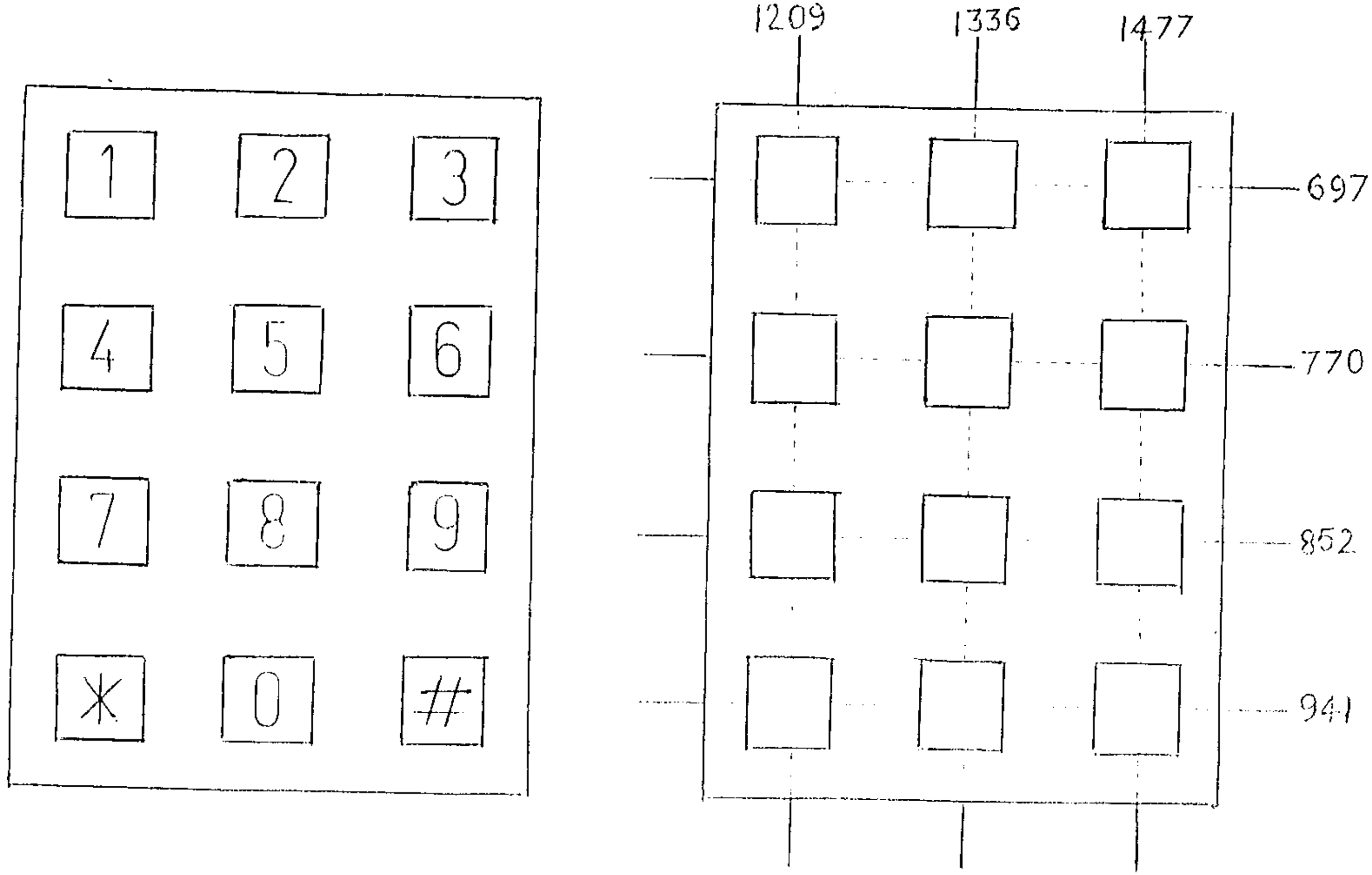


FIG 1.2 PULSE DIALING

The above figure is got when the number three is dialed.

generation also called DTMF (Dual Tone Multi Frequency) signaling. In this method, each digit is assigned one frequency from both low group and high group of the frequencies. A unique tone for each combination of low and high group of frequencies is transmitted over the voice transmission path of the telephone line. Fig 1.3 shows the allocation of frequencies for different digits.



TELEPHONE KEYPAD

DTMF

FIG 1.3

2. PARAMETERS OF TELEPHONE

1.DC voltage

DC potential across the telephone lines when the handset is on-hook nominally is 48 volts and 10 volts when the handset is off-hook.

2.Line current

When the handset is off-hook, the current drawn is about 50-60mA.

3.D.C resistance

Typical value of the resistance introduced across the telephone lines, is 300 ohms.

4.Dial tone

It is a continuous tone of 400Hz modulated by a 25Hz signal. This signal indicates the subscriber that his lines are connected to a first free selector and he can dial the number.

5.Ring

The ringer is activated by an electrical signal of 75v amplitude

3. INTRODUCTION TO MAINS SIGNALLING

Mains signalling is a method by which signals can be superimposed on mains wiring for remote control of electrical equipment. The superimposed signal frequency and amplitude are in such a way that the signal doesn't affect the 230 V , 50 Hz power signal.

The superimposed signal could be any of the following:

Speech and voice frequency signals used for telephony, telemetry, telecontrol, teleprotection, telegraphy etc.

The idea of powerline signaling is not new .Such signaling has been practically demonstrated and utilized for decades . Such a technique is called powerline carrier communication (PLCC). The idea of PLCC originated when there arouse a need for intercommunication between various remotely situated hydroelectric power generating stations, substations and control rooms. This was later extended to various other areas of application.

The superimposed signal (here, the telephone signal) is of very small amplitude say 4-6 V. The survival of such a small amplitude travelling along the strong 220 V power signal is possible due to the frequency of the communication signal, which is about 500-2500 Hz whereas the mains voltage is of very low frequency (50 Hz). About 3 kHz channel bandwidth is consumed by the voice signal.

The main advantages of the powerline communication system are the ease of installation, flexibility and relatively low cost because it uses existing mains wiring.

3.1 GENERAL PRECAUTIONS

While electricity is a great boon for mankind, the electric shock is a very dangerous phenomenon, making it imperative to exercise utmost care while handling electric gadgets.

Normally, most electric and electronic gadgets are fitted inside cabinets that are insulated from the electrical parts. Under ideal conditions all such gadgets are safe to handle. But in practice there is always a possibility of the gadget becoming faulty for some reason and giving a shock on being touched. Therefore, sure-safety measures that work unconditionally should be provided. That specifically is the purpose of the SAFETY GROUND. This wire serves a very important purpose in that it is linked to the life-saving safety ground.

A three wire system of AC distribution should be ensured in the home. All AC outlet sockets should have a 3- hole configuration. As a standard practice in our country, the live and neutral points are of the same size. The live connection is at the right hand side while the neutral connection is at the left hand side . The earth or the ground point is bigger than the other two and its connection is symmetrically above the live and neutral connections in the AC socket. As per convention, red wire is used for live path, black or white wire is used for the neutral path and green wire is used for the ground path.

4. SYSTEM LAYOUT

This project aims at connecting the telephone terminal to the telephone line coming from the exchange through the powerlines.

The regular telephone set without any modifications whatsoever is connected to the regular 230 volts AC powerlines via the **telephone set interface** that we have made.

The interface is so designed that it simulates the exchange and the telephone operates as it would if it were connected directly to the telephone line. The interface provides a connection point for the telephone, detects the off-hook condition, provides for the ring signal and all other facilities necessary for the regular operation of the telephone. Our interface also connects the telephone to the powerlines and enables bi-directional speech and control signal exchange.

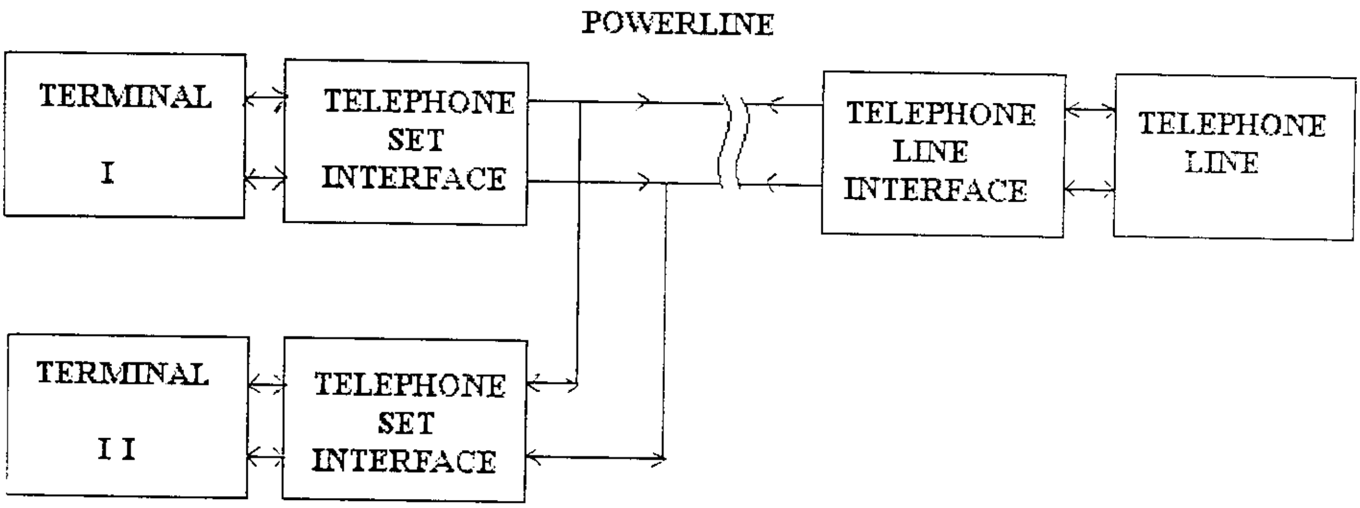
To the phone line outlet, a second interface called the **telephone line interface,** is connected. This interface, in turn, will simulate a normal telephone connected to the phone line, i.e. to the telephone exchange it will appear as if a normal telephone is connected to the line as such. The interface also connects the telephone line to the powerline. The interface exchanges bi-directional speech and control signals with the telephone set interface through the powerline.

This interface is responsible for the detection of the ring signal, simulating the dialing (both pulse and tone) to the exchange and also enables bi-directional voice communication between the two interfaces.

Both the interfaces are properly coupled to the powerline through coupling capacitors that prevent the DC voltage from entering the powerline.

The actual lines used in our system are the **neutral** and the **earth** wires found in a common domestic powerline system. The voltage between the earth and the neutral wires is expected to be perfectly zero, i.e. the earthing at the house and the power station is at the same level. However this is never really the case anywhere and a small voltage usually exists between these lines. This actually helps in the transmission of the signals through the lines. Normally 50 Hz interference is present through these lines and is suitably attenuated through 50 Hz line rejection at either end.

Voice coupling can be achieved through a driving amplifier that amplifies the voice and control signals for transmission over the powerlines. Tones are used



SYSTEM LAYOUT

FIG 4.1

5. THE TELEPHONE LINE INTERFACE

-The telephone line interface has the following functions:

1. To simulate a normal on hook telephone set.
2. To detect the incoming ring signals from the exchange and notify the telephone interface through the powerline.
3. To simulate the normal handset off hook when the telephone at the telephone interface has been raised.
4. To enable voice, tone and pulse communication between the interfaces.
5. To monitor the ambient powerline conditions, and to disconnect itself from the mains in case of potentially damaging situations.

The telephone line interface layout is as shown in figure 5.1.

TELEPHONE LINE INTERFACE

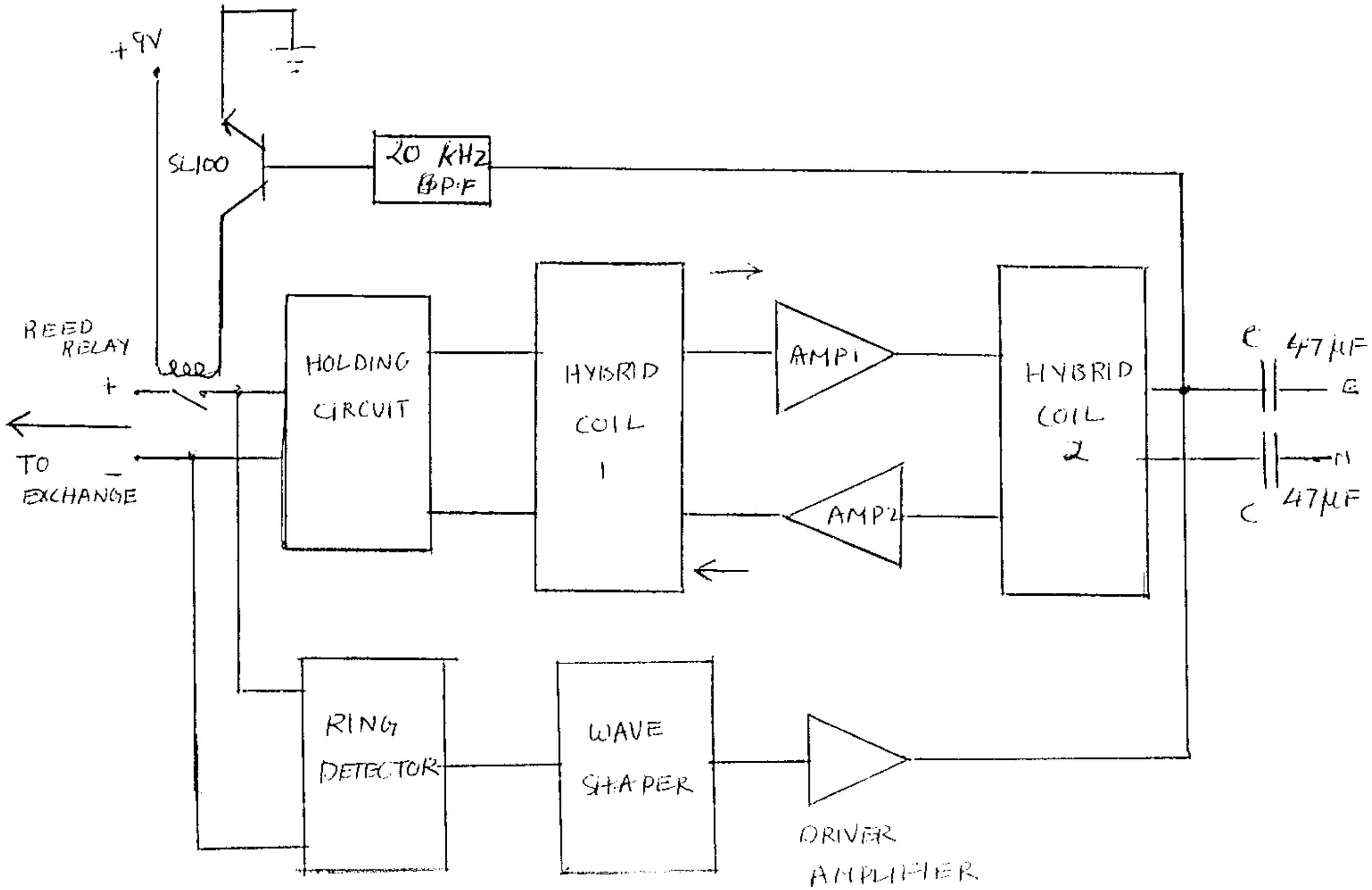


FIG 5.1

5.1 BRIEF DESCRIPTION OF THE TELEPHONE LINE INTERFACE:

The telephone line interface links the telephone line with the household mains.

The salient features of this block are mentioned below:

5.1.1 Power supply :

This unit serves to provide the necessary DC voltages to operate the speech amplifiers, the sensing and the controlling circuits that simulate the normal telephone operation. It is essentially just a regulated DC supply.

5.1.2 Holding circuit:

This circuit is switched on - line through the reed relay. When this circuit is connected to the telephone line it will provide a DC path for the loop current to flow while simultaneously providing an audio coupling path of low impedance.

5.1.3 Hybrid circuit amplifier network:

The much required isolation between the incoming and outgoing speech is provided by the use of two hybrid circuits. The fundamental purpose of this network is to separate the bi-directional speech signals, which are then amplified separately to the required levels and then to recombine them suitably.

5.1.4 Audio processing network:

This block serves to amplify the audio signals consisting of the voice and tones. It couples all the audio signals from the telephone line to the power line terminals namely the neutral and the ground.

As can be inferred tone dialing is achieved through the audio network.

5.1.5 Ring detector and indicator:

This circuit (fig 5.2) uses a bridge rectifier to trigger a monostable when a ring signal appears across the telephone line. The monostable is built around a 555 IC. The IC produces a two-second high pulse when it senses the rising edge of the ring signal. The two-second interval is chosen to correspond to the two second on time of the ring signal of 25 Hz. This signal is fed to the outgoing audio amplifier line that drives it through the powerline.

5.1.6 Hook status control and pulse dialing network:

This comprises of the reed relay energising circuit. The reed relay is responsible for the ' on ' or ' off ' hook simulation. The reed relay

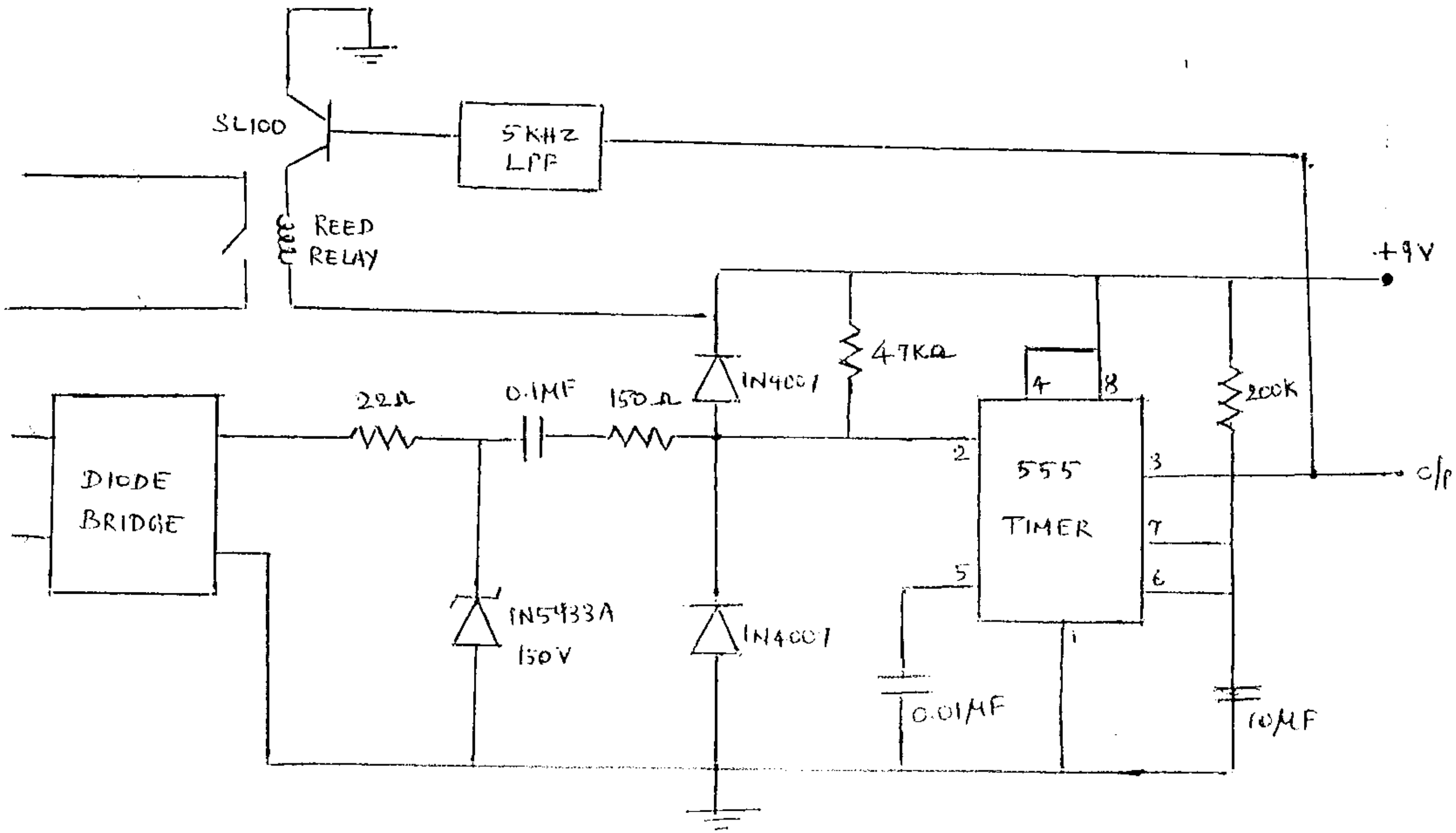


FIG 5.2 RING DETECTOR AND WAVE SHAPER

is turned on through a SL100 driver. A 20 kHz pulse train triggers the SL100 through a high pass filter. The pulse train is generated at the telephone interface whenever the handset is off- hook. Since the reed can switch at a maximum frequency of a few kHz, the 20 kHz pulse train would be sensed as DC. In the pulse dialing mode the dial pulses generated by the telephone are used to switch on and off the 20 kHz pulse train at the telephone interface, which is transmitted to the other interface through the power line. This modulated train is amplified and is driven through the powerline and switches the reed relay at the telephone line end, at the appropriate rate .Thus pulse dialing to the exchange is achieved remotely.

5.1.7 Protection circuits:

Since the system is interfaced to the telephone line it has the standard protection incorporated into it. The polarity guard and the metal oxide varistor protects the interface circuits from accidental mis-operation of the hook simulation and from spurious peaks at the mains crossover junction a control circuit monitors the mains voltage and if an irregularity in the connection is detected it disconnects the communication circuitry from the mains.

6. TELEPHONE SET INTERFACE

The various functions to be handled by the telephone set. interface are as follows

1. To simulate the exchange line conditions at the telephone set.
2. To supply 48 volts DC supply to the set to enable the internal operations of the telephone.
3. To detect the ring signal from the telephone line interface through the powerline and to denote the set by ringing.
4. To detect the off-hook condition whenever the user lifts the handset and to transmit the same to the other end interface through the powerline.
5. To transmit the dial numbers in any form i.e. either through pulse or tone format of dialing.
6. To enable voice , tone and pulse communication between the interfaces.
7. To monitor the ambient powerline conditions and to disconnect

itself from the mains in case of potentially damaging situations.

The telephone set interface layout is as shown in figure 6.1.

6.1 BRIEF DESCRIPTION OF THE TELEPHONE SET INTERFACE:

The telephone set interface consists of various modules to simulate an actual telephone operation at the receiver end. The modules are

6.1.1 DC power supply

6.1.2 Ringer circuit

6.1.3 Off hook detector

6.1.4 Dialing detector and transmitter

6.1.5 Signal amplifier

6.1.6 Protection circuits

As said earlier, the signal transmission uses the earth and the neutral lines in a three-line supply.

6.1.1 DC POWER SUPPLY

The 48 volts DC power supply is given to the telephone to operate the

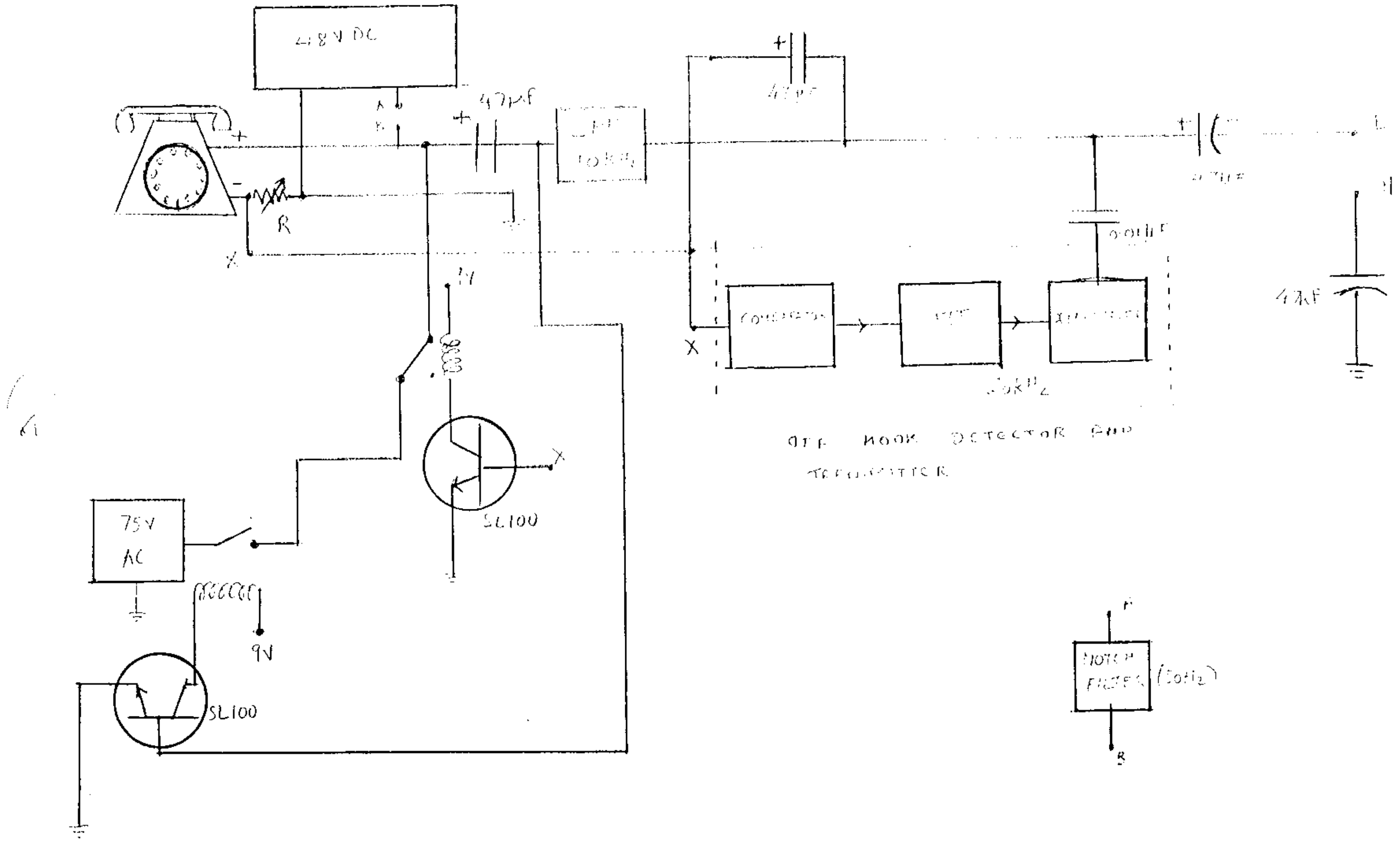


FIG 6.1 TELEPHONE SET INTERFACE

components inside the telephone.

The circuit (fig 6.2)gets its input from a transformer that has 230 volts on the primary side and 75 volts on the secondary side. The circuit ensures that a constant DC supply flows to the telephone set.

A 50 Hz notch filter is provided at the output of the powersupply to eliminate the possibility of 50 Hz noise damaging the DC supply.

6.1.2 RINGER CIRCUIT

The ring is generated using the secondary coil of the transformer, which supplies a 75 volt 50 Hz signal to the telephone. The ring is given through a changeover relay, which switches between ringing and voice transmission modes. The changeover relay is normally in the ringing mode when the relay coil is not energised. Another relay is used to modulate the ringing signal in synchronism with the incoming ring signal that is generated at exchange. The relay is energised when the 20kHz is detected over the powerline. Thus the ring signal is given to the telephone set only when this make relay is energised by the ring detector circuit's output at the telephone line interface end. The signal triggers an SL100 circuit, which in turn

POWER SUPPLY FOR 48 Vd.c / 75 Va.c

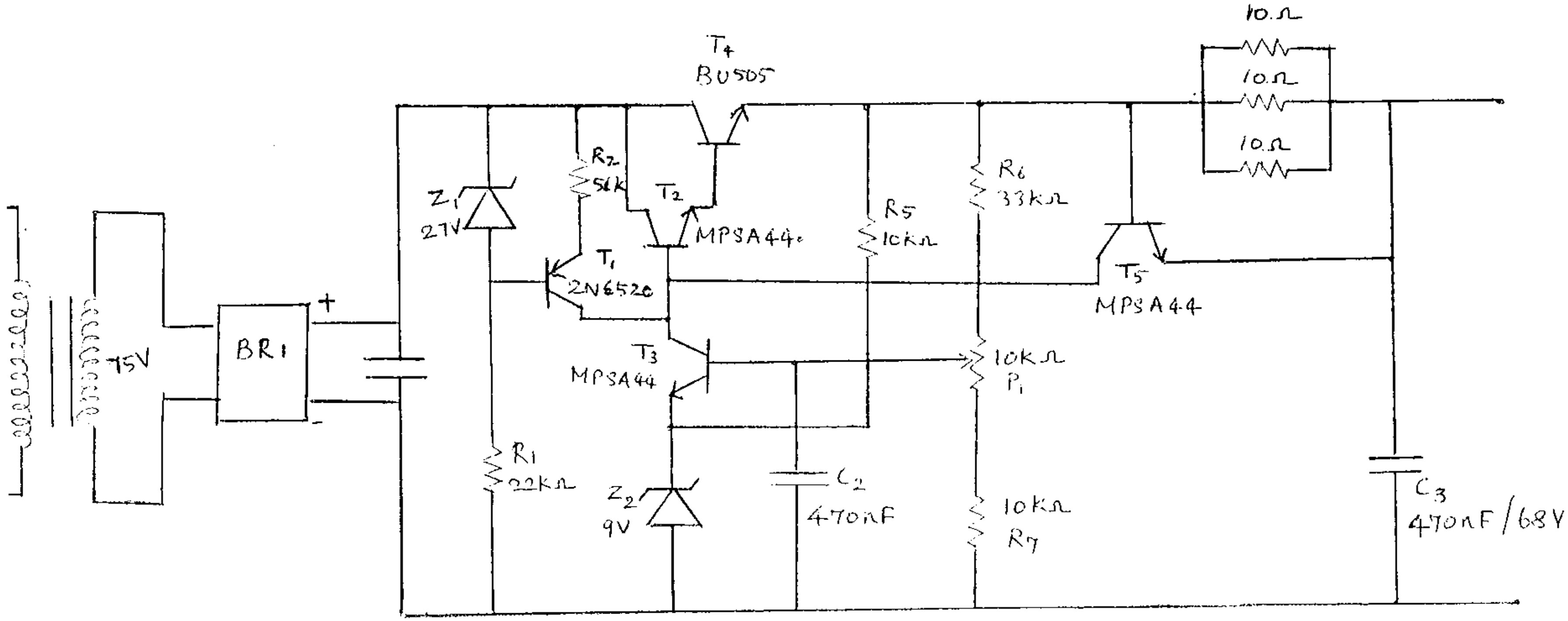


FIG 6.2

energises the relay coil.

6.1.3 OFF HOOK DETECTOR

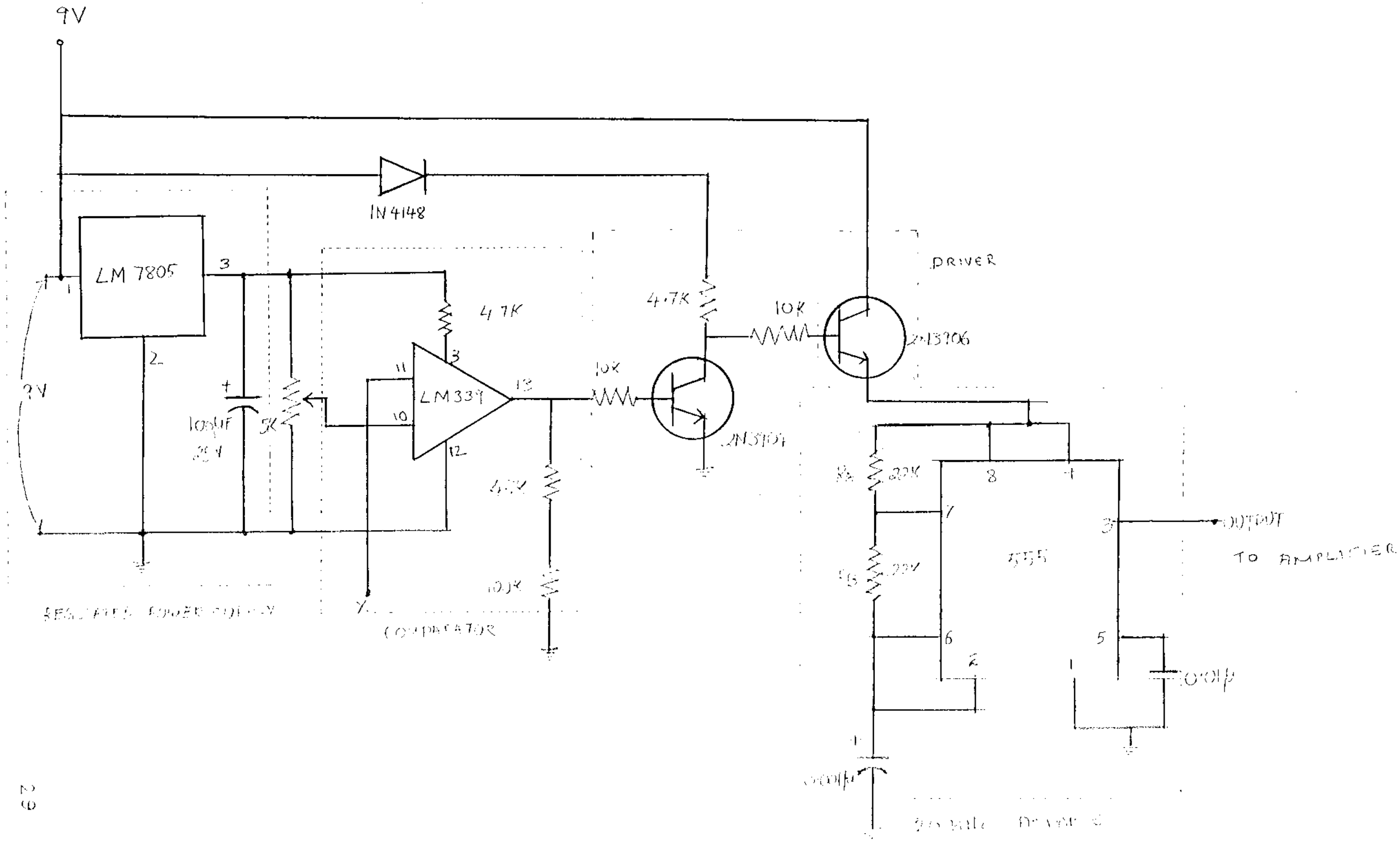
The off hook condition of the telephone is indicated by a drop from 48 volts to 10 volts in DC in line voltage. Additionally, the telephone now draws more current to power the internal circuits. The resistance in series with the telephone set is used to detect this off hook condition. The voltage drop across this resistance is used in two ways.

First, the voltage drives a SL100 circuit connected to the changeover relay and makes the relay changeover from ringing mode to audio coupling mode. This stops the ring and the telephone is switched to audio coupling mode.

Secondly the drop triggers a comparator circuit constructed around LM339(fig 6.3). This drives an astable multivibrator using 555-timer circuit through a transistor pair, that sends out a 20 kHz signal along the powerline to the telephone line interface end. This relay is used to drive the holding circuit to indicate off hook condition to the exchange.

OFF HOOK DETECTOR AND TRANSMITTER

FIG 6.3



6.1.4 DIAL DETECTOR AND TRANSMITTER

Pulse dialing is done by detecting the voltage drop across the resistor when pulse dialing is used. This voltage will be pulsed in accordance with the digit dialed. This pulsed voltage is then used to modulate the 20 kHz output of the 555 astable by driving it on and off as per the dialing pulses. This modulated 20 kHz wave is then transmitted through the powerline by the driving amplifier. The dial pulses switch the reed relay at a rate corresponding to the dial pulses at the telephone line interface end. The reed relay switches the holding circuit at the same on and off and thus mimics the pulse dialing action on the telephone end. This is registered as valid dialing by the exchange.

Tone dialing is within the audio frequency range and is directly sent in the voice transmission circuit via the powerline to the telephone line interface

6.1.5 SIGNAL AMPLIFIER

The signal amplifier circuit (fig 6.4) is used to amplify the dial signals from the dialer circuit so that the signal power is sufficient to drive the signal for longer distances over the powerline.

6.1.6 PROTECTION CIRCUITS

Protection circuits are used at various places in the circuit to prevent the accidental malfunctioning of the setup. A 50 Hz notch filter is provided at the output of the powersupply to eliminate the possibility of the 50 Hz ring signal damaging the 48 Volts dc telephone supply at the telephone interface end. Capacitors have been used to prevent the DC from entering the communication line namely the ground and neutral terminals .A low pass filter with a cut-off of 10kHz is used to prevent any higher frequency signals, such as the 20kHz signal from the astable multivibrator. from entering the audio lines and thereby causing interference.

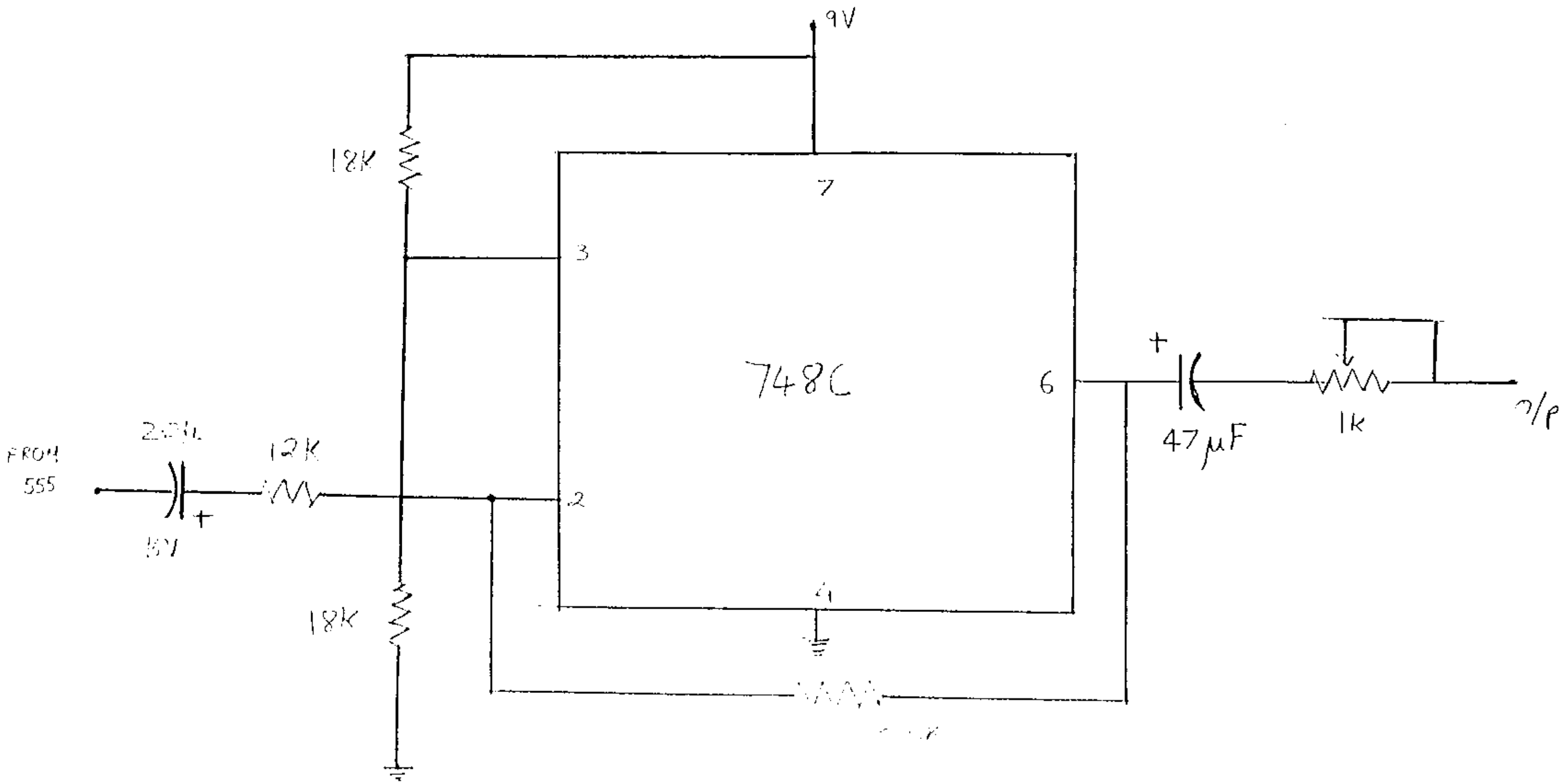


FIG 6.4

SCOPE OF THE PROJECT

Our project is an innovation to add to the myriad world of Hi-tech electronic gizmos simple and portable interface,which will do away with all line extensions from the household telephone box.We propose to increase the number of phones used simultaneously to any desired quantity.Standard digital technology helps us hereby allowing us to encode each signal and hence make it possible to carry out simultaneous conversations.

The tremendous potential of this project can be understood when we bring to light the fact that even data communication is possible using powerlines!Data communications ,the word that opens into the world of Internet,E-mail and computer communications can be made simpler and cheaper by using the already existing and widespread powerlines.

Unfortunately lines in India are generally old and have low bandwidth so such an innovation is impossible at present.It is possible that in future when better situations prevail,our ultimate dream may be fulfilled.

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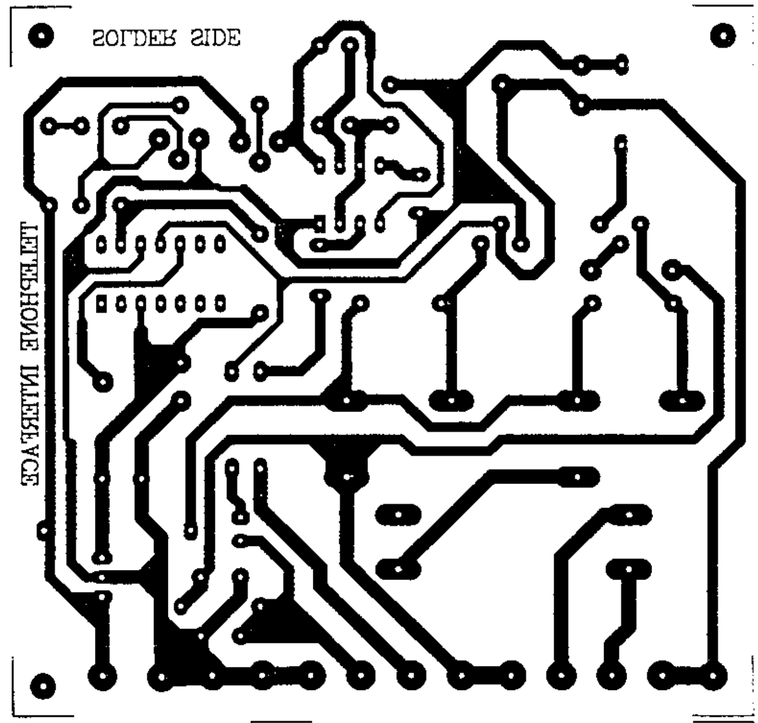
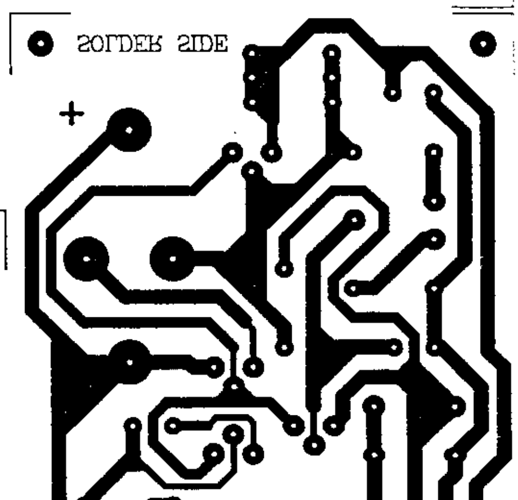
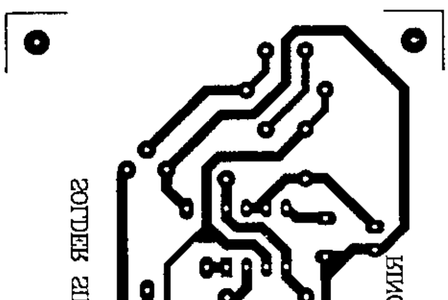
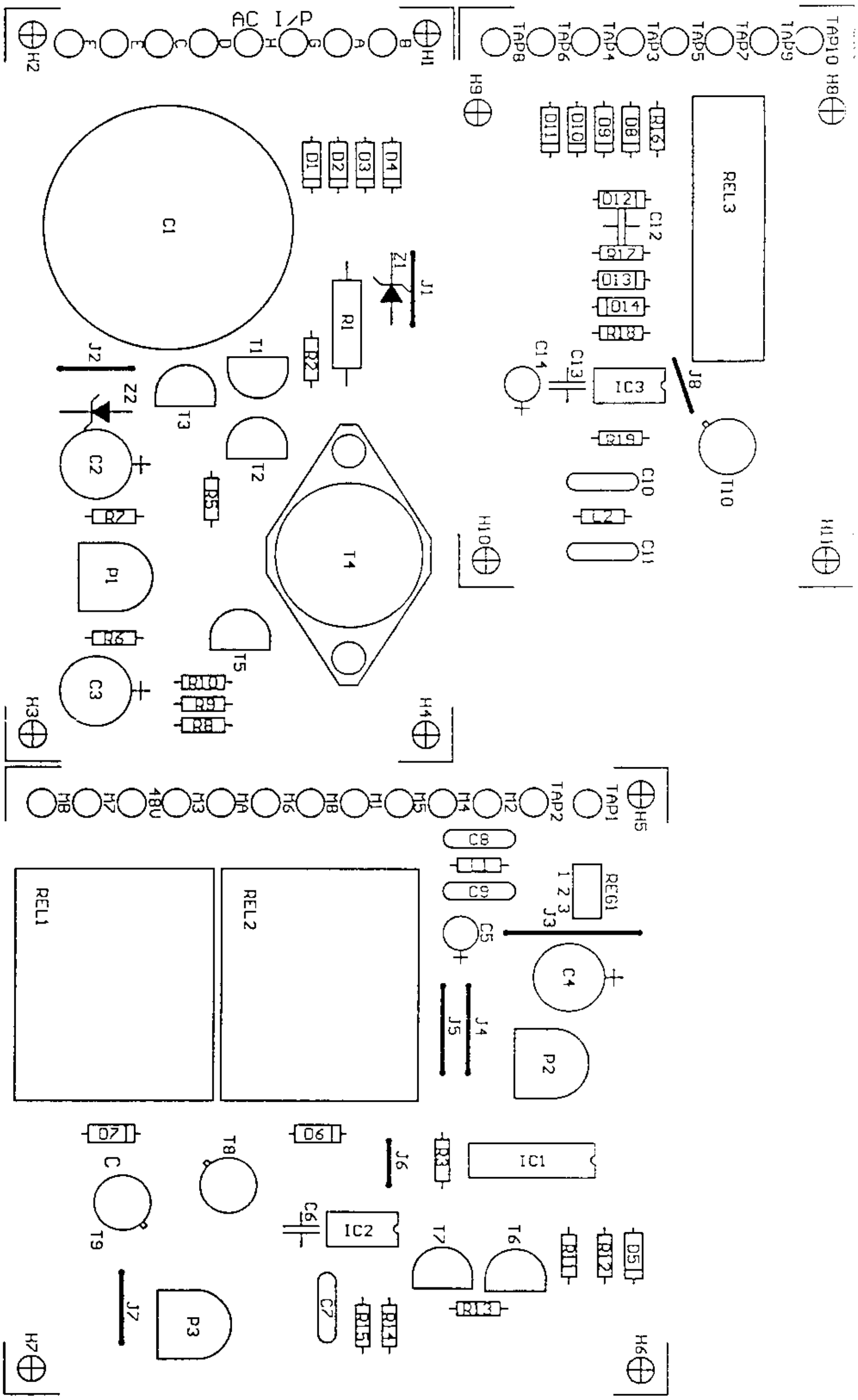

SOLDER SIDE
TELEPHONE INTERFACE


SOLDER SIDE
POWER SUPPLY
+
+
+


SOLDER SIDE
RING DETECTOR & SHAPER


AC I/P
H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 H11
TAP1 TAP2 TAP3 TAP4 TAP5 TAP6 TAP7 TAP8 TAP9 TAP10
C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14
D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12 D13 D14
R1 R2 R3 R5 R6 R7 R8 R9 R10 R11 R12 R13 R14 R15 R16 R17 R18 R19
T1 T2 T3 T4 T5 T6 T7 T8 T9 T10
J1 J2 J3 J4 J5 J6 J7 J8
Z1 Z2
P1 P2 P3
IC1 IC2 IC3
REL1 REL2 REL3
REG1
L1 L2
18U

LM139/239/339, LM139A/239A/339A, LM2901, LM3302 Low Power Low Offset Voltage Quad Comparators

General Description

The LM139 series consists of four independent precision voltage comparators with an offset voltage specification as low as 2 mV max for all four comparators. These were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage. These comparators also have a unique characteristic in that the input common-mode voltage range includes ground, even though operated from a single power supply voltage.

Application areas include limit comparators, simple analog to digital converters; pulse, squarewave and time delay generators; wide range VCO; MOS clock timers; multivibrators and high voltage digital logic gates. The LM139 series was designed to directly interface with TTL and CMOS. When operated from both plus and minus power supplies, they will directly interface with MOS logic – where the low power drain of the LM339 is a distinct advantage over standard comparators.

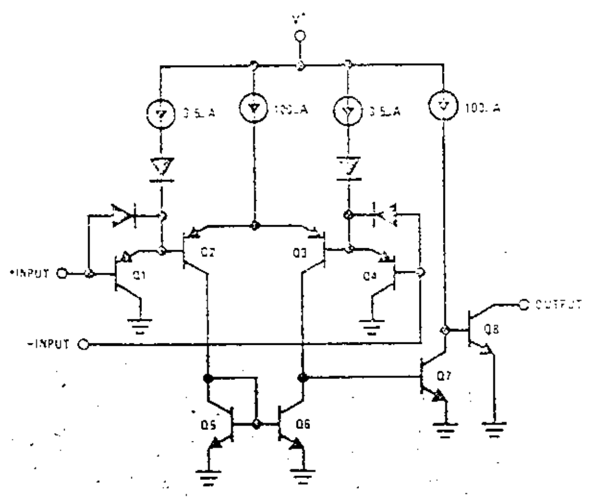
Advantages

- High precision comparators
- Reduced V_{OS} drift over temperature
- Eliminates need for dual supplies
- Allows sensing near gnd
- Compatible with all forms of logic
- Power drain suitable for battery operation

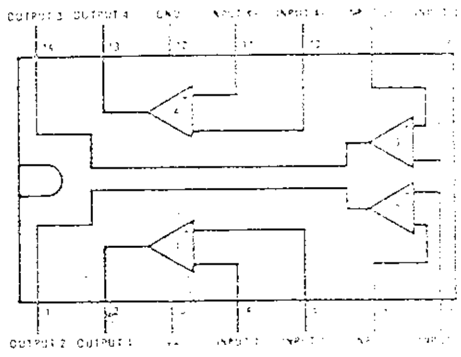
Features

- Wide single supply voltage range or dual supplies
  - LM139 series, 2 V_{DC} to 36 V_{DC} or
  - LM139A series, LM2901 ±1 V_{DC} to ±18 V_{DC}
  - LM3302 2 V_{DC} to 28 V_{DC} or ±1 V_{DC} to ±14 V_{DC}
- Very low supply current drain (0.8 mA) – independent of supply voltage (2 mW/comparator at +5 V_{DC})
- Low input biasing current 25 nA
- Low input offset current ±5 nA and offset voltage ±3 mV
- Input common-mode voltage range includes gnd
- Differential input voltage range equal to the power supply voltage
- Low output saturation voltage 250 mV at 4 mA
- Output voltage compatible with TTL, DTL, ECL, MOS and CMOS logic systems

Schematic and Connection Diagrams



Dual-In-Line and Flat Package

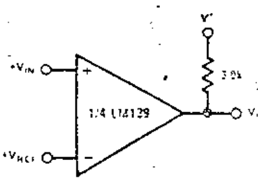


TOP VIEW

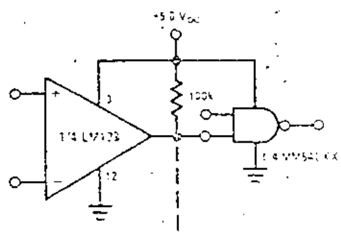
Order Number LM139J, LM139AJ, LM239J, LM239AJ, LM339J, LM339AJ, LM2901J or LM3302J
See NS Package J14A

Order Number LM339N, LM339AN, LM2901N or LM3302N
See NS Package N14A

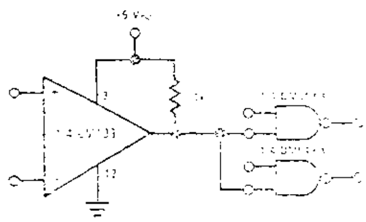
Typical Applications ($V^+ = 5.0\ V_{DC}$)



Basic Comparator



Driving CMOS



Driving TTL

Absolute Maximum Ratings

	LM139/LM239/LM339 LM139A/LM239A/LM339A LM2901	LM3302
Supply Voltage, V^+	$36\ V_{DC}$ or $\pm 18\ V_{DC}$	$28\ V_{DC}$ or $\pm 14\ V_{DC}$
Differential Input Voltage	$36\ V_{DC}$	$28\ V_{DC}$
Input Voltage	$-0.3\ V_{DC}$ to $+36\ V_{DC}$	$-0.3\ V_{DC}$ to $+28\ V_{DC}$
Power Dissipation (Note 1)		
Molded DIP	570 mW	570 mW
Cavity DIP	900 mW	
Flat Pack	800 mW	
Output Short-Circuit to GND, (Note 2)	Continuous	Continuous
Input Current ($V_{IN} < -0.3\ V_{DC}$), (Note 3)	50 mA	50 mA
Operating Temperature Range		
LM339A	0°C to +70°C	−40°C to +85°C
LM239A	−25°C to +85°C	
LM2901	−40°C to +85°C	
LM139A	−55°C to +125°C	
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C	300°C

Electrical Characteristics ($V^+ = 5\ V_{DC}$, Note 4)

PARAMETER	CONDITIONS	LM139A			LM239A, LM339A			LM139			LM239, LM339			LM2901			LM3302			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$, (Note 9)		±1.0	±2.0		±1.0	±2.0		±2.0	±5.0		±2.0	±5.0		±2.0	±7.0		±3	±20	mV_{DC}
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$ with Output in Linear Range, $T_A = 25°C$, (Note 5)		25	100		25	250		25	100		25	250		25	250		25	500	nA_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, $T_A = 25°C$		±3.0	±25		±5.0	±50		±3.0	±25		±5.0	±50		±5	±50		±3	±100	nA_{DC}
Input Common-Mode Voltage Range	$T_A = 25°C$, (Note 6)	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	V_{DC}
Supply Current	$R_L = \infty$ on all Comparators, $T_A = 25°C$		0.8	2.0		0.8	2.0		0.8	2.0		0.8	2.0		0.8	2.0		0.8	2	mA_{DC}
	$R_L = \infty$, $V^+ = 30V$, $T_A = 25°C$														1	2.5				mA_{DC}
Voltage Gain	$R_L \geq 15\ k\Omega$, $V^+ = 15\ V_{DC}$ (To Support Large V_O Swing), $T_A = 25°C$	50	200		50	200			200			200		25	100		2	30		V/mV
Large Signal Response Time	V_{IN} = TTL Logic Swing, $V_{REF} = 1.4\ V_{DC}$, $V_{RL} = 5\ V_{DC}$, $R_L = 5.1\ k\Omega$, $T_A = 25°C$		300			300			300			300			300			300		ns
Response Time	$V_{RL} = 5\ V_{DC}$, $R_L = 5.1\ k\Omega$, $T_A = 25°C$, (Note 7)		1.3			1.3			1.3			1.3			1.3			1.3		μs
Output Sink Current	$V_{IN(-)} \geq 1\ V_{DC}$, $V_{IN(+)} = 0$, $V_O \leq 1.5\ V_{DC}$, $T_A = 25°C$	6.0	16		6.0	16		6.0	16		6.0	16		6.0	16		6.0	16		mA_{DC}
Saturation Voltage	$V_{IN(-)} \geq 1\ V_{DC}$, $V_{IN(+)} = 0$, $I_{SINK} \leq 4\ mA$, $T_A = 25°C$		250	400		250	400		250	400		250	400			400		250	500	mV_{DC}
Output Leakage Current	$V_{IN(+)} \geq 1\ V_{DC}$, $V_{IN(-)} = 0$,		0.1			0.1			0.1			0.1			0.1			0.1		[illegible]

PARAMETER	CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNITS
Input Offset Voltage	(Note 9)			4.0			4.0			9.0			9.0		9	15			40	mV_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$			±100			±150			±100			±150		50	200			300	nA_{DC}
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$ with Output in Linear Range			300			400			300			400		200	500			1000	nA_{DC}
Input Common-Mode Voltage Range		0		$V^+-2.0$	0		$V^+-2.0$	0		$V^+-2.0$	0		$V^+-2.0$	0		$V^+-2.0$	0		$V^+-2.0$	V_{DC}
Saturation Voltage	$V_{IN(-)} \geq 1\ V_{DC}$, $V_{IN(+)} = 0$, $I_{SINK} \leq 4$ mA			700			700			700			700		400	700			700	mV_{DC}
Output Leakage Current	$V_{IN(+)} \geq 1\ V_{DC}$, $V_{IN(-)} = 0$, $V_O = 30\ V_{DC}$			1.0			1.0			1.0			1.0			1.0			1.0	μA_{DC}
Differential Input Voltage	Keep all V_{IN}'s $\geq 0\ V_{DC}$ (or V^-, if used), (Note 8)			36			36			36			36	0		36			28	V_{DC}

Note 1: For operating at high temperatures, the LM339/LM339A, LM2901, LM3302 must be derated based on a 125°C maximum junction temperature and a thermal resistance of 175°C/W which applies for the device soldered in a printed circuit board, operating in a still air ambient. The LM239 and LM139 must be derated based on a 150°C maximum junction temperature. The low bias dissipation and the "ON-OFF" characteristic of the outputs keeps the chip dissipation very small ($P_D \leq 100$ mW), provided the output transistors are allowed to saturate.

Note 2: Short circuits from the output to V^+ can cause excessive heating and eventual destruction. The maximum output current is approximately 20 mA independent of the magnitude of V^+.

Note 3: This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral NPN parasitic transistor action on the IC chip. This transistor action can cause the output voltages of the comparators to go to the V^+ voltage level (or to ground for a large overdrive) for the time duration that an input is driven negative. This is not destructive and normal output states will re-establish when the input voltage, which was negative, again returns to a value greater than $-0.3\ V_{DC}$ (at 25°C).

Note 4: These specifications apply for $V^+ = 5\ V_{DC}$ and $-55°C \leq T_A \leq +125°C$, unless otherwise stated. With the LM239/LM239A, all temperature specifications are limited to $-25°C \leq T_A \leq +85°C$, the LM339/LM339A temperature specifications are limited to $0°C \leq T_A \leq +70°C$, and the LM2901, LM3302 temperature range is $-40°C \leq T_A \leq +85°C$.

Note 5: The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the reference or input lines.

Note 6: The input common-mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3V. The upper end of the common-mode voltage range is $V^+ -1.5V$, but either or both inputs can go to $+30\ V_{DC}$ without damage (25V for LM3302).

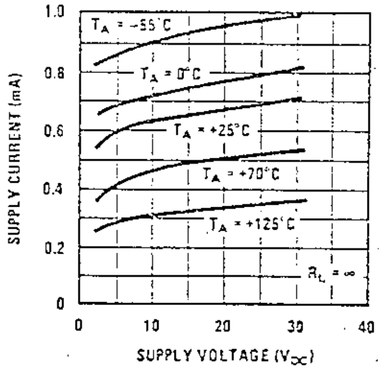
Note 7: The response time specified is a 100 mV input step with 5 mV overdrive. For larger overdrive signals 300 ns can be obtained, see typical performance characteristics section.

Note 8: Positive excursions of input voltage may exceed the power supply level. As long as the other voltage remains within the common-mode range, the comparator will provide a proper output state. The low input voltage state must not be less than $-0.3\ V_{DC}$ (or $0.3\ V_{DC}$ below the magnitude of the negative power supply, if used) (at 25°C).

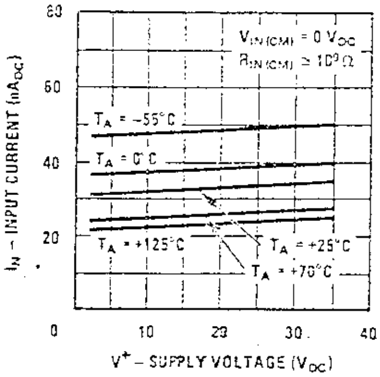
Note 9: At output switch point, $V_O \simeq 1.4\ V_{DC}$, $R_S = 0\Omega$ with V^+ from $5\ V_{DC}$; and over the full input common-mode range ($0\ V_{DC}$ to $V^+ - 1.5\ V_{DC}$).

Typical Performance Characteristics LM139/LM239/LM339, LM139A/LM239A/LM339A, LM3302

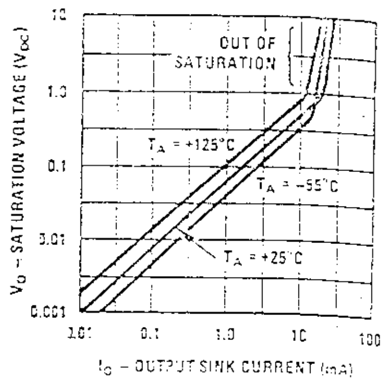
Supply Current



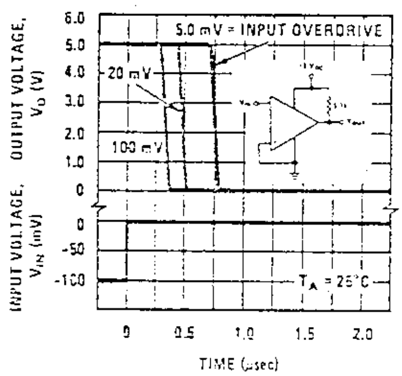
Input Current



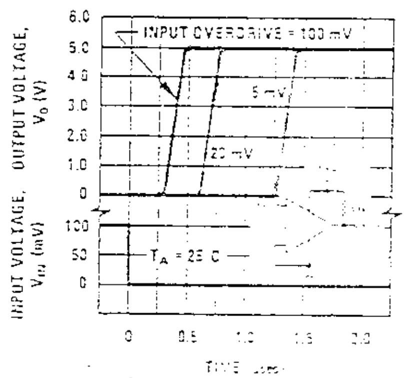
Output Saturation Voltage



Response Time for Various Input Overdrives – Negative Transition

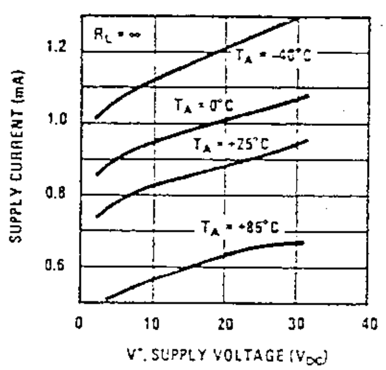


Response Time for Various Input Overdrives – Positive Transition

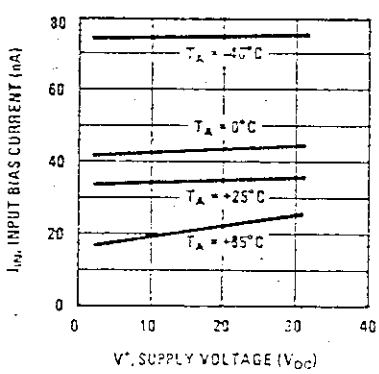


Typical Performance Characteristics LM2901

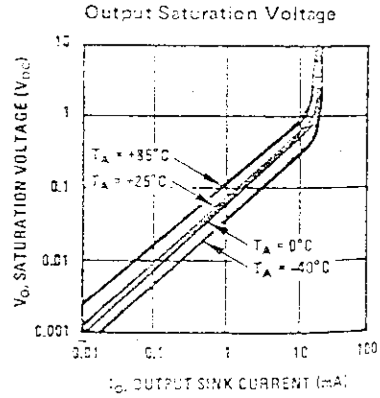
Supply Current



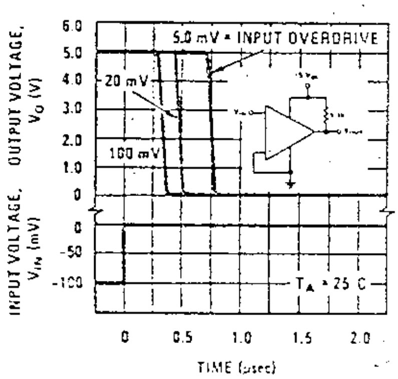
Input Current



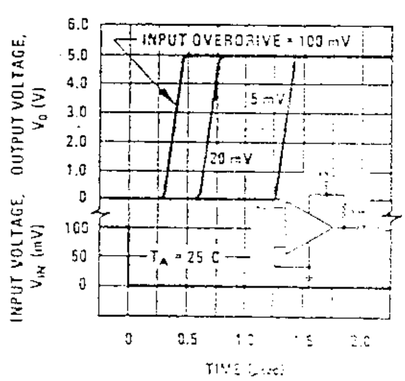
Output Saturation Voltage



Response Time for Various Input Overdrives—Negative Transition



Response Time for Various Input Overdrives—Positive Transition



ı555/LM555C Timer

ıneral Description

LM555 is a highly stable device for generating ırate time delays or oscillation. Additional terminals provided for triggering or resetting if desired. In the delay mode of operation, the time is precisely conıd by one external resistor and capacitor. For astable ation as an oscillator, the free running frequency and cycle are accurately controlled with two external tors and one capacitor. The circuit may be triggered reset on falling waveforms, and the output circuit source or sink up to 200 mA or drive TTL circuits.

ıtures

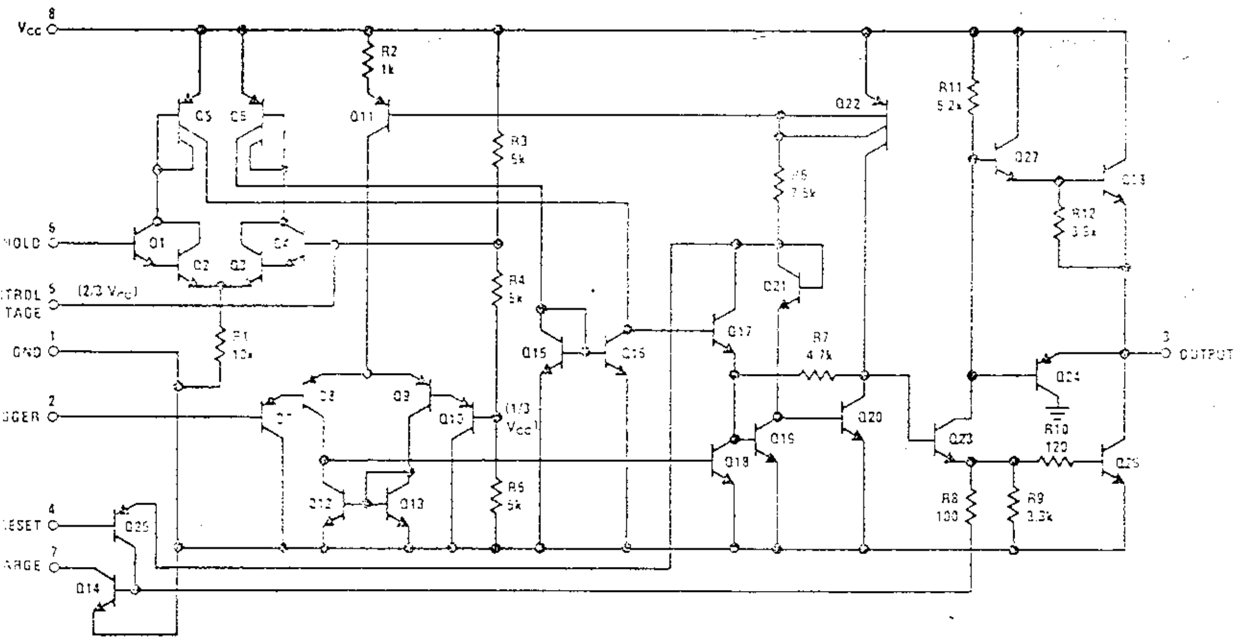
ırect replacement for SE555/NE555
ıiming from microseconds through hours
ıperates in both astable and monostable modes

- Adjustable duty cycle
- Output can source or sink 200 mA
- Output and supply TTL compatible
- Temperature stability better than 0.005% per °C
- Normally on and normally off output

Applications

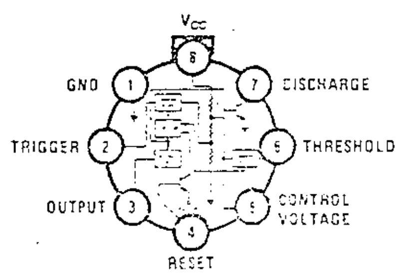
- Precision timing
- Pulse generation
- Sequential timing
- Time delay generation
- Pulse width modulation
- Pulse position modulation
- Linear ramp generator

ıematic Diagram



ınection Diagrams

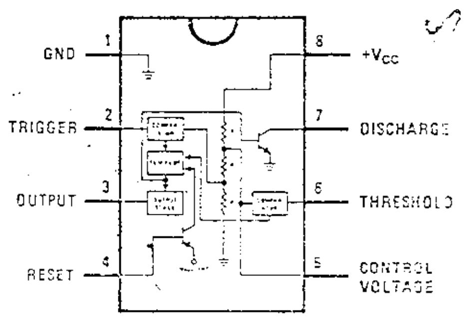
Metal Can Package



TOP VIEW

Order Number LM555H, LM555CH
See NS Package H08C

Dual-In-Line Package



TOP VIEW

Order Number LM555CN
See NS Package N08B
Order Number LM555J or LM555CJ
See NS Package J08A

ɔplication Hints

e LM139 series are high gain, wide bandwidth ,ices which, like most comparators, can easily illate if the output lead is inadvertently allowed capacitively couple to the inputs via stray acitance. This shows up only during the output age transition intervals as the comparator chan- states. Power supply bypassing is not required solve this problem. Standard PC board layout elpful as it reduces stray input-output coupling. lucing the input resistors to < 10 kΩ reduces feedback signal levels and finally, adding even nall amount (1 to 10 mV) of positive feedback steresis) causes such a rapid transition that illations due to stray feedback are not possible. iply socketing the IC and attaching resistors to pins will cause input-output oscillations during small transition intervals unless hysteresis is d. If the input signal is a pulse waveform, with tively fast rise and fall times, hysteresis is not uired.

pins of any unused comparators should be unded.

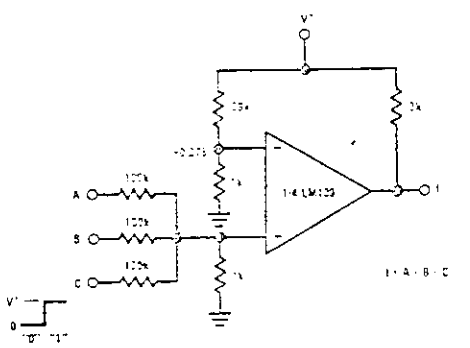
bias network of the LM139 series establishes a n current which is independent of the magni- e of the power supply voltage over the range from 2 V_{DC} to 30 V_{DC}.

usually unnecessary to use a bypass capacitor ss the power supply line.

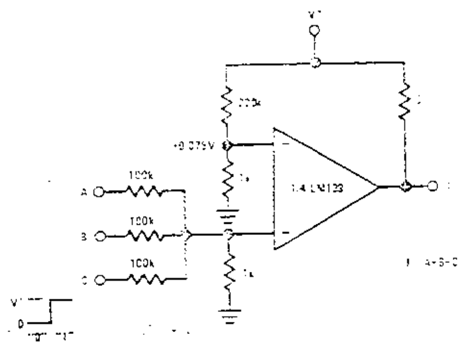
The differential input voltage may be larger than V^+ without damaging the device. Protection should be provided to prevent the input voltages from going negative more than -0.3 V_{DC} (at 25°C). An input clamp diode can be used as shown in the applications section.

The output of the LM139 series is the uncommitted collector of a grounded-emitter NPN output transistor. Many collectors can be tied together to provide an output OR'ing function. An output pull-up resistor can be connected to any available power supply voltage within the permitted supply voltage range and there is no restriction on this voltage due to the magnitude of the voltage which is applied to the V^+ terminal of the LM139A package. The output can also be used as a simple SPST switch to ground (when a pull-up resistor is not used). The amount of current which the output device can sink is limited by the drive available (which is independent of V^+) and the β of this device. When the maximum current limit is reached (approximately 16 mA), the output transistor will come out of saturation and the output voltage will rise very rapidly. The output saturation voltage is limited by the approximately 60Ω r_{sat} of the output transistor. The low offset voltage of the output transistor (1 mV) allows the output to clamp essentially to ground level for small load currents.

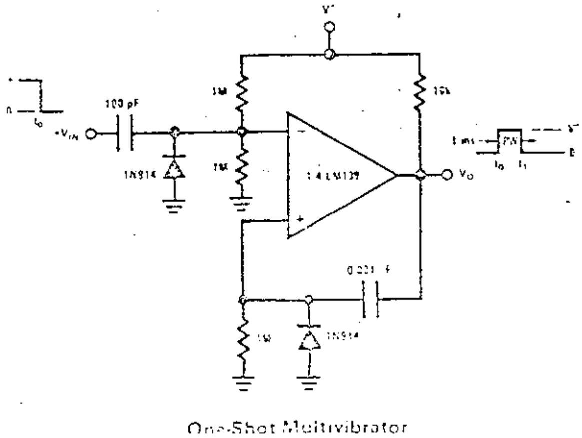
ɔical Applications ($V^+ = 15\ V_{DC}$)



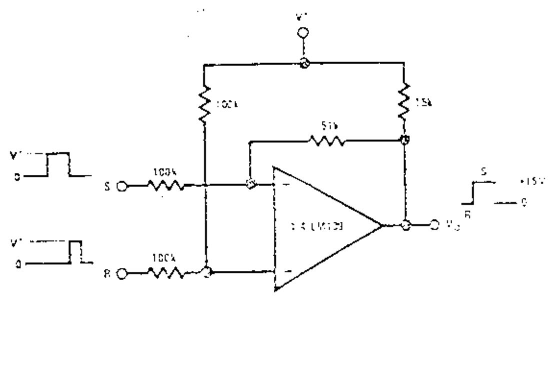
AND Gate



OR Gate

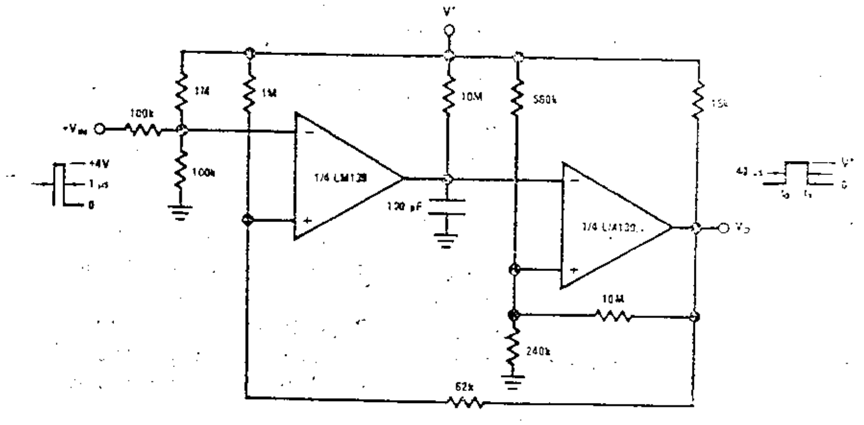


One-Shot Multivibrator

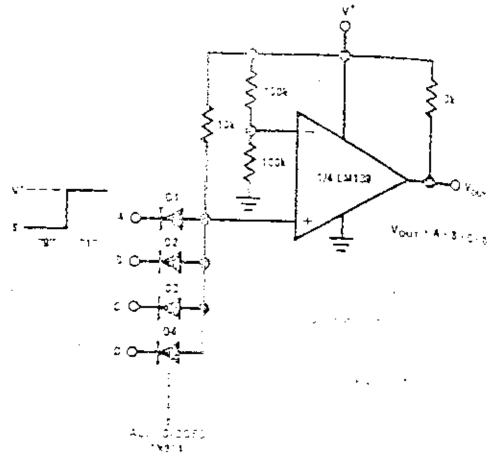


Bi-Stable Multivibrator

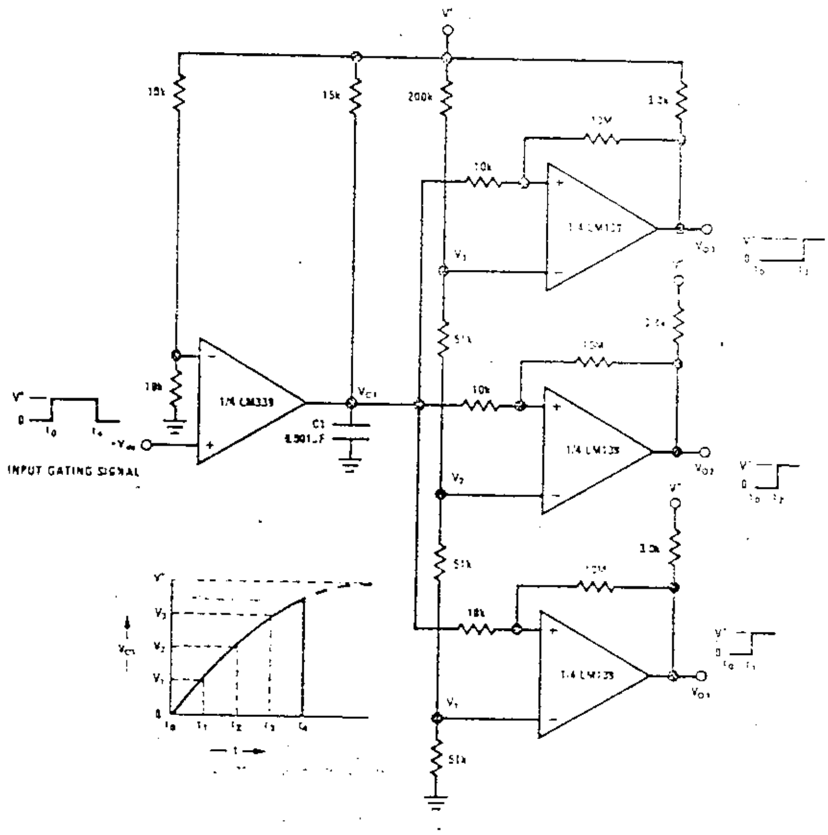
Typical Applications (Continued) ($V^+ = 15\ V_{DC}$)



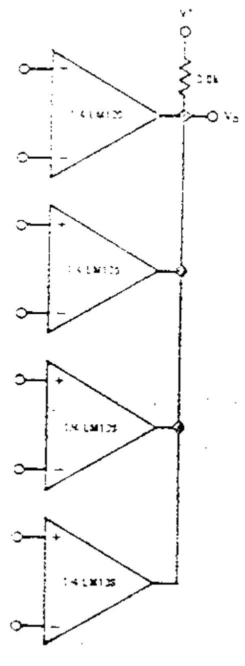
One-Shot Multivibrator with Input Lock Out



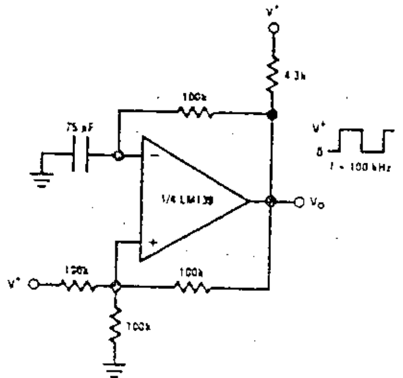
Large Fan-in AND Gate



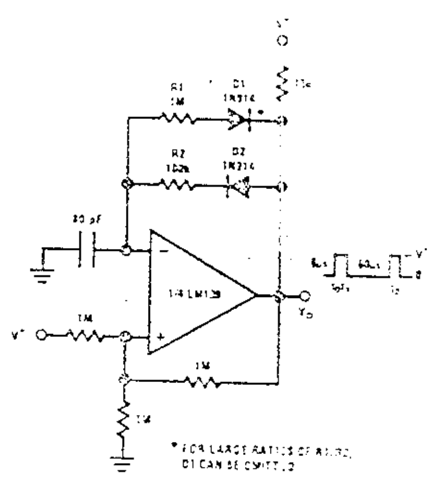
Time Delay Generator



ORing the Outputs

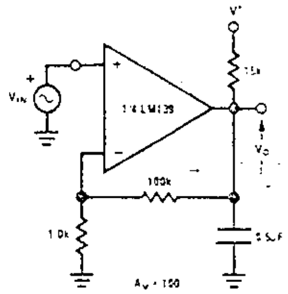


Squarewave Oscillator

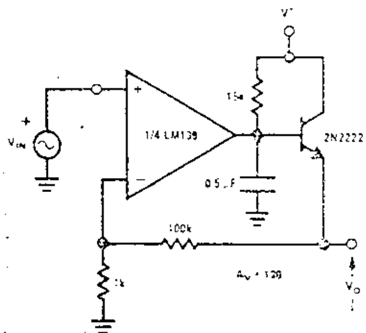


Pulse Generator

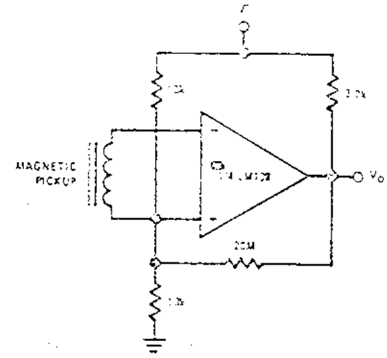
Typical Applications (Continued) ($V^+ = 5\ V_{DC}$)



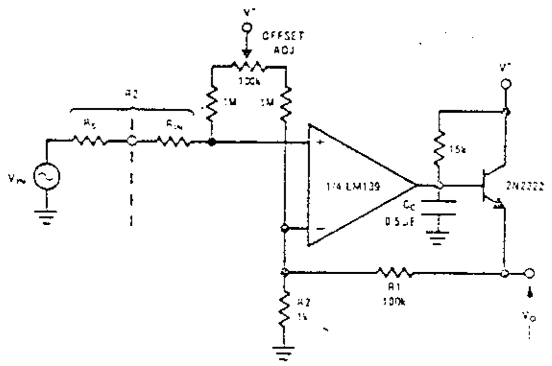
Low Frequency Op Amp



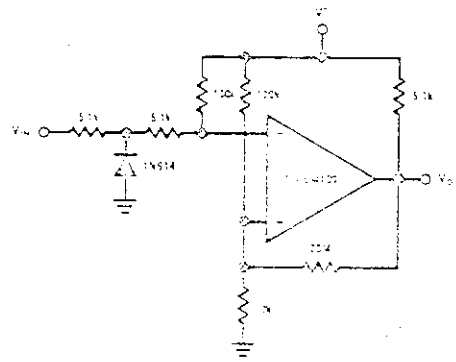
Low Frequency Op Amp
($V_O = 0V$ for $V_{IN} = 0V$)



Transducer Amplifier

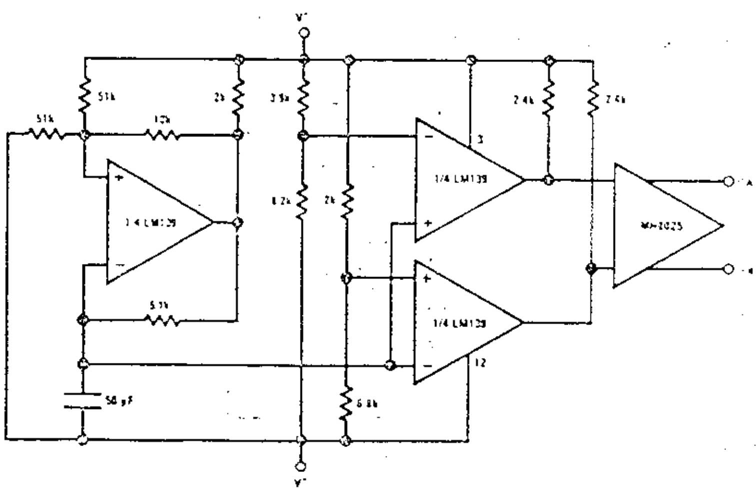


Low Frequency Op Amp with Offset Adjust

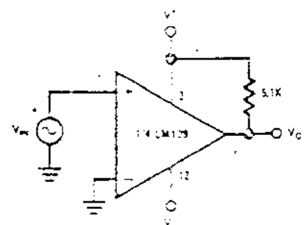


Zero Crossing Detector (Single Power Supply)

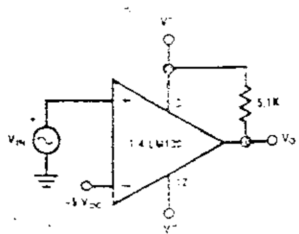
Split-Supply Applications ($V^+ = +15\ V_{DC}$ and $V^- = -15\ V_{DC}$)



MOS Clock Driver



Zero Crossing Detector



Comparator With a Negative Reference

Absolute Maximum Ratings

Supply Voltage	+18V
Power Dissipation (Note 1)	600 mW
Operating Temperature Ranges	
LM555C	0°C to +70°C
LM555	−55°C to +125°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

Electrical Characteristics (T_A = 25°C, V_{CC} = +5V to +15V, unless otherwise specified)

PARAMETER	CONDITIONS	LIMITS						UNITS
		LM555			LM555C			
		MIN	TYP	MAX	MIN	TYP	MAX	
Supply Voltage		4.5		18	4.5		16	V
Supply Current	V_{CC} = 5V, R_L = ∞		3	5		3	6	mA
	V_{CC} = 15V, R_L = ∞		10	12		10	15	mA
	(Low State) (Note 2)							
Timing Error, Monostable								
Initial Accuracy			0.5			1		%
Drift with Temperature	R_A, R_B = 1k to 100 k,		30			50		ppm/°C
	C = 0.1μF, (Note 3)							
Accuracy over Temperature			1.5			1.5		%
Drift with Supply			0.05			[illegible]		%/V
Timing Error, Astable								
Initial Accuracy			1.5			2.25		%
Drift with Temperature			90			150		ppm/°C
Accuracy over Temperature			2.5			3.0		%
Drift with Supply			0.15			0.30		%/V
Threshold Voltage			0.667			0.667		x V_{CC}
Trigger Voltage	V_{CC} = 15V	4.8	5	5.2		5		V
	V_{CC} = 5V	1.45	1.67	1.9		1.67		V
Trigger Current			0.01	0.5		0.5	0.9	μA
Reset Voltage		0.4	0.5	1	0.4	0.5	1	V
Reset Current			0.1	0.4		0.1	0.4	mA
Threshold Current	(Note 4)		0.1	0.25		0.1	0.25	μA
Control Voltage Level	V_{CC} = 15V	9.6	10	10.4	9	10	11	V
	V_{CC} = 5V	2.9	3.33	3.8	2.6	3.33	4	V
Pin 7 Leakage Output High			1	100		1	100	nA
Pin 7 Sat (Note 5)								
Output Low	V_{CC} = 15V, I_7 = 15 mA		150			180	[illegible]	mV
Output Low	V_{CC} = 4.5V, I_7 = 4.5 mA		70	100		80	200	mV
Output Voltage Drop (Low)	V_{CC} = 15V							
	I_{SINK} = 10 mA		0.1	0.15		0.1	0.25	V
	I_{SINK} = 50 mA		0.4	0.5		0.4	0.75	V
	I_{SINK} = 100 mA		2	2.2		2	2.5	V
	I_{SINK} = 200 mA		2.5			2.5		V
	V_{CC} = 5V							
	I_{SINK} = 8 mA		0.1	0.25				V
	I_{SINK} = 5 mA					0.25	0.35	V
Output Voltage Drop (High)	I_{SOURCE} = 200 mA, V_{CC} = 15V		12.5			12.5		V
	I_{SOURCE} = 100 mA, V_{CC} = 15V	13	13.3		12.75	13.3		V
	V_{CC} = 5V	3	3.3		2.75	3.3		V
Rise Time of Output			100			100		ns
Fall Time of Output			100			100		ns

Note 1: For operating at elevated temperatures the device must be derated based on a +150°C maximum junction temperature and a thermal resistance of +45°C/W junction to case for TO-5 and +150°C/W junction to ambient for both packages.

Note 2: Supply current when output high typically 1 mA less at V_{CC} = 5V.

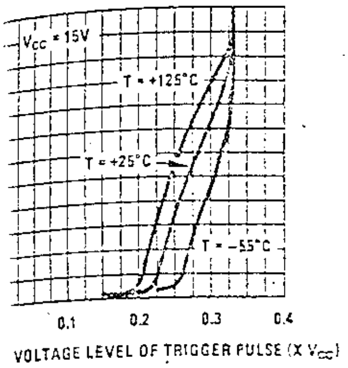
Note 3: Tested at V_{CC} = 5V and V_{CC} = 15V.

Note 4: This will determine the maximum value of $R_A + R_B$ for 15V operation. The maximum total ($R_A + R_B$) is 20 MΩ.

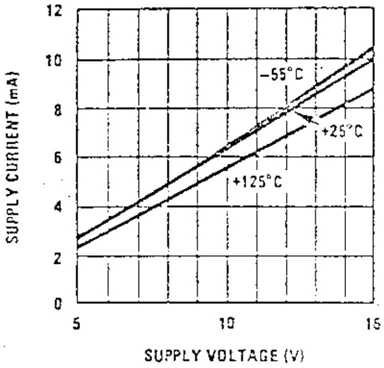
Note 5: No protection against excessive pin 7 current is necessary providing the package dissipation rating will not be exceeded.

cal Performance Characteristics

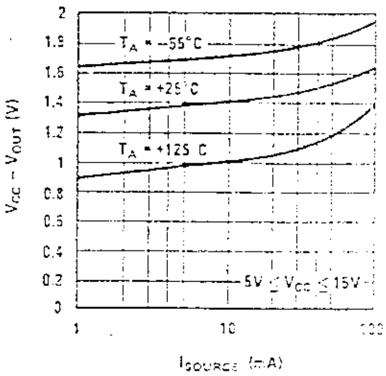
Minimum Pulse Width Required for Triggering



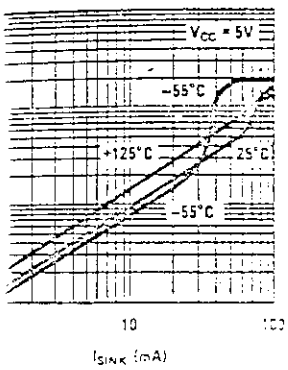
Supply Current vs Supply Voltage



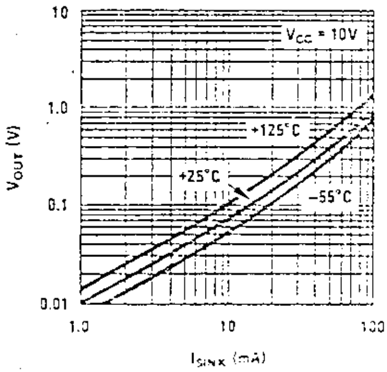
High Output Voltage vs Output Source Current



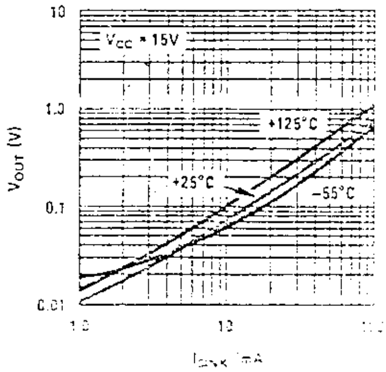
ow Output Voltage vs utput Sink Current



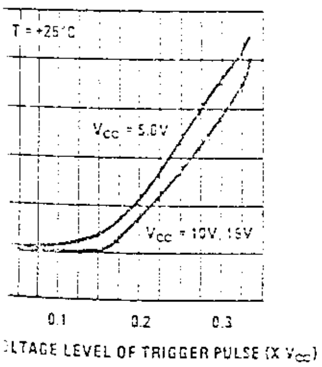
Low Output Voltage vs Output Sink Current



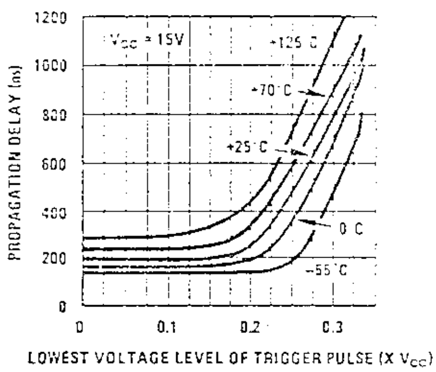
Low Output Voltage vs Output Sink Current



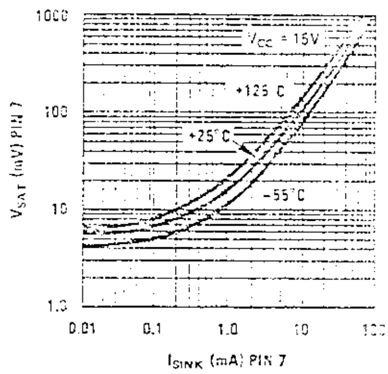
tput Propagation Delay vs ltage Level of Trigger Pulse



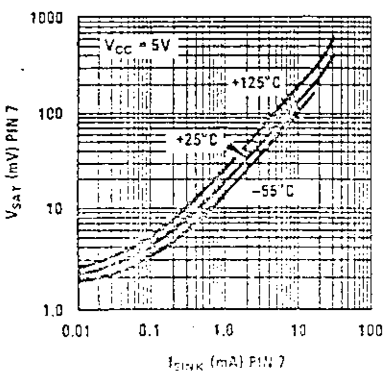
Output Propagation Delay vs Voltage Level of Trigger Pulse



Discharge Transistor (Pin 7) Voltage vs Sink Current



Discharge Transistor (Pin 7) Voltage vs Sink Current



or, R_A, in the monostable circu
ant current source, a linear ramp

Applications Information

MONOSTABLE OPERATION

In this mode of operation, the timer functions as a one-shot (*Figure 1*). The external capacitor is initially held discharged by a transistor inside the timer. Upon application of a negative trigger pulse of less than 1/3 V_{CC} to pin 2, the flip-flop is set which both releases the short circuit across the capacitor and drives the output high.

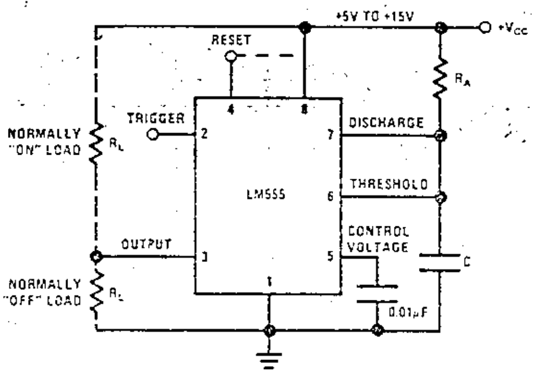


FIGURE 1. Monostable

The voltage across the capacitor then increases exponentially for a period of $t = 1.1\ R_A C$, at the end of which time the voltage equals 2/3 V_{CC}. The comparator then resets the flip-flop which in turn discharges the capacitor and drives the output to its low state. *Figure 2* shows the waveforms generated in this mode of operation. Since the charge and the threshold level of the comparator are both directly proportional to supply voltage, the timing internal is independent of supply.

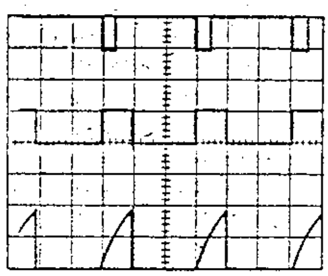


FIGURE 2. Monostable Waveforms

During the timing cycle when the output is high, the further application of a trigger pulse will not effect the circuit. However the circuit can be reset during this time by the application of a negative pulse to the reset terminal (pin 4). The output will then remain in the low state until a trigger pulse is again applied.

When the reset function is not in use, it is recommended that it be connected to V_{CC} to avoid any possibility of false triggering.

Figure 3 is a nomograph for easy determination of R, C values for various time delays.

NOTE: . or op·ratin·ble operation, the trigger should be driver ce of +45°C/W junction f timing cycle.

.. 2: Supply current when output I

AS te 3: Tested at V_{CC} = 5V and V_{CC}

Note 4: This will determine the maximum in *Figure 4* (pins 2

Note 5: No protection against excessive self and free run as a

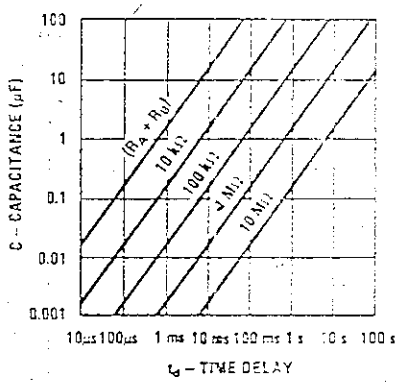


FIGURE 3. Time Delay

multivibrator. The external capacitor charges through $R_A + R_B$ and discharges through R_B. Thus the duty cycle may be precisely set by the ratio of these two resistors.

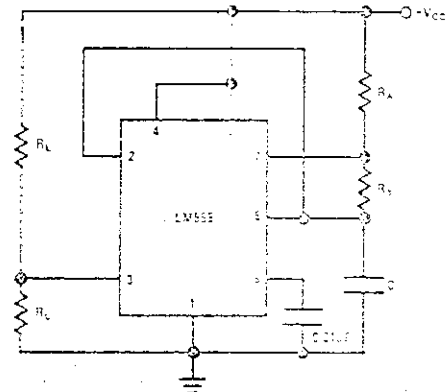


FIGURE 4. Astable

In this mode of operation, the capacitor charges and discharges between 1/3 V_{CC} and 2/3 V_{CC}. As in the triggered mode, the charge and discharge times, and therefore the frequency are independent of the supply voltage.

Figure 5 shows the waveforms generated in this mode of operation.

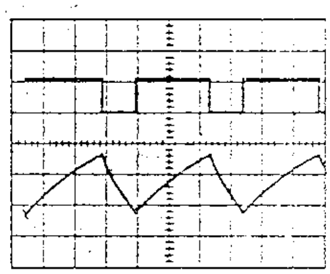


FIGURE 5. Astable Waveforms

The charge time (output high) is given by:

$$t_1 = 0.693\ (R_A + R_B)\ C$$

And the discharge time (output low) by:

$$t_2 = 0.693\ (R_B)\ C$$

Thus the total period is:

$$T = t_1 + t_2 = 0.693\ (R_A + 2R_B)\ C$$

Applications Information (Continued)

The frequency of oscillation is:

$$f = \frac{1}{T} = \frac{1.44}{(R_A + 2\,R_B)\,C}$$

Figure 6 may be used for quick determination of these RC values.

The duty cycle is: $D = \dfrac{R_B}{R_A + 2R_B}$

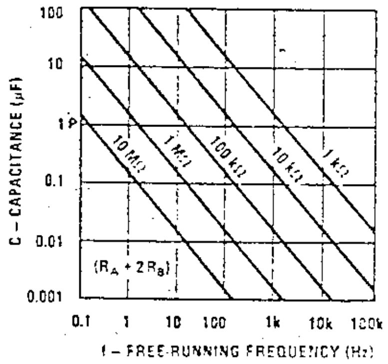


FIGURE 6. Free Running Frequency

FREQUENCY DIVIDER

The monostable circuit of *Figure 1* can be used as a frequency divider by adjusting the length of the timing cycle. *Figure 7* shows the waveforms generated in a divide by three circuit.

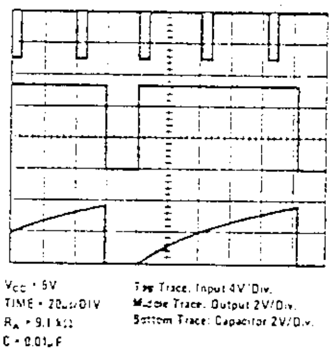


FIGURE 7. Frequency Divider

PULSE WIDTH MODULATOR

When the timer is connected in the monostable mode and triggered with a continuous pulse train, the output pulse width can be modulated by a signal applied to pin 5. *Figure 8* shows the circuit, and in *Figure 9* are some waveform examples.

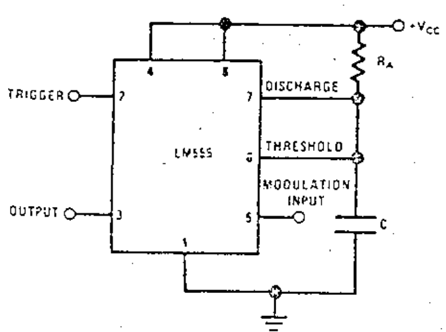


FIGURE 8. Pulse Width Modulator

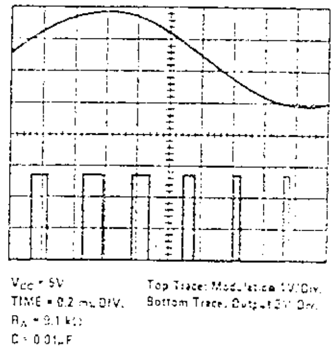


FIGURE 9. Pulse Width Modulator

PULSE POSITION MODULATOR

This application uses the timer connected for astable operation, as in *Figure 10*, with a modulating signal again applied to the control voltage terminal. The pulse position varies with the modulating signal, since the threshold voltage and hence the time delay is varied. *Figure 11* shows the waveforms generated for a triangle wave modulation signal.

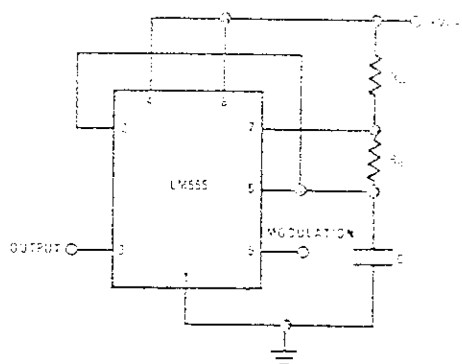


FIGURE 10. Pulse Position Modulator

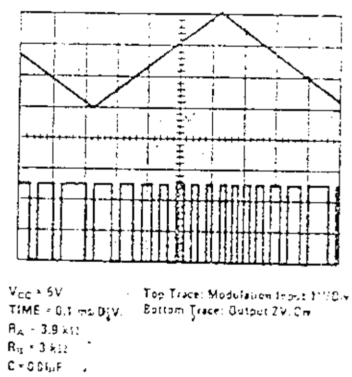


FIGURE 11. Pulse Position Modulator

LINEAR RAMP

When the pullup resistor, R_A, in the monostable circuit is replaced by a constant current source, a linear ramp