DESIGN AND DEVELOPMENT OF LOOP EXTENDER/REPEATER FOR PATCOM'S ANALOG CARD (CHA-03)

BY

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DEDICATION!

DEDICATED TO OUR BELOVED PARENTS WHO HAVE BEEN A SOURCE OF CONSTANT ENCOURAGEMENT FOR US.

DECLARATION

No portion of this work presented in this dissertation has been submitted in support of another award of qualification either at this institution or elsewhere.

ACKNOWLEDGEMENTS

All praise be to Almighty Allah who bestowed minute portion of boundless knowledge by virtue of which we were able to accomplish this challenging task. We would have never been able to reach success without the able supervision and guidance of our project Directing Staff MAJOR IMRAN RASHEED who had been a constant source of encouragement and guidance.

ABSTRACT

The induction of state of the art PATCOMS equipment has revolutionized the communication scenario of Pakistan Army. In field conditions, the importance of provision of vital information to commanders at all level can never be denied. It has often experienced that units/detachments are deployed in AOR much ahead of the formations/unit headquarters. A normal analog PATCOMS subscriber number which has a maximum line length of 6 kms can not be extended to such isolated units/detachments deployed beyond the recommended line distance as no line extender/repeaters are presently available with PATCOMS equipment.

The functionality of this project is to describe the specifications for a device which will be used to enhance the existing range of the analog extention of patcoms. This device will include two separate circuits,one each for exch side(DMU-220) and the other for the subscriber side. Each device will act as self-contained independent systems. This configuration will allow the signal to be enhanced and amplified at both ends.The device is planned to contain a power amplifier in the voice frequency range, an echo cancellation device,and an impedance matching unit.

Project Specification

1.1 Background

In today's economy, it is an immense need that people are demanding more and more cost effective systems for communication to function efficiently. To make up for this demand, companies are enhancing their communication systems and applications which is effective in both efficiency and cost.

For this reason, it is necessary to make communication between our defense equipments as easy as possible by allowing the ARMY with ease for greater distance and lesser cost. For the implementation of this project the equipment of well know and developed communication company called MITEL was used.

1.2 Motivation

The big scope of this project was to develop a module to aid in the extention in the existing range of the PATCOM's analog subscriber to serve the units and detachments deployed at far away from the main Headquarters.This will help in serving these units and detachments as well as in saving the complete PATCOMS link and inturn saving a lot for the national exchequer.

1.3 Implementation

To implement the design , two different circuit boards were designed. The two boards consisted of a exchange side modem and the subscriber side modem. The exchange side accepts signals from DMU-220and transfer the information to subscriber side modem. The signals from the exchange side before being received by the subscriber side modem are amplified and boosted.The same process is repeated by the subscriber side modem when the signals received are from the user side.

LIST OF FIGURES

CHAPTER 1: DELTA MULTIPLEXER UNIT (DMU-220)

CHAPTER 1: DELTA MULTIPLEXER UNIT

1.1 INTRODUCTION

1.1.1 General

This guide is intended for the general guidance of readers of the Delta Multiplexer Unit (DMU-220) hereafter called DMU-220 and does not contain the detailed circuitry of DMU-220. The DMU-220 is an autonomous high capacity Multiplexer for local subscribers.

1.2 DATA

1.2.1 Description

Description: Delta Multiplexer Unit
Type: DMU-220

1.2.2 Physical data for the DMU-220

Width: 483 mm (19î)
Height: 266 mm (10,5î)
Depth: 364 mm (14,2î) (including handles)
Weight: maximum 30 kg (66,14lb)

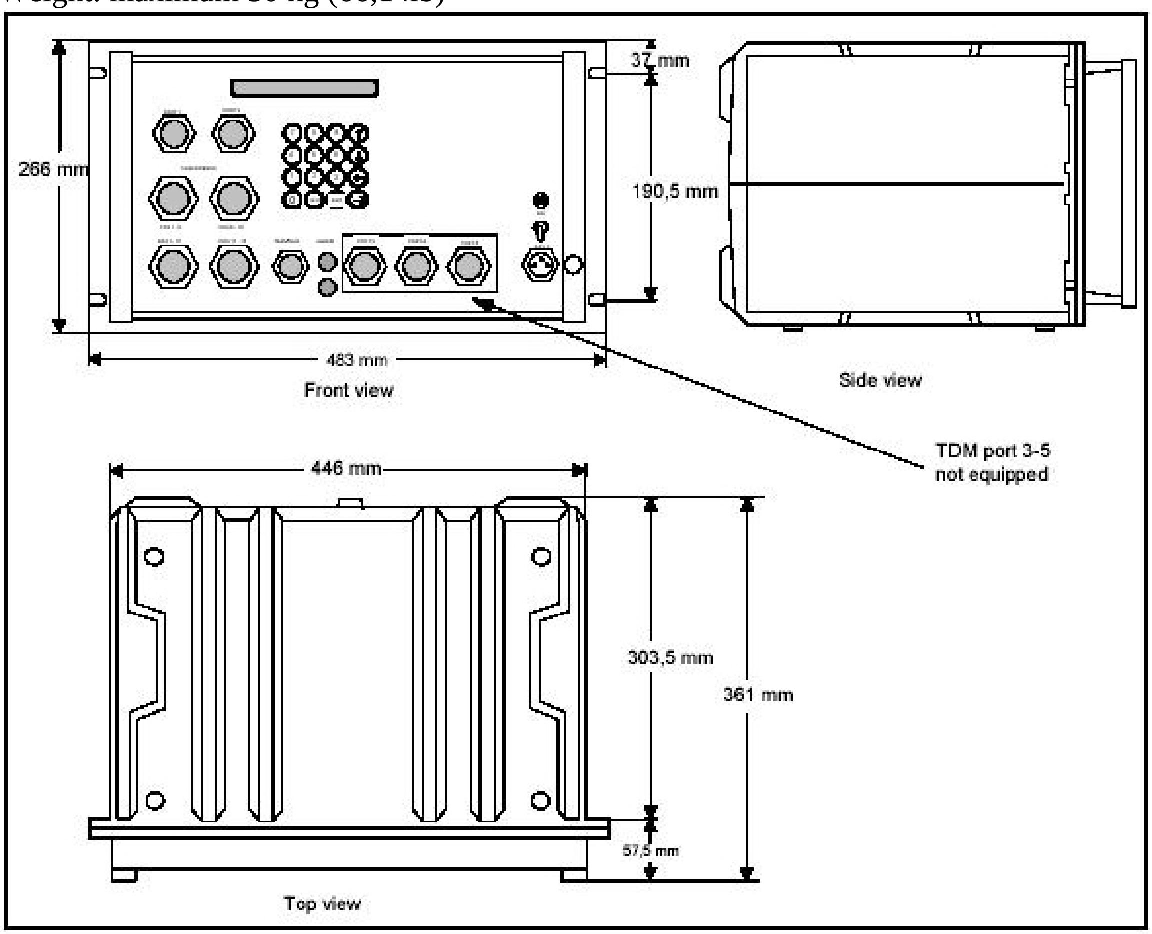

Figure 1.1 DMU-220 Physical Dimensions

1.2.3 Technical data CPX

1.2.3.1 General

The DMU-220 is Multiplexer Unit with access for local subscribers. The Multiplexing system is based on the Time Division Multiplexing (TDM) concept. The DMU-220 is equipped with 2 TDM ports that provide communication between the DMU-220 and the network.DMUs,CPXs and TDSs can also be connected to the TDM ports.Local subscribers can be analog or digital.

1.2.3.2 TDM connections

The DMU-220 provides 2 TDM connections. Both TDM ports are equal and can be connected to the following equipment:

Equipment type	TDM bitrate (Kbit/s)	Description
CPX	512 or 1024	Tactical Switch with: - 5 TDM ports (EUROCOM A interface, trunk group) - 15 local subscriber lines (16-128 Kbit/s)
DMU200	512	Delta Multiplexer with: - 1 TDM port (EUROCOM A interface, loop group) - 15 local subscriber lines (16 or 32 Kbit/s). Single DMU200 or - Up to 30 local subscriber lines (16 Kbit/s). Master / slave DMU200.
DMU210	512 or 1024	Delta Multiplexer with: - 2 TDM ports (EUROCOM A interface, loop group) - 15 local subscriber lines (16 or 32 Kbit/s). Single DMU210 or - 30 local subscriber lines (16 or 32 Kbit/s). Master / slave DMU210
DMU220	512 or 1024	Delta Multiplexer with: - 2 TDM ports (EUROCOM A interface, loop group) - 15 local subscriber lines (16 or 32 Kbit/s). Single DMU220 or - 30 local subscriber lines (16 or 32 Kbit/s). Master / slave DMU220
TDS	512	Tactical Delta Switch with: - 8 TDM ports (EUROCOM A interface, loop group) - 15 subscriber lines on each port, 32 Kbit/s. - 30 subscriber lines on each port, 16 Kbit/s.

Table 1: Equipments Connected to TDM Ports

1.2.3.3 Subscriber connections

The DMU-220 can be equipped with 15 line cards. Both analog and digital subscribers can be connected.

Function	Type	Description
ANALOG LINE CARDS	CHA2	Is used to connect 2- and 4-wire analog equipment
	CHA3	Is used to connect 2- and 4-wire analog equipment
	LTA	Is used to connect 2-wire analog telephones. Up to 3 telephones on one line card
DIGITAL LINE CARDS	CHD	Is used to connect 2- and 4-wire digital equipment
	CHP	Is used to connect 2- and 4-wire digital equipment. In addition can data equipment with RS-232-C or RS-422 interface be connected. Bitrate from 300 bit/s to 256 kbit/s.
	LTD	Is used to connect 2-wire digital equipment. Up to 3 equipments on one line card
	CHO1	Is used to connect MLT210/MLT220. 2 units for each CHO1 card and totally 5 CHO1 cards in one CPX (totally 9 MLT210/MLT220 in one CPX, CHO1 card no. 5 can handle one MLT). Bitrate is 160 kbit/s. Is also used to connect PS200. One PS200 require one CHO1 card (2 lines). Bitrate is 2 * 160 kbit/s.
	ISDN	Is used to connect ISDN equipment (2B + D).
	CHF1	Is used to connect 32 kbit/s asynchronous user equipment.

Table 2: Line Cards used in DMU-220

1.2.3.4 Data stored in battery backup memory

The data stored in the battery backup memory(configuration type,line card modes,line card types etc) will last at least 2 years when the DMU-220 is powered off.

1.2.3.5 Electrical specifications

TDM interface (Port 1 - Port 2)

Data signal: - AMI (Alternate Mark Inversion)
Clock signal: - NRZ (Non Return to Zero)
Transmission speed: - 512, 1024 kbit/s (Port 2 has only 512 kbit/s)
Pulse: - Rectangular
Peak voltage: - ± 0.5 V across 130 ohm load
Return loss: - >16 dB
Maximum cable length: - 50 m (max attenuation 2 dB)
Power feeding: - 24 V DC, max. 550mA drawn (option)
Cable attenuation: - 2 dB (maximum)

Alarm terminals:

Relay controlled: - The maximum current drawn with relay contacts closed is 150mA.
- The maximum voltage over open contacts is 100 V.

Subscriber connections:

Connection:	-2 kohms in serial with 2 mF
Ringing voltage	-250 Vrms, 25 Hz (1 second maximum)
	-60 Vrms, 25 Hz (Minimum)
DC Voltage	-70 VDC maximum

Power supply:

Operating voltage: - 24 V DC nominal (19 V - 32 V)
Maximum ripple (21 - 30 V): - 4 V p-p, 1 Hz - 200 kHz
Power consumption: -70 W (maximum, including current feeding of external equipment)

1.2.4 Pin-out description

The following tables show the pin-out and the signal names on the TDM port-, terminal, power-, and subscriber connectors.

Pin no.	Signal
E	Data Tx (a)
F	Data Tx (b)
G	Data Rx (a)
H	Data Rx (b)
J	Clock Tx (a)
K	Clock Tx (b)
L	Clock Rx (a)
M	Clock Rx (b)
N	Alignment Command (a)
P	Alignment Command (b)
T	Power Feed (Out) +24 V DC
U	Not used
V	GND

Table 3: TDM Port Connections

POS 1 - 15 CONNECTOR		POS 1 - 5, POS 6 - 10 and POS 11 - 15 CONNECTORS				
POS	Pin No.	POS 1-5	POS 6-10	POS 11-15	Signal Pair	Pin No.
1	C D				Signalling S Signalling R	V W
2	A B	1	6	11	Receive (a) Receive (b)	M L
3	F E				Send (a) Send (b)	C D
4	J K				Signalling S Signalling R	a Z
5	G H	2	7	12	Receive (a) Receive (b)	R S
6	M L				Send (a) Send (b)	A B
7	R S				Signalling S Signalling R	d e
8	N P	3	8	13	Receive (a) Receive (b)	N P
9	U T				Send (a) Send (b)	F E
10	X Y				Signalling S Signalling R	b c
11	V W	4	9	14	Receive (a) Receive (b)	U T
12	a Z				Send (a) Send (b)	J K
13	d e				Signalling S Signalling R	g f
14	b c	5	10	15	Receive (a) Receive (b)	X Y
15	g f				Send (a) Send (b)	G H

Table 4: subscriber connectors

Pin no.	Signal
A	DC input (Polarity independent)
B	Not connected
C	DC input (Polarity independent)

Table 5: Power Connector

1.3. DESIGN AND FUNCTIONALITY

1.3.1 General

The DMU-220 is:

- An intelligent Multiplexer which permits connection of many different types of equipment to its 15 subscriber lines.
- Equipped with 2 TDM ports for bitrates 512 or 1024 kbits/s.
- Provided with a Multiplexing system based on the time division Multiplexing (TDM) concept.
- Small,light-weight and has low power consumption.
- Designed to be rack mounted and to meet military environmental standards for harsh environments.

The DMU-220 can:

- Be used as a stand-alone unit or flexible arrangement of deployed networks, including support of star, ring, chain or mesh type topologies.
- Be equipped with various types of line interfaces. Each line interface supports various types of subscriber equipment such as telephones (digital and analog), radios, and PTT / PABXes

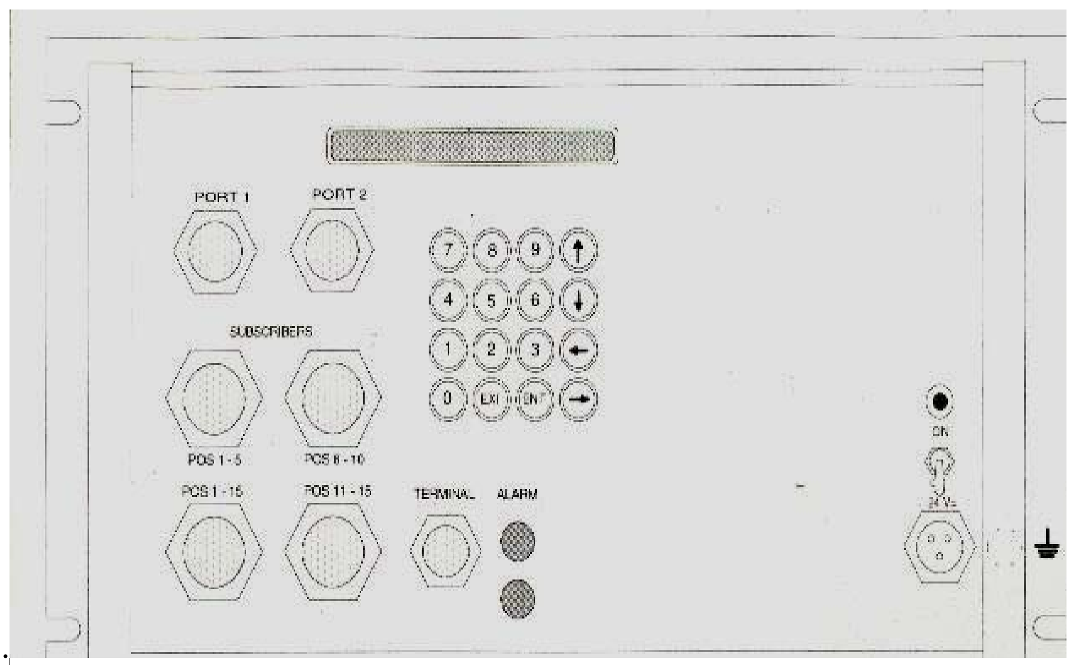

Figure1.2 front layout of the DMU-220

1.3.2 Analog Equipment:

- Telephones (LB telephones, CB telephones both pulse- and DTMF ñ signaling)
- PTT / PABX (pulse- and DTMF signaling)
- INMARSAT M terminal
- DECT System
- HF, VHF, UHF radio connections

1.3.3Digital Equipment:
- Multi Line Terminals (MLT210/MLT220) requires special line card (CHO1)
- Digital Voice Terminals; Digital Access Point (DAP) and Eurocom Terminal (ET-10)
- Digital None Secure Terminal (DNVT)
- HF, VHF, UHF radio connections, connected via DAP
- Data equipment (up to 32kbit/s), connected via DAP
- High speed data equipment (up to 256kbit/s), require special line card (CHP)
- PABX / PTT (ISDN-signaling), require special line card (ISDN)
- ISDN terminals, require special line card (ISDN)
- Packet Switch (PS200), require special line card (CHO1)

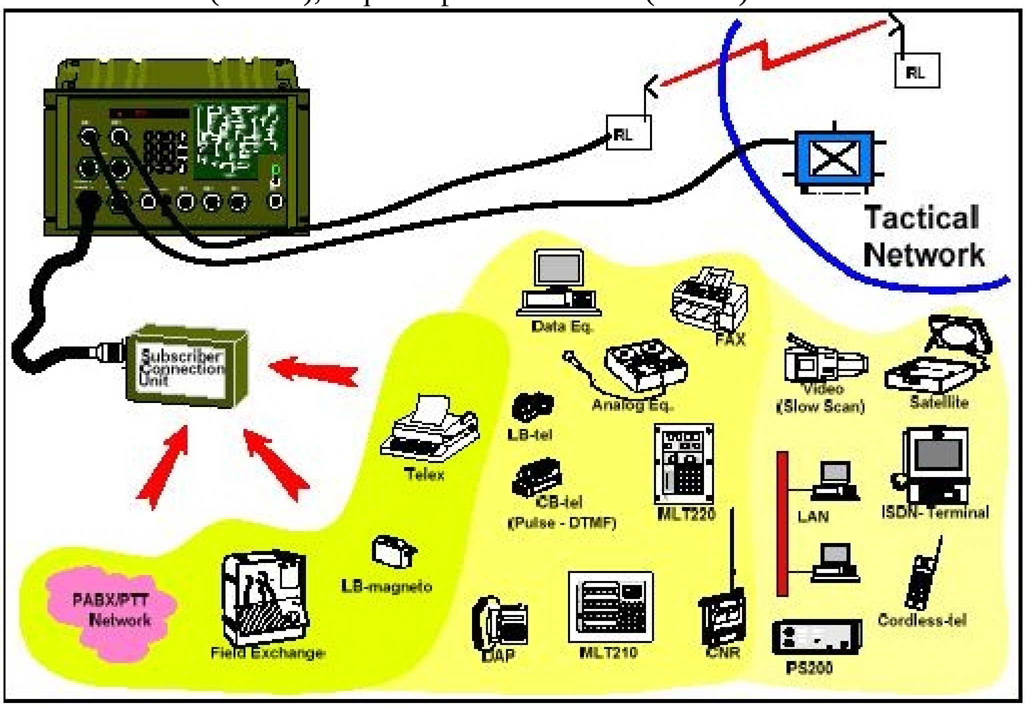

Figure1.3: Subscriber Connections towards DMU-220

1.3.4 Synchronization
The DMU-220 provides support of the following synchronization modes:
- Plesiochronous operation (use of internal clock). Used for stand-alone units only.
- Synchronization from an external master clock via a TDM port 1 or 2

1.3.5 Transmission system
The DMU-220 is designed with a standard TDM interface to the multi channel transmission system. This enables the user to implement the transmission system, which best meets the requirements of that particular application.
Transmission systems that can be used are:
- Cable (multi wire)
- Field cable (4-wire) with LTU
- Fiber optical cable with FTU
- Radio Links utilizing ECCM features such as spread spectrum, frequency hopping and adaptive power control

- Bulk-encryption on link level. The TDM ports supports the EUROCOM 'A' alignment command (Line 5) for alignment of the crypto synchronization

1.4 TDM Port Connections

The DMU-220 has an automatic equipment detection function on the TDM ports.The bitrate is fixed and set according to the configuration selected.The equipment types which can be connected to a TDM port are shown in the table below:

Equipment type	TDM bitrate (Kbit/s)	Description
CPX	512 or 1024	Tactical Switch with: - 5 TDM ports (EUROCOM A interface, trunk group) - 15 local subscriber lines (16-128 Kbit/s)
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DMU210	512 or 1024	Delta Multiplexer with: - 2 TDM ports (EUROCOM A interface, loop group) - 15 local subscriber lines (16 or 32 Kbit/s). Single DMU210 or - 30 local subscriber lines (16 or 32 Kbit/s). Master / slave DMU210
DMU220	512 or 1024	Delta Multiplexer with: - 2 TDM ports (EUROCOM A interface, loop group) - 15 local subscriber lines (16 or 32 Kbit/s). Single DMU220 or - 30 local subscriber lines (16 or 32 Kbit/s). Master / slave DMU220
TDS	512	Tactical Delta Switch with: - 8 TDM ports (EUROCOM A interface, loop group) - 15 subscriber lines on each port, 32 Kbit/s. - 30 subscriber lines on each port, 16 Kbit/s.

Table 6 TDM port connections (possible equipment types)

1.5 Modes for CHA3

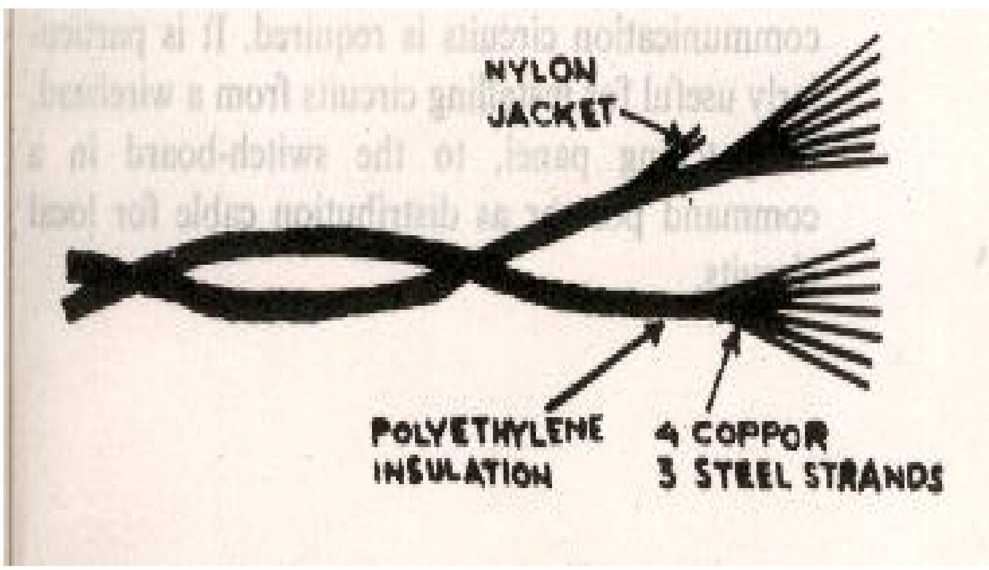
For CHA3 line cards the modes 02-49 shall be used when the bit rate is 16 kbit/s.The modes 50-99 shall be used when the bit rate is 32 kbit/s. CHA3 is used for connecting of analog subscribers.

Mode no	No of Wires	Subscriber type	Power feed	Signalling to subscriber	Signalling from subscriber	Comment
01						Undefined card / no card in position
02						Disconnected line (release)
03						Disconnected line (zero)
06/56	2	CB phone	ON	Ringing current	Loop closure with DTMF signalling	Default mode
10/60	2	LB phone		Ringing current	Ringing current	
11/61	2	CB phone	ON	Ringing current	Loop closure	
12/62	2	External network (PABX/PTT)		Loop closure	Ringing current	Ringing current = call to 990 Can be used as DOD line
18/68	4	LB phone		S-Wire	R-Wire 2)	R = OFF-HOOK and ON-HOOK
19/69	4	CB phone	ON	S-Wire	R-Wire 3)	R = OFF-HOOK or dialling
20/70	4	External network (PABX/PTT)		S-Wire	R-Wire 4)	S = OFF-HOOK or dialling
23/73	4	Through-connection		S-Wire	R-Wire 5)	
37/87	2	External network (PABX/PTT)		Loop closure with DTMF signalling	Ringing current	Ringing current = call to 990 Dial and call progress tone detection Can be used as DOD line
38/88	4	DTMF Through-connection		S-Wire	R-Wire 6)	Dial and call progress tone detection
40/90	2	Transparent		No signalling	No signalling	Open for continuous traffic (DTTA)
41/91	4	Transparent		No signalling	No signalling	Open for continuous traffic (DTTA)
44/94	2	LB phone		Ringing current	Ringing current	Ringing current = call to 990
45/95	4	LB phone		S-Wire	R-Wire	Ringing current = call to 990
46/96	2	Field exchange		Long ringing current (3 sec)	Ringing current	Ringing current = call to 990
47/97	4	GATR Radio interface		S-Wire	R-Wire 1)	Direct traffic both ways
48/98	2	External network (PABX/PTT)		Loop closure with DTMF signalling	Ringing current	Ringing current = call to 990 No dial tone detection Can be used as DOD line
49/99	4	Radio interface		S-Wire	R-Wire 1)	Point to point only

Table7 Modes for analog line card, CHA3

LB phone=The telephone is power fed from a local battery (field telephone)
CB phone=The telephone is power fed from a central battery (DMU-220)

CHAPTER 2: WIRE WD-1/TT



CHAPTER 2: WIRE WD-1/TT

2.1 Field wire WD-1/TT

Field wire WD-1/TT consist of two twisted ,individually insulated , conductors having the following characteristics:-

1. American wire gauge (AWG) No.23(Each conductor)
2. Four tined–copper strands and three galvanized steel strands.
3. And inner insulation of polyethylene and an outer insulation jacket of Nylon.
4. Tensile strength of approximately 90.71Kg (Both conductors).
5. Weighs 21.77 Kg per 1.6Km.
6. Direct current (DC) loop resistance from 200 to 234 ohms per 1.6 Km at 21.110 Fahrenheit (F).
7. Loss at 1 kilocycle (kc) at 21,100 F is 2.5 decibel (db) per 1.6 Km, under wet condition, and 1.5 db per mile under dry conditions.

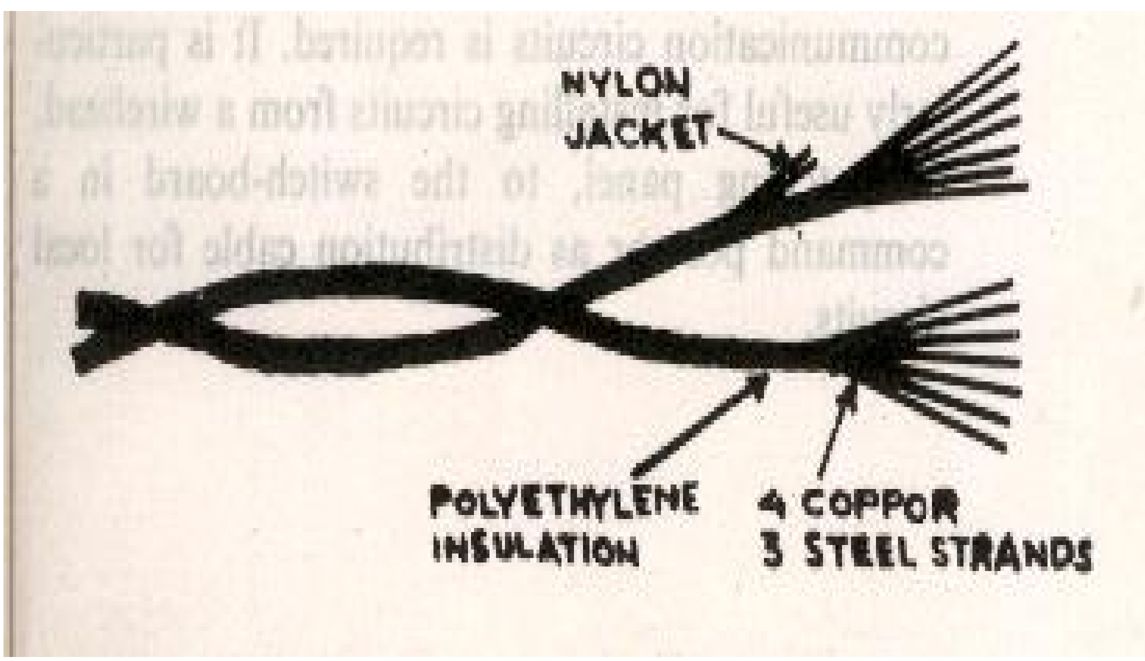


Figure2.1 WD-1/TT

CHAPTER 3: PROJECT SPECIFICATIONS

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3.1 Project Specifications

1. DC Voltages.
   - a. Off Hook 11 VDC
   - b. On Hook 60 VDC

2. Ringing voltages 80 Vrms

3. Current (Off hook) 30 mA

4. Signal frequency 300-800 Hz

1. After 5 kms
   - a. On Hook Voltages 60 VDC
   - b. Off Hook Voltages 8.7VDC
   - c. Off hook Current 30 mA
   - d. Ringing Voltages 73 Vrms
2. After 20 Kms
   - a. On hook Voltages 60 VDC
   - b. Off hook Voltages 7.87VDC
   - c. Off hook current 14 mA
   - d Ringing Voltages 51.8 Vrms

3. Losses
   - a. Voltage Loss 1.454 dbs
   - b. Current Loss 3.30 dbs

4. Gain Requirement
   - a. Voltage Gain 1.454 dbs
   - b. Current Gain 3.30 dbs

5. Initial Signal level (2 Wire)
   - a. 2 Wire in 0 dbm Nominal
   - b. 2 Wire out -4 dbm Nominal

6. Line Impedence 600 ohms

7. Signal Types
- DTMF Signal (Dail Tone)
- Ring Signal
- Tone Signal (500 Hz)
- Speech Signal
- Hook on
- Hook off

3.2 DTMF Signal

	1209	1336	1477	1633 Hz
697	1	2	3	A
770	4	5	6	B
852	7	8	9	C
941	*	0	#	D

Table 8 DTMF Signal

Dail Tone |350|440| Hz
Ring |440|480| Hz
Busy |480|620| Hz

3.3 Technical Data for CHA3

-Connections: 2-wire
4-wire(R&S)

-Bit-rate 16 kbits/s
32 kbits/s

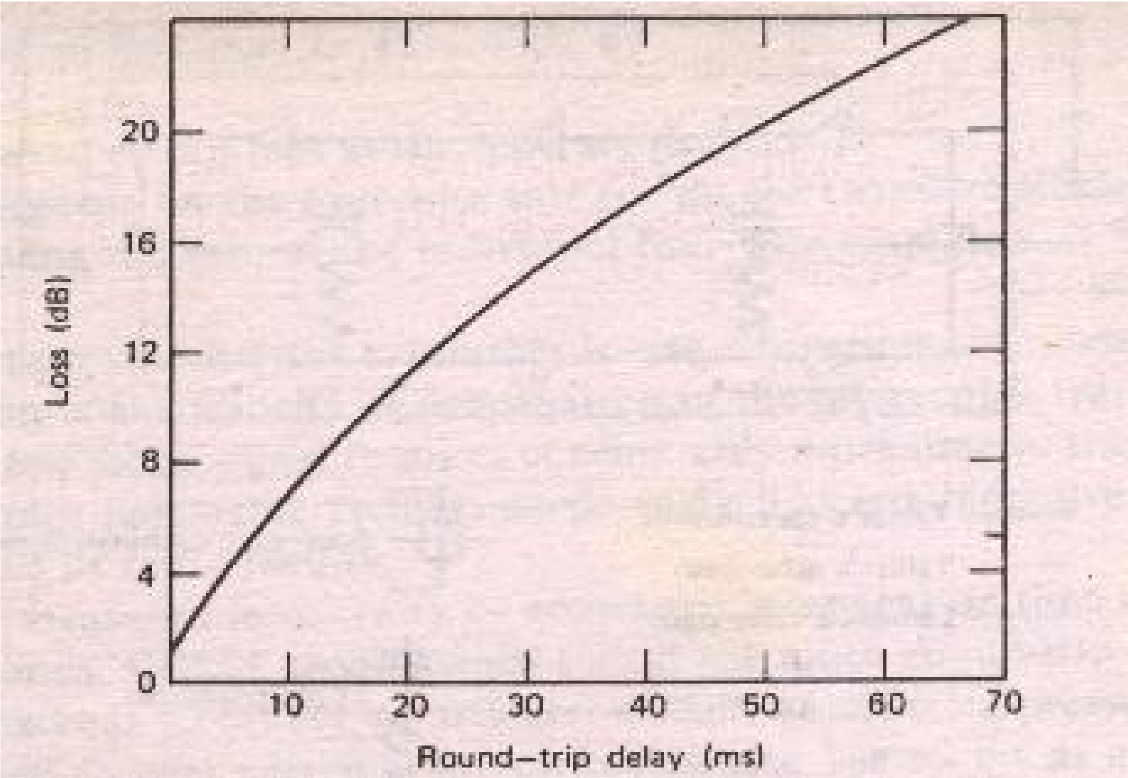
-Signal level 2-wire in, 0 dbm nominal
2-wire out, -4 dbm nominal
4-wire in, 0 dbm nominal
4-wire out, -1 dbm nominal
Typical line length using WD-1/TT is 6 km

-Impedance 600 ohms

-Cross talking 2-wire (channel to channel) > 58 db
4-wire (send/receive) > 45 db

-Ringing voltage	80 Vrms, 25 Hz (150 V peak voltage)
-Call detection LB Telephone 25Hz	Call detected if ringing vltage > 25 V rms Call cannot detected if ringing voltage< 7 V rms
-Current feeding CB telephone	1,2 kohm line loop > 26 mA (max 31 mA) Off-hook detected > 18 mA Off-hook not detected < 7 mA

CHAPTER 4: THE BASICS



CHAPTER 4: THE BASICS

4.3 Noise

CCITT Rec. 103 treats noise. It equates noise to length of a circuit. This is equated at the rate of 4 pWp/km. Assume a national connection is 2500 km long, or 2500 km to reach the international interface. Then we would expect to measure no more than 10,000 pWp at that point. The reader should consult CCITT Recs. G.152 and G.153 for further information. Actual design objectives should improve on these specifications by proper choice of equipment and system layout and engineering.

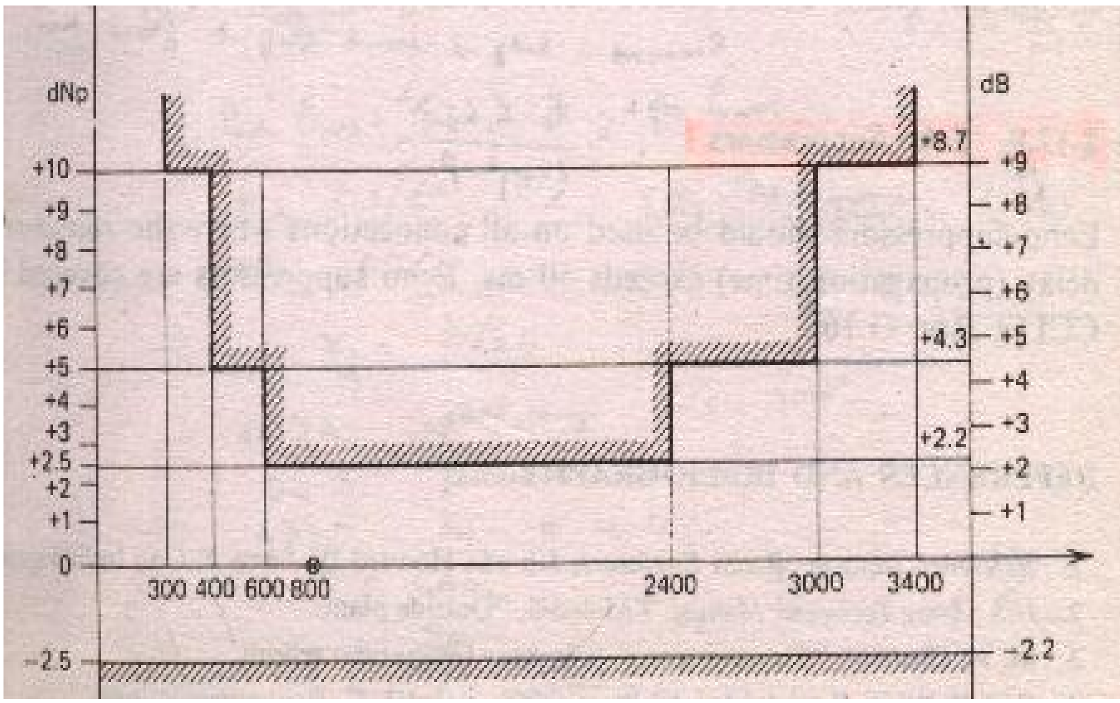


Figure 4.1 Attenuation Distortion

SourceCCITT Rec. G.131

It assumes that the nominal 4-kHz voice channel is used straight through. The attenuation distortion as shown in the figure is a result of 12 circuits of a four-wire chain in tandem. Note that the slope from 300 to 600 Hz and from 2400-3400 Hz is approximately 6.6 dB. The slope for one link, therefore, would be 6.5/12 or approximately 0.5 dB. From this we can derive the attenuation distortion permissible for each link to the international interface.

4.4 Echo, Singing, and Design Loss

4.4.1 General

The operation of the hybrid with its two-wire connection on one end and four-wire connection on the other leads us to the discussion of two phenomena that, if not properly designed for, may lead to major impairments in communication. These impairments are echo and singing.

4.4.2 Echo

As the name implies, echo in telephone systems is the return of a talker's voice. The returned voice, to be an impairment, must suffer some noticeable delay.Thus we can say that echo is a reflection of the voice. Analogously, it may be considered as that part of the voice energy that bounces off obstacles in a telephone connection. These obstacles are impedance irregularities, more properly called impedance mismatches.Echo is a major annoyance to the telephone user. It affects the talker more than the listener. Two factors determine the degree of annoyance of echo: its loudness, and how long it is delayed.

4.4.3 Singing

Singing is the result of sustained oscillations due to positive feedback in telephone amplifiers or amplifying circuits. Circuits that sing are unusable and promptly overload multichannel carrier equipment. Singing may be thought of as echo that is completely out of control. This can occur at the frequency at which the circuit is resonant. Under such conditions the circuit losses at the singing frequency are so low that oscillation will continue even after the impulse that started it ceases to exist.

The primary cause of echo and singing generally can be attributed to the mismatch between the balancing network and its two-wire connection associated with the subscriber loop. It is at this point that the major impedance mismatch usually occurs and an echo patch exists. Ideally the hybrid balancing network must match each and every subscriber line to which it may be switched. Obviously the impedances of the four-wire trunks (lines) may be kept fairly uniform. However, the two-wire subscriber lines may vary over a wide range. The subscriber loop may be long or short, may or may not have inductive loading, and may or may not be carrier derived. The hybrid imbalance causes signal reflection or signal "return." The better the match, the more the return signal is attenuated. The amount that the return signal (or reflected signal) is attenuated is called the return loss and is expressed in decibels.

Let us consider now the problem of match. For our case the impedance match is between the balancing network (N) and the two-wire line (L).

$$\text{Return LOSS dB} = 20 \log 10 \frac{ZN+ZL}{ZN-ZL}$$

If the network perfectly balances the line, ZN = ZL, and the return loss would be infinite. Return loss may also be expressed in terms of reflection coefficient, or

$$\text{Return loss dB} = 20 \log 10 \frac{1}{\text{Reflection coefficient}}$$

Where the reflection coefficient = reflected signal/incident signal.
The CCITT uses the term “balance return loss” (see CCITT Rec, G.122) and classifies it as two types:

1. Balance return loss from the point of view of echo. *This is the return loss across the band of frequencies from 500 to 2500 Hz.
2. Balance return loss from the point of view of stability. This is the return loss between O and 4000 Hz.

For frequencies outside the 500-2500-Hz band, return loss values often are below the desired 11 dB. For these frequencies we are dealing with return loss from the point of view of stability. CCITT recommends that balance return loss from the point of view of stability (singing) should have a value of not less than 2 dB for all terminal conditions encountered during normal operation (CCITT Rec. G.122, p. 3.

- Called echo return loss (ERL) in VNL (north American practice), but uses a weighted distribution of level.
- Improved return loss at the term set (hybrid).
- Adding loss on the four-wire side (or on the two-wire side).
- Reducing the gain of the individual four-wire amplifiers.

The annoyance of echo to a subscriber is also a function of its delay. Delay is a function of the velocity of propagation of the intervening transmission facility. A telephone signal requires considerably more time to traverse 100 km of a voice pair cable facility, particularly if it has inductive loading, than 100 km of radio facility.

Delay is measured in one-way or round-trip propagation time measured in milliseconds. CCITT recommends that if the mean round-trip propagation time exceeds 50 ms for a particular circuit, an echo suppressor should be used. Bell System practices in North America use 45 ms as a dividing line. In other works, where echo delay is less than that stated above, echo will be controlled by adding loss.
An echo suppressor is an electronic device inserted in a four-wire circuit which effectively blocks passage of reflected signal energy. The device is voice operated with a sufficiently fast reaction time to “reverse” the direction of transmission, depending on which subscriber is talking at the moment. The blocking of reflected energy is carried out by simply inserting a high loss in the return four wire patch.

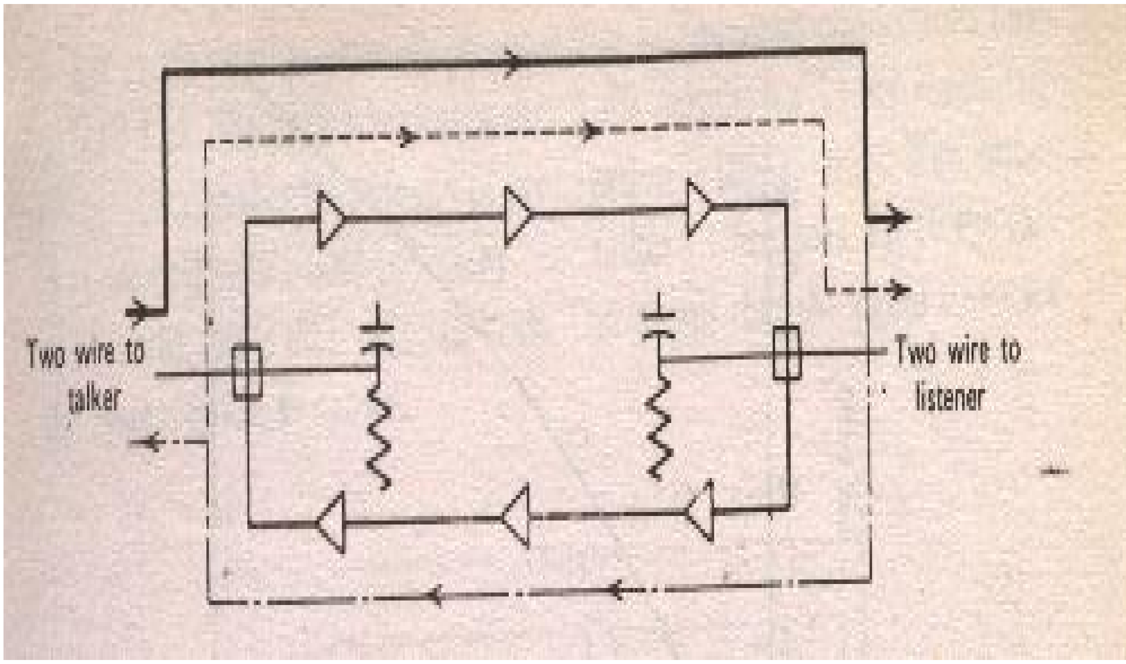


Figure 4.2 Echo path on a four-wire circuit.

4.3 Effects of Transmission Losses and Noise in Analog Communication Systems

In any communication system there are usually two dominant factors that limit the performance of the system. One factor is additive noise generated by electronic devices that are used to filter and amplify the communication signal. Second factor that affects the performance of a communication system is signal attenuation. Basically all physical channels, including wire-line and radio channels, are lossy. Hence, the signal is attenuated (reduced in amplitude) as it travels through the channel. A simple mathematical model of the attenuation

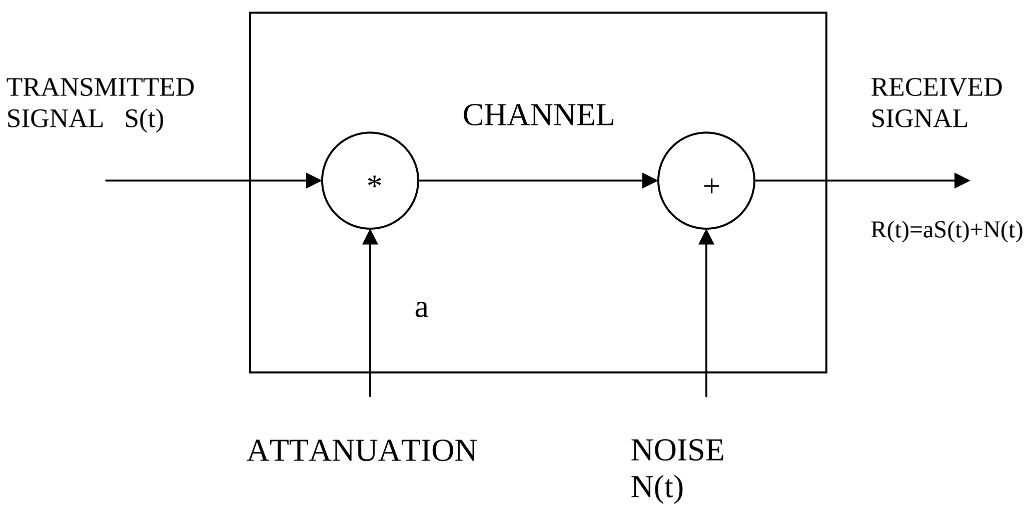


Figure4.3 Model of channel with attenuation and noise

may be constructed, as shown in Figure 4.3 by multiplying the transmitted signal b a factor a <1. Consequently , if the transmitted signal is s(t), the received signal is

$$r(t)=as(t)+n(t)$$

Clearly, the effect of signal attenuation is to reduce the amplitude of the desired signal s(t) and, thus, to render the communication signal more vulnerable to additive noise.

In many channels, such as wirelines and microwave LOS channels, signal attenuation can be offset by using amplifiers to boost the level of the signal during transmission. However, an amplifier also introduces additive noise in the process of amplification and, thus, corrupts the signal. This additional noise must be taken into consideration in the design of the communication system. In this section, we consider the effects of attenuation encountered in signal transmission through a channel and additive thermal noise generated in electronic amplifiers. We also look how these two factors influence the design of a communication system.

4.6 Effective Noise Temperature and Noise Figure

When we employ amplifiers in communication systems to boost the level of a signal, we are also amplifying the noise corrupting the signal. Since any amplifier has some finite passband, we may model an amplifier as a filter with frequency-response characteristic H (f). Let us evaluate the effect of the amplifier on an input thermal noise source.

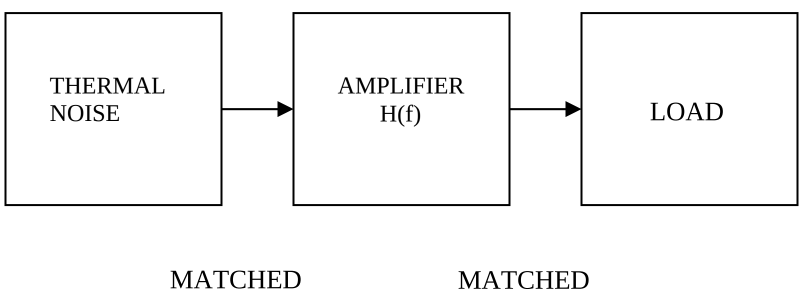


Figure4.4 Thermal noise converted to amplifier and load

Figure 4.4 illustrates a thermal noise source connected to a matched two-port network having frequency response H (f). The output of this network is connected to a matched load. First, we recall that the noise power at the output of the network is

Pno={ Sn(f)\H(f)\2=$\frac{No}{2}$}\H(f)\2df

The noise-equivalent bandwidth of the filter is defined as

Bneq=$\frac{1}{2g}$ {\H(f)\2df

where, by definition, g = \H(f)\2max is the maximum available power gain of the amplifier. Consequently, the output noise power from an ideal amplifier that introduces no additional noise may be expressed as

Pno = gNo Bneq

Any practical amplifier introduces additional noise at its output due to internally generation noise. Hence, the noise power at its output may be expressed as

Pno=gNo Bneq + Pni
=gkT Bneq + Pni

where Pni is the power of the amplifier output due to internally generated noise. Therefore,

Te= $\frac{Pni}{gkBneq}$

which we call the effective noise temperature of the two-port network (amplifier. Then,
Pno=gkBneq (T+Te)

Thus, we interpret the output noise as originating from a thermal noise source at temperature T+Te.

As signal source at the input to the amplifier with power Psi will produce an output with power
Pso = gPsi

Hence, the output SNR from the two-port network is

$$\left(\frac{S}{N}\right)_o = \frac{Psp}{Pgo} = \frac{gPsi}{gkT\ Bneq\ (1+Te/T)}$$
$$= \frac{Pst}{NoBneq\ (1+Te/T)}$$
$$= \frac{1}{1=Te/T}\left(\frac{S}{N}\right)_i$$

where, by definition, (S/N), is the input SNR to the two-port network. We observe that the SNR at the output of the amplifier is degraded (reduced) by the factor (1=Te/T).

Thus, Te is a measure of the noisiness of the amplifier. An ideal amplifier is one for which Te=O.

When T is taken as room temperature To(290 K) the factor (1+Te/To) is called the noise figure of the amplifier. Specifically, the noise figure of a two-port network is defined as the ratio of the output noise power Pno to the output noise power of an ideal (noiseless) two-port network for which the thermal noise source is at room temperature (To=290 K). Clearly, the ratio

$$F=\left[1+\frac{Te}{To}\right]$$

Is the noise figure of the amplifier. Consequently, Equation may be expressed as

$$\left[\frac{S}{N}\right]_o=\left[\frac{1}{F}\right]\left[\frac{S}{N}\right]_i$$

By taking the logarithm of both sides of Equation, we obtain

$$10\log\left[\frac{S}{N}\right]_o= -10\log F+10\log\left[\frac{S}{N}\right]_i$$

Hence, 10 log F represents the loss in SNR due to the additional noise introduced by the amplifier. The noise figure for many low-noise amplifiers such as traveling wave tubes in below 3dB. Conventional integrated circuit amplifiers have noise figures of 6 dB-7 dB.

It is easy to show hat the overall noise figure of a cascade of K amplifiers with gains gk and corresponding noise figures Fk, $1\leq k \geq K$ is

$$F= F1 + \frac{F2-1}{g1} + \frac{F3-1}{g1g2} +...+ \frac{Fk-1}{g1g2\ldots gk-1}$$

This expression is known as Fries' formula. We observe that the dominant term is F1, which is the noise figure of the first amplifier stage. Therefore, the front end of a receiver should have a low-noise figure and a high gain. In that case, the remaining terms in the sum will be negligible.

In LOS radio systems the transmission loss is given as

$$L=\left[\frac{4rd}{r}\right]2$$

where r=c/f is the wavelength of the transmitted signal; c is the speed of light (3x103 m/sec), f is the frequency of the transmitted signal, and d is the distance between the transmitter and the receiver in meters. In radio transmission, L is called the free-space path loss.

4.7 Noisy Communications Channels

We consider a basic problem associated with the transmission of a signal over a noisy communication channel. For the sack of being specific, suppose we require that a telephone conversation be transmitted from New York to Los Angeles. If the signal is transmitted by radio, then, when the signal arrives as its destination it will be greatly attenuated and also combined with noise due to thermal noise present in all receivers, and to all manner of random electrical disturbances which are added to the radio signal during its propagation. As a reserve the received signal may not be distinguishable against its background of noise. The situation is not fundamentally different if the signal is transmitted over wire. Any physical wire transmission path will both attenuate and distort a signal in an amount which increases with path length. Unless the wire path is completed and perfectly shielded as in the case of a perfect coaxial cable, electrical noise and crosstalk disturbances from neighboring wire paths will also be picked up and note that even coaxial cable does not provide complete freedom from crosstalk External low-frequency magnetic fields will penetrate the outer conductor of the coaxial cable and thereby induce signals on the cable. In telephone cable, where coaxial cables are combined with parallel wire signal paths, it is common practice to wrap the coax in Perm ally for the sake of magnetic shielding. Even the use of fiber optic cables which are relatively immune to such interference, does not significantly alter the problem since receiver noise is often the noise source of large power.

One attempt to resolve this problem is simply to raise the signal level at the transmitting end to so high a level that, in spite of the attenuation, the receive signal substantially overrides the noise. (Signal distortion may be corrected separately by equalization). Such a solution is hardly feasible on the grounds that the signal power and consequent voltage levels at the transmitter would be difficult to handle. For example, at 1 kHz, a telephone cable may be expected to produce an attenuation of the order of 1 dB per mile. For a 3000-mile run, even if we were satisfied with a received signal of 1 mV, the voltage at the transmitting end would have to be 10 147 volts.

An amplifier at the receiver will not help the above situation, since at the point both signal and noise levels will be increased together. But suppose that repeater (repeater is the term used for an amplifier in a communications channel) is located at the midpoint of the long communications path. This repeater will raise the signal level; in addition, it will raise the level of only the noise introduced in the first half of the communications path. Hence, such a midway repeater, as contrasted with an amplifier at the receiver, has the advantage to improving the received signal-to-noise ratio. This midway repeater will relieve the burden imposed on transmitter and cable due to higher power requirement when the repeater is not used.

The next step is of course, to use additional repeaters, say initially at the one quarter and three quarter points and thereafter at points in between the added repeater serves to lower the maximum power level encountered on the communications link and each repeater improves the signal-to-noise ratio over what would result if the corresponding gain were introduced at the receiver.

In the limit we might, conceptually at least, use an infinite number of repeaters. We could even adjust the gain of each repeater to be infinitesimally greater than unity by just the amount to overcome the attenuation in the infinitesimal section between repeaters. In the end we would thereby have constructed a channel which had no attenuation. The signal at the receiving terminal of the channel would then be the unattenuated transmitted signal. We would then, in addition, have at the receiving end all the noise introduced at all points of the channel. This noise is also received without attenuation, no matter howe far away from the receiving end the noise was introduced.

This situation is actually somewhat more dismal than has just been intimated since each repeater (transistor amplifier) introduces some noise on its own accord. Hence, as more repeaters are cascaded, each repeater must be designed to more exacting standards with respect to noise figure (see Sec 14.10). This limitation of the system we have been describing for communicating over long channels is that once noise has been introduced any place along the channel, we are "stuck" with it.

If we now were to transmit a digital signal over the same channel we would find that significantly less signal power would be needed in order to obtain the same performance at the receiver. The reason for this is that the significant parameter is now not the signal-to-noise ratio but the probability of mistaking a digital signal for a different digital signal. In practice we find that signal to noise ratios of 40-60 dB are required for analog signals while 10-12 dB are required for digital signals. This reason and others, to be discussed subsequently, have resulted in a large commercial and military switch to digital communications.

4.6 Transmission design to control echo and singing

Echo is an annoyance to the subscriber.

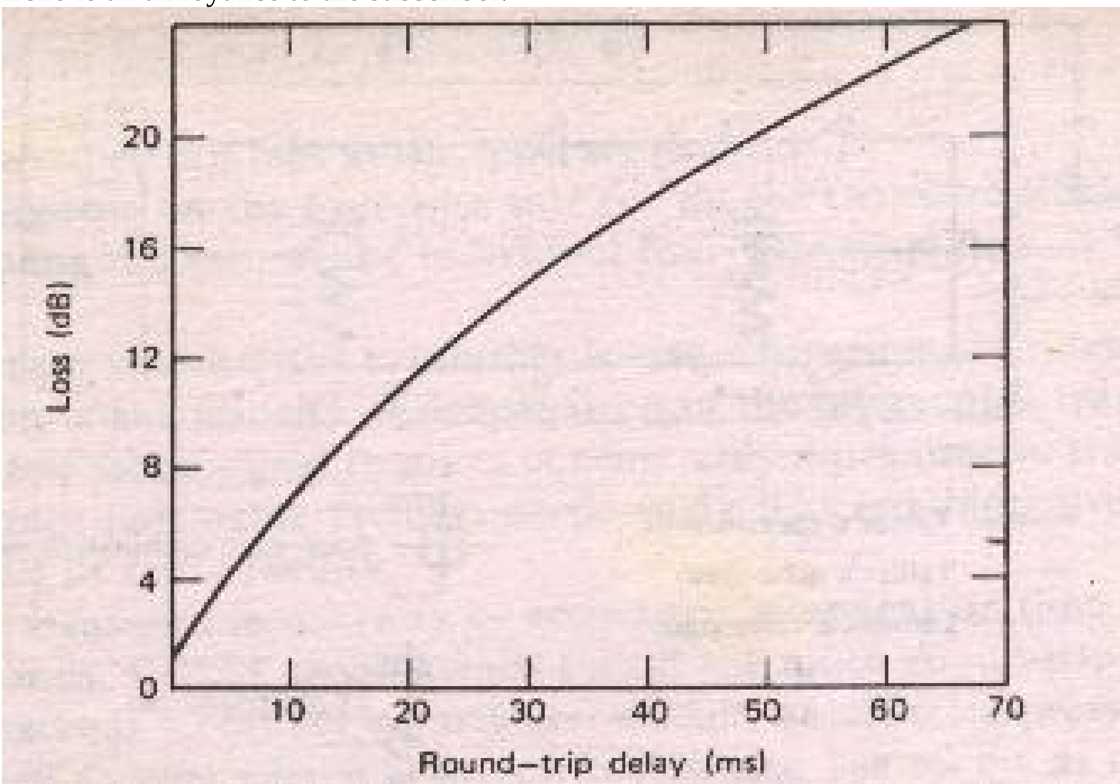
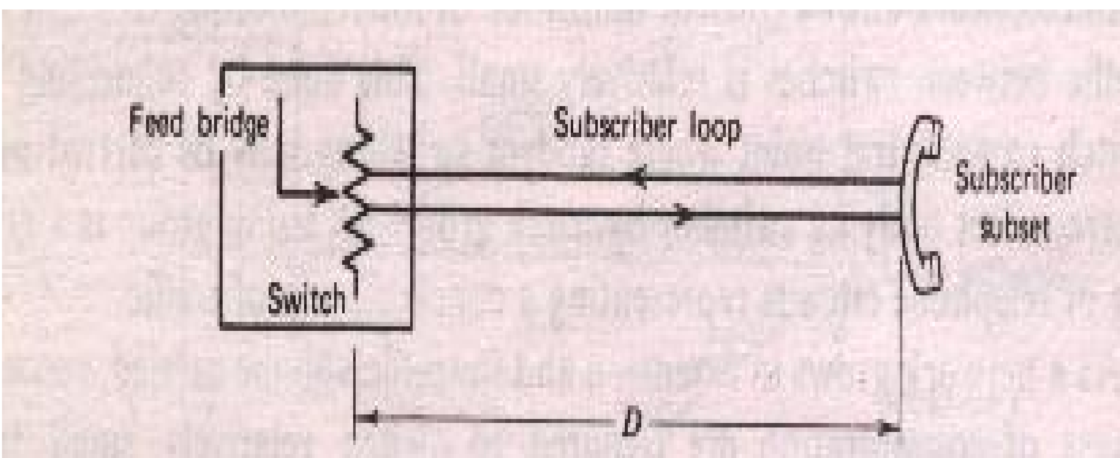


Figure 4.5 Echo path delay to echo path loss.

The curve in Figure 4.5 is a group of points at which the average subscriber will tolerate echo as a function of its delay. The greater the return signal is delay, the more annoying it is to the telephone talker (i.e., the more the echo signal must be attenuated). For instance, if the echo path delay on a particular circuit is 20 ms, an 11-dB loss must be inserted to make echo tolerable to the talker.

To control singing all four-wire paths must have some loss. Once they go into a gain condition, and we refer here to overall circuit gain, we will have positive feedback and the amplifiers will begin to oscillate or "sing". North American practice calls for a 4-dB loss on all four-wire circuits to ensure against singing. CCITT recommends a minimum loss for a national network of 7 dB (CCITT Rec. G. 122, p. 2.).

CHAPTER 5: TELEPHONE LOOP LENGTH



5.2 Telephone Loop Length

Subscriber's telephone sets are interconnected via a switch or network of switches. Present commercial telephone service provides for transmission and reception on the same pair of wires that connect the subscriber to the local switch. Let us now define some terms.

The pair of wires connecting the subscriber to the local switch that serves him is the subscriber loop. It is a wire pair typically supplying a metallic path for the following.

- Talk battery for the telephone transmitter.
- An ac ringing voltage for the bell on the telephone instrument supplied from a special ringing source voltage.
- Current to flow through the loop when the telephone instrument is taken out of its cradle, telling the switch that it requires "access" and permitting line seizer at the switching center.
- The telephone dial that, when operated, makes and breaks the de current on the closed loop, which indicates to the switching equipment the number of the distant telephone with which communication is desired.

The typical subscriber loop is supplied battery by means of a battery feed circuit

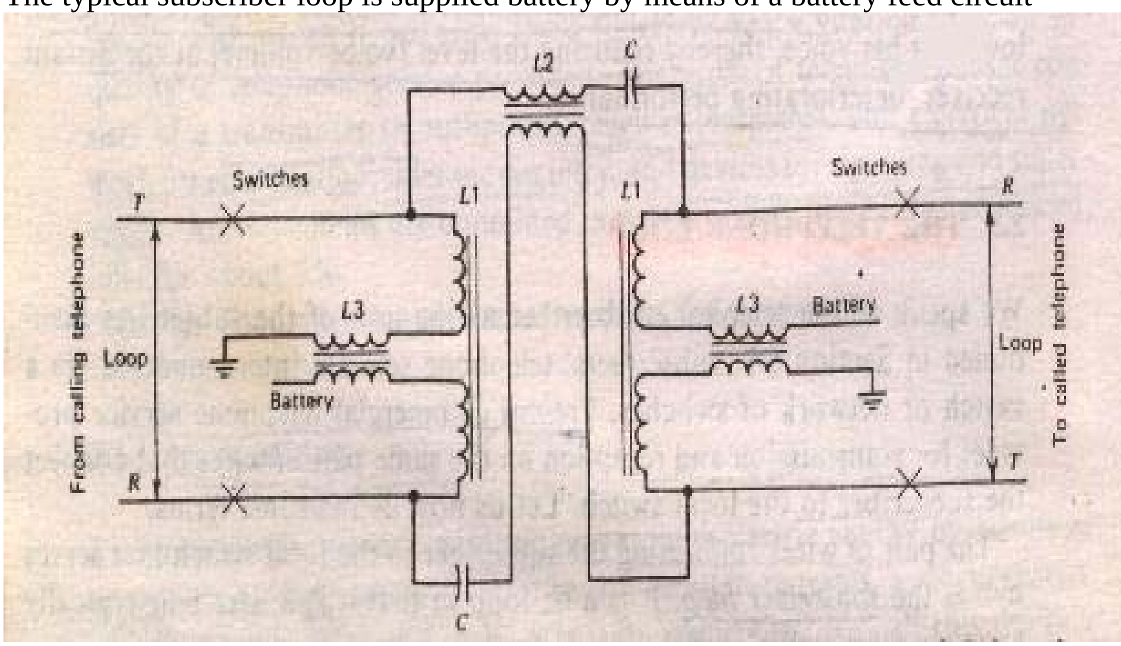


Figure 5.1 Battery feed circuit

at the switch. Such a circuit is shown in Figure 5.1; one important aspect of battery feed is line balance. Telephone battery voltage has been fairly well standardized at – 48 V.

5.2.1 Telephone loop length limits

It is desirable from an economic viewpoint to permit subscriber loop lengths to be as long as possible. Thus the subscriber area served by a single switching center may be much larger. As a consequence, the total number of switches or telephone central offices may be reduced to a minimum. For instance if loops were limited to 4 km in length, a switching center could serve all subscribers within a radius of something less than 4 km. If 10 km were the maximum loop length, the radius of an equivalent area that one office could cover would be extended an additional 6 km, out to a total of nearly 10 km. It is evident that to serve a large area, fewer switches (switching centers) are required for the 10 km situation than for the 3 km. The result is fewer buildings, less land to buy, fewer locations where maintenance is required, and all the benefits accuring from greater centralization, which become even more evident as subscriber density decreases, such as in rural areas.

The two basic criteria that must be considered when designing subscriber loops, and which limit their length, are the following:

- Attenuation limits (covered under what we call transmission design).
- Signaling limits (covered under what we call resistance design).

Attenuation in this case refers to loop loss in decibels (or nepers) at

- 1000 Hz in North America.
- 800 Hz in Europe and many other parts of the world.

As a loop is extended in length, its loss at reference frequency increases. It follows that at some point as the loop is extended, level will be attenuated such that the subscriber cannot hear sufficiently well.

Likewise, as a loop is extended in length, some point is reached where signaling and /or supervision is no longer effective. This limit is a function of the IR(voltage) drop of the line. We know that R increases as length increases. With today's modern telephone sets, the first to suffer is usually the "supervision". This is a signal sent to the switching equipment requesting "seizure" of a switch circuit and, at the same time, indicating the line is busy. "Off-hook" is a term more commonly used to describe this signal condition. When a telephone is taken "off-hook" (i.e., out of its cradle), the telephone loop is closed and current flows, closing a relay at the switch. If current flow is insufficient the relay will not close or it will close and open intermittently (chatter) such that line seizure cannot be effected.

Signaling and supervision limits are a function of the conductivity of the cable conductor and its diameter or gauge. Consider a copper conductor. The larger the conductor, the higher the conductivity and thus the longer the loop may be for signaling purposes. Copper is expensive so we cannot make the conductor as large as we would wish and extend subscriber loops long distances. First, we must describe what a subscriber considers as hearing sufficiently well, which is embodied in "transmission design" (regarding subscriber loop).

5.2 Design of subscriber loop

5.2.1 Introduction

The subscriber loop connects a subscriber telephone subset with a local switching center.. A subscriber loop in nearly all cases is two wire with simultaneous transmission in both directions.

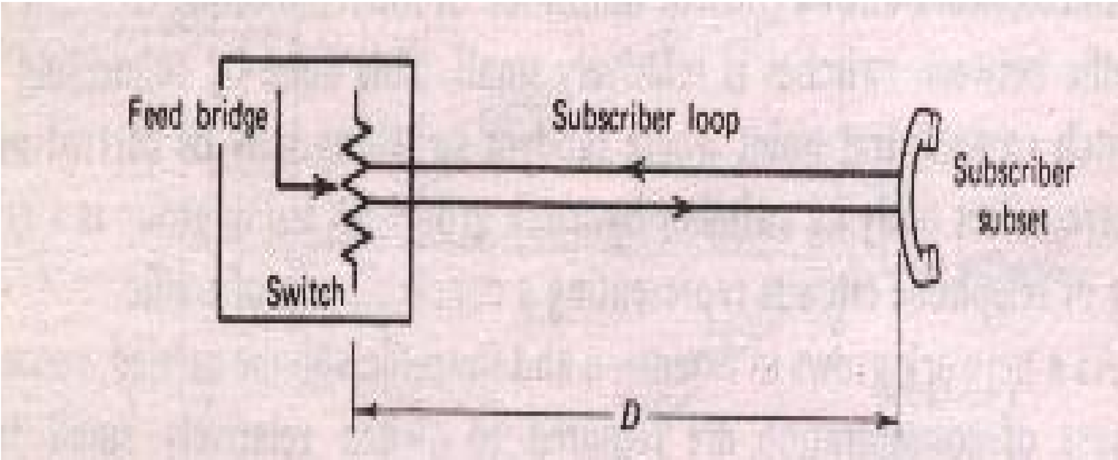


Figure5.2 Subscriber loop model

5.2.2 Transmission Design

The attenuation of a wire pair used on a subscriber loop varies with frequency, resistance, inductance capacitance and leakage conductance. Resistance of the line will depend on temperature.

Gauge of Conductor	n/1000 ft of loop	n/mi of loop	n/km of loop
26	83.5	440	237
24	51.9	274	148
22	32.4	171	92.4
19	16.1	85	45.9

Table 9

American Wire Gauge	Diameter (mm)	Resistance (n/km)* at 20oC
11	2.305	4.134
12	2.053	5.210
13	1.828	6.571
14	1.628	8.284
15	1.450	10.45
16	1.291	13.18
17	1.150	16.61
18	1.024	20.95
19	0.9116	26.39
20	0.8118	33.30
21	0.7229	41.99
22	0.6439	52.95
23	0.5733	66.80
24	0.5105	84.22
25	0.4547	106.20
26	0.4049	133.9
27	0.3607	168.9
28	0.3211	212.9

29	0.2859	268.6
30	0.2547	338.6
31	0.2268	426.8
32	0.2019	538.4

Table 10 American Wire Gauge vs Wire Diameter

For open-wire lines attenuation may vary ± 12% between winter and summer conditions. For buried cable, which we are more concerned with, loss variations due to temperature are much less.

5.4 The Reference Equivalent

5.4.1 Definition

Hearing "sufficiently well" on a telephone connection is a subjective matter under the blanket heading of "customer satisfaction". Various methods have been devised over the years to rate telephone connections regarding customer (subscriber) satisfaction. Subscriber satisfaction will be affected by the following regarding the received telephone signal:

- Level.
- Signal-to-noise ratio
- Response or attenuation frequency characteristic

A common rating system in use today to grade customer satisfaction is the "reference equivalent" system. This system considers only the first criterion mentioned above, namely, level. It must be emphasized that subscriber satisfaction is subjective. To measure satisfaction, the world regulative body for telecommunications, the International Telecommunication Union, devised a system of rating sufficient level to "satisfy", using the familiar decibel as the unit of measurement. It is particularly convenient in that, first disregarding the subscriber telephone subset, essentially we can add losses and gains (measured at 800 Hz) in the intervening network end-to-end, and determine the reference equivalent of a circuit by then adding this sum to a decibel value assigned to the subset, or to a subset plus a fixed subscriber loop length with wire gauge stated.

Let us look at how the reference equivalent system was developed, keeping in mind again that it is a subjective measurement dealing with the likes and dislikes of the "average" human being. Development took place in Europe. A standard for reference equivalent is determined using a team of qualified personnel in a laboratory. A telephone connection was established in the laboratory which was intended to be the most efficient telephone system known.

The original reference system or unique master reference consisted of the following:

- A solid-back telephone transmitter.
- Bell telephone receiver.
- Interconnecting these, a "zero decibel loss" subscriber loop.
- Connecting the loop, a manual, central battery, 22-V dc telephone exchange (switch).

At present more accurate measurement methods have evolved. A more modern reference system is now available in the ITU laboratory in Geneva, Switzerland, called the NOSFER. From this master reference, field test standards are available to telephone companies, administrations, and industry to establish the reference equivalent of telephone subsets in use. These field test standards are equivalent to the NOSFER.

The NOSFER is made up of a standard telephone transmitter, receiver, and network. The reference equivalent of a subscriber's subset, together with the associated subscriber line and feeding bridge, is a quantity obtained by balancing the loudness of received speech signals and is expressed relative to the whole or a corresponding part of the NOSFER (or field) reference system.

5.4 Two-Wire/Four-Wire Transmission

5.4.1 Two-Wire Transmission

By its basic nature a telephone conversation requires transmission in both directions. When both directions are carried on the same wire pair, we call it two-wire transmission. The telephones in our home and office are connected to a local switching center by means of two-wire circuits. A more proper definition for transmitting and switching purposes is that when oppositely directed portions of a single telephone conversation occur over the same electrical transmission channel or path, we call this two-wire operation.

5.5.2 Four-Wire Transmission

Carrier and radio systems require that oppositely directed portions of a single conversation occur over separate transmission channels or paths (or using mutually exclusive time periods) . Thus we have two wires for the transmit path and two wires for the receive path, or a total of four wires for a full-duplex (two-way) telephone conversation. For almost all operational telephone systems, the end instrument (i.e, the telephone subset) is connected to its intervening network on a two-wire basis*.
Nearly all long distance telephone connections traverse four-wire links. From the near-end user the connection to the long distance network is two wire. Likewise, the far-end user is also connected to the long-distance network via a two-wire link.

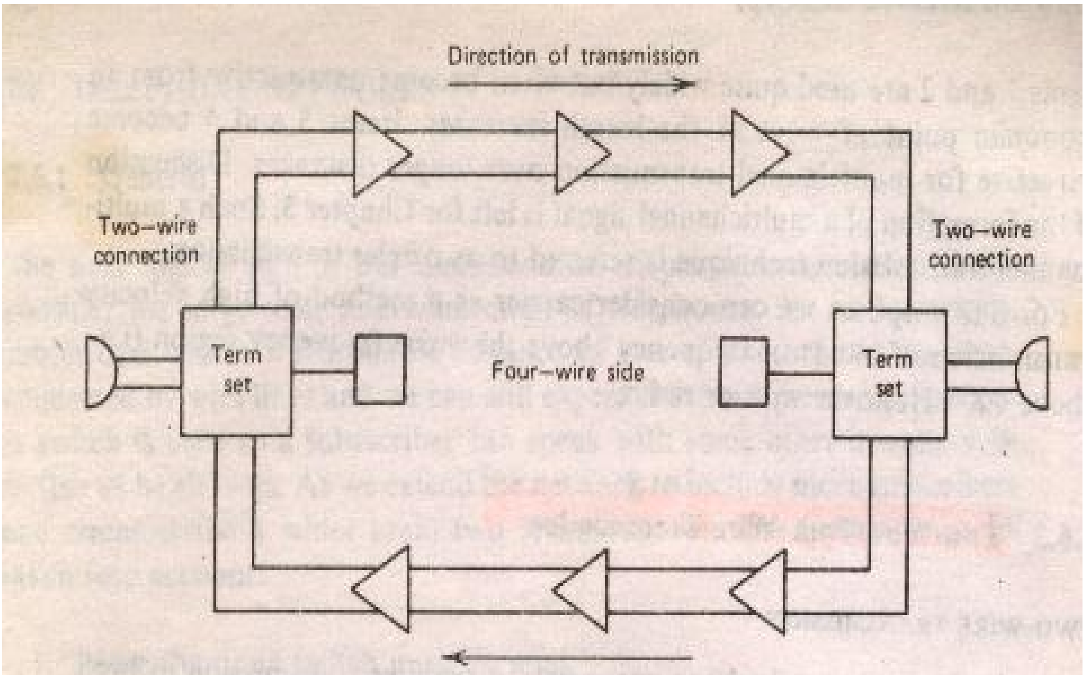


Figure 5.3 long distance telephone connection

Such a long-distance connection is shown in Figure 5.3. Schematically, the four-wire interconnection is shown as if it were wire line, single channel with amplifiers. More likely it would be multi-channel carrier on cable and/or multiplex on radio. However, the amplifiers in the figure serve to convey the ideas that this chapter considers.

5.5.3 The Operation Of A Hybrid

A hybrid, for telephone work (at voice frequency), is a transformer. For a simplified description, a hybrid may be viewed as a power splitter with four sets of wire pair connections.

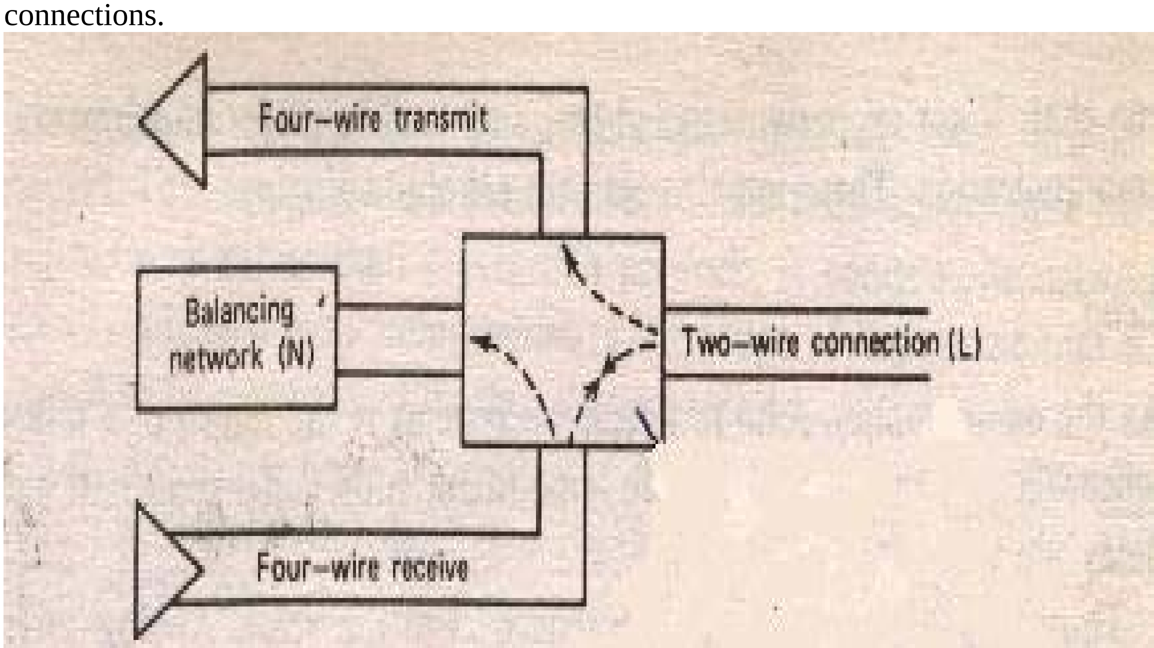


Figure5.4 Operation of a hybrid transformer

A functional block diagram of a hybrid device is shown in Figure 2.3. Two of these wire pair connections belong to the four-wire path, which consists of a transmit pair and a receive pair. The third pair is the connection to the two-wire link to the subscriber subset. The last wire pair connects the hybrid to a resistance-capacitance balancing network, which electrically balances the hybrid with the two-wire connection to the subscriber's subset over the frequency range of the balancing network. An artificial line may also be used for this purpose.

The hybrid function permits signals to pass from any pair through the transformer to both adjacent pairs but blocks signals to the opposite pair. Signal energy entering from the four-wire side divides equally, half dissipating into the balancing network and half going to the desired two-wire connection. Ideally no signal energy in this path crosses over the four-wire transmit side.

Signal energy entering from the two-wire subset connection divides equally, half of it dissipating in the impedance of the four wire side receive path, and half going to the four-wire side transmit path. Here the ideal situation is that no energy is to be dissipated by the balancing network (i.e., there is a perfect balance). The balancing network is supposed to display the characteristic impedance of the two-wire line (subscriber connection) to the hybrid.

In the description of the hybrid, in every case, ideally half of the signal energy entering the hybrid is used to advantage and only half is dissipated, wasted. Also keep in mind that any passive device inserted in a circuit such as a hybrid has an insertion loss. As a rule of thumb, we say that the insertion loss of a hybrid is 0.5 dB. Thus there are two losses here:

Hybrid insertion loss	0.5 dB
Hybrid dissipation loss	3.0 dB (half power)
	3.5 dB total

5.6 Repeaters for Signal Transmission

Analog repeaters are basically amplifiers that are generally used in telephone wireline channels and microwave LOS radio channels to boost the signal level and, thus, to offset the effect of signal attenuation in transmission through the channel.

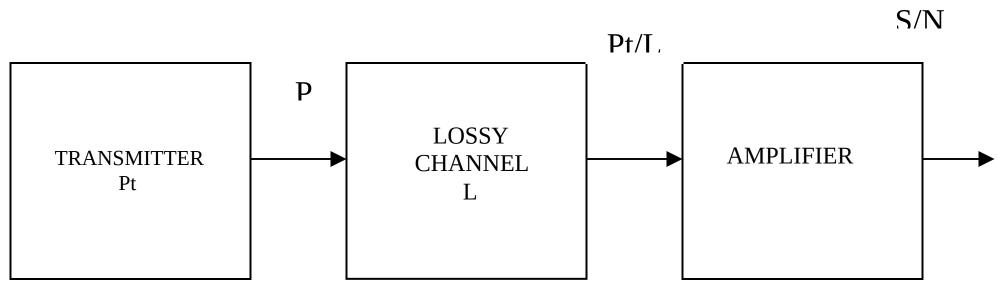


Figure 5.5 A system in which a repeater is used to amplify the signal
Hence, the input signal power at the input to the repeater is

$$PR = PT/L$$

The output power from the repeater is

$$Po = gPR = gPT/L$$

We may select the amplifier gain g to offset the transmission loss. Hence, g=L and Po=Pt.
Now, the SNR at the output of the repeater is

$$\left(\frac{S}{N}\right)_1 = \frac{1}{Fa}\left(\frac{S}{N}\right)_i$$

$$= \frac{1}{Fa}\left(\frac{PR}{NoBneq}\right) = \left(\frac{1}{Fa}\right)\frac{PT}{LnoBneq}$$

$$= \frac{1}{Fa}\left(\frac{PT}{NoBneq}\right)$$

Based on this result, we view the lossy transmission medium followed by the amplifier as a cascade of two networks, one with a noise figure L and the other with a noise figure Fa. Then, for the cascade connection, the overall noise figure is

$$F = L = \frac{Fa-1}{ga}$$

If we select ga = 1/L, then,

$$F = L + \frac{Fa-1}{1/L} = Lfa$$

Hence, the cascade of the lossy transmission medium and the amplifier is equivalent to a single network with noise figure LFa.
Now, suppose that we transmit the signal over K segments of the channel where each segment as its own repeater.,

Then, if $F_i = L_iF_{ai}$ is the noise figure of the ith section, the overall noise figure for the K sections is

$$F = L_1F_{a1} = \frac{L_2F_{a2}-1}{L_1/g_{a1}} + \frac{L_3F_{a3}-1}{(L_1/G_{a1})(L_2/G_{a2})} \ldots$$
$$+ \frac{L_KF_{aK}-1}{(L_1/G_{a1})(L_2/G_{a2})\ldots(L_K/G_{aK})}$$

Therefore, the SNR at the output of the repeater (amplifier) at the receiver is

$$\left(\frac{S}{N}\right)_o = \frac{1}{F}\left(\frac{S}{N}\right)_i$$
$$= \frac{1}{F}\left(\frac{P_T}{N_oB_{neq}}\right)$$

In the important special case where the K segments are identical; i.e., $L_i=L$ for all i and $F_{ai} = F_a$ for all i, and where the amplifier gains are designed to offset the losses in each segment; i.e., $G_{ai}=L_i$ for all I, then the overall noise figure becomes

$$F = KLF_a - (K-1) = KLF_a$$

Hence,

$$\left(\frac{S}{N}\right)_o = \frac{1}{KLF_a}\left(\frac{P_T}{N_oB_{neq}}\right)$$

Therefore, the overall noise figure for the cascade of the K identical segments is simply K times the noise figure of one segment.

5.5.2 VF REPEATERS

VF repeaters in telephone terminology imply the use of unidirectional amplifiers at voice frequency on VF trunks. On a two-wire trunk two amplifiers must be used on each pair with a hybrid in and a hybrid out.

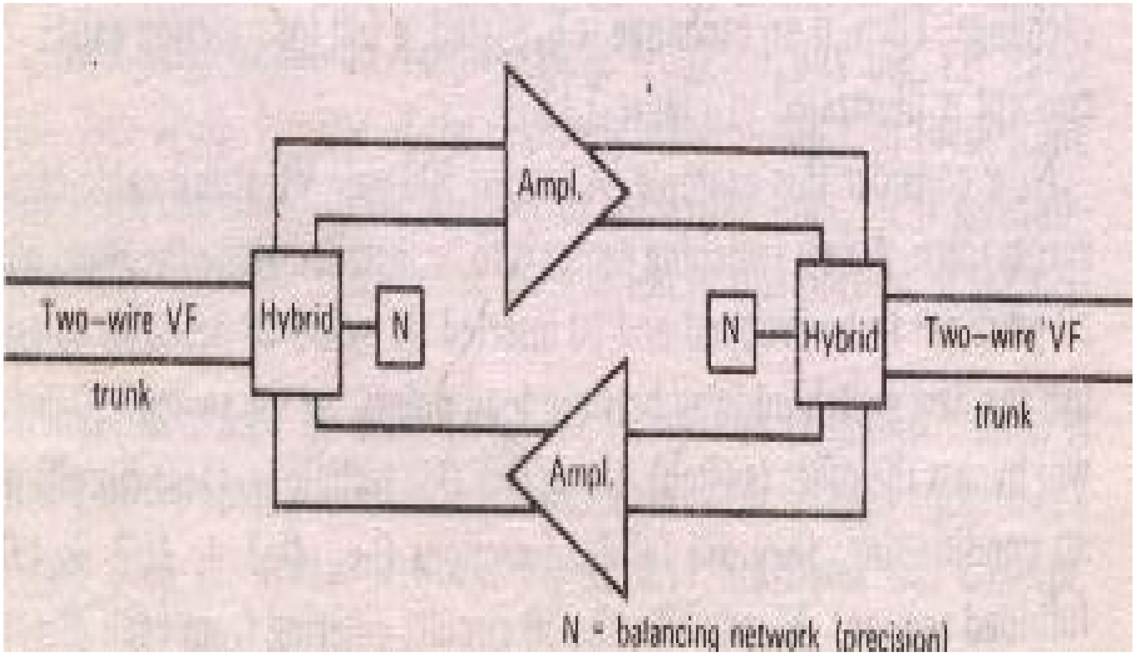


Figure5.6 VF repeater

The gain of a VF repeater can be run up as high as 20 or 25 dB, and originally they were used on 50-mi, 19 gauge loaded cable in the long distance (toll) plant. Today they are seldom found on long-distance circuits, but do have application on local trunk circuits, where the gain requirements are considerably less. Trunks using VF repeaters have the repeater's gain adjusted to the equivalent loss of the circuit minus the 4-dB loss to provide the necessary singing margin. In practice a repeater is installed at each end of the trunk circuit to simplify maintenance and power feeding. Gains may be as high as 6-8 dB. An important consideration with VF repeaters is the balance at the hybrids. Hence precision balancing networks may be used instead of the compromise networks employed at the two-wire, four-wire interface. It is common to achieve a 21-dB return loss, 27 dB is also possible, and theoretically, 35 dB can be reached.

Another repeater commonly used on two-wire trunks is the negative impedance repeater. This repeater can provide a gain as high as 12 dB, but 7 or 8 dB is more common is practice. The negative-impedance repeater requires a line build out (LBO) at each port and is a true two-way, two-wire repeaters.

5.6 Loading

In many situations it is desirable to extend subscriber loop lengths beyond the limits. Common methods to attain longer loops without exceeding loss limits are the following:

- **Increase conductor diameter.**
- **Use amplifiers and/or loop extenders.***
- **Use inductive loading.**

Loading tends to reduce transmission loss on subscriber loops and other types of voice pairs at the expense of good atteunation-frequency response beyond 3000-34000 Hz.

Loading a particular voice pair loop consists of inserting series inductances (loading coils) into the loop at fixed intervals. Adding load coils tends to

- **Decrease the velocity of propagation.**
- **Increase impedance**

*A loop extender is a device that increases battery voltage on a loop extending signaling range. It may also contain an amplifier, thereby extending transmission loss limits.

Loaded cables are coded according to the spacing of the load coils. The standard code for load coils regarding spacing is shown in Table below.

Code Letter	Spacing (ft)	Spacing (m)
A	700	213.5
B	3000	915
C	929	283.3
D	4500	1372.5
E	5575	1700.4
F	2787	850
H	6000	1830
X	680	207.4
Y	2130	649.6

Table 11 Code for Load Coil Spacing

Loaded cables typically are designated 19-H-44, 24-B-88, and so forth. The first number indicates the wire gauge, the letter is taken from Table 2.7 and is indicative of the spacing, and the third item is the inductance of the coil in millihenries (mH). 19-H-66 is a cable commonly used for long-distance operation in Europe. Thus the cable has 19-guage voice pairs loaded at 1830-m intervals with coils of 66-mH inductance. The most commonly used spacings are B, D and H.

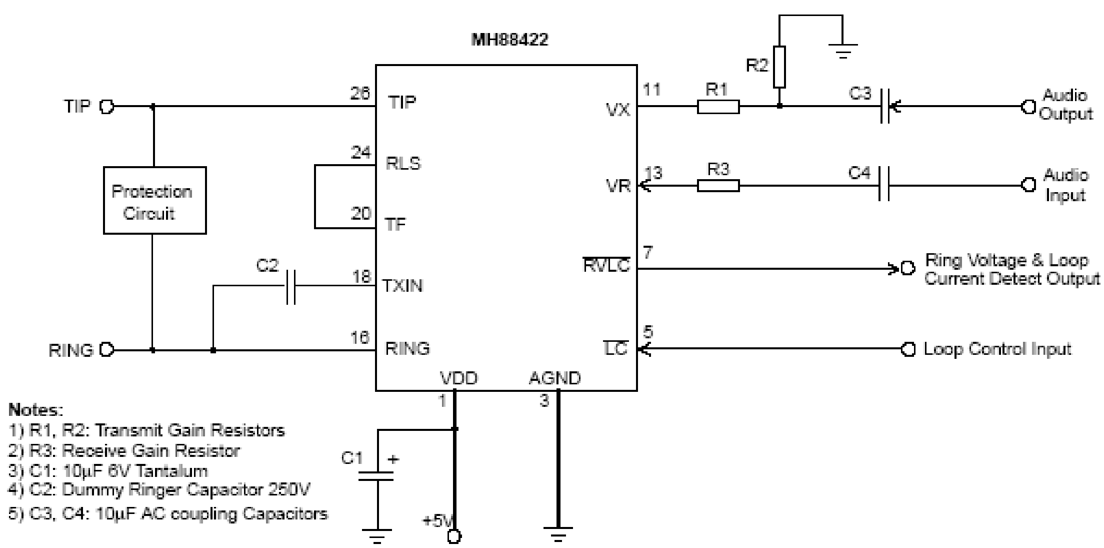
Table 12 will be useful to calculate attenuation of loaded loops for a given length. For example, for 19-H-88 (last entry in table) cable, the attenuation per kilometer is 0.26 dB (0.42 dB statute mi). Thus for our 6-dB loop loss limit, we have 6/0.26, limiting the loop to 23 km in length (14.3 statute mi). When determining signaling limits in loop design, add about 15 n per load coil as series resistors. The tendency in many administrations is to use a new loading technique. This has been taken from “unigauge design”. With this technique no loading is required on any loop less than 5000 m long (15,000 ft). For loops longer than 5000 m, loading starts at the 4200-m point and load coils are installed at 1830-m intervals thereon. The loading intervals should not vary by more than 2%.

Diameter (mm)	AWG No	Mutual Capacitance (nF/km)	Type of Loading	Loop Resistance (n/km)	Attenuation at 1000 Hz (dB/km)
0.32	28	40	None	433	2.03
		50	Non		2.27
0.40		40	None	277	1.62
		50	H-66		1.42
		50	H-88		1.24
0.405	26	40	None	270	1.61
		50	None		1.79
		40	H-66	273	1.25
		50	H-66		1.39
		40	H-88	274	1.09
		50	H-88		1.21
0.50		40	None	177	1.30
		50	H-66	180	0.92
		50	H-88	181	0.80
0.511	24	40	None	170	1.27
		50	None		1.42
		40	H-66	173	0.79
		50	H-66		0.88
		40	H-88	174	0.69
		50	H-88		0.77
0.60		40	None	123	1.08
		50	None		1.21
		40	H-66	126	0.58
		50	H-88	127	0.56
0.644	22	40	None	107	1.01
		50	None		1.12
		40	H-66	110	0.50
		50	H-66		0.56
		40	H-88	111	0.44
0.70		40	None	90	0.92
		50	H-66		0.48
		40	H-88	94	0.37
0.80		40	None	69	0.81
		50	H-66	72	0.38
		40	H-88	73	0.29
0.90		40	None	55	0.72
0.91	19	40	None	53	0.71
		50	None		0.79
		40	H-44	55	0.31

Table 12 Properties of Cable Conductors

Source: ITT, Telecommunication Planning Documents – Outside Plant.

CHAPTER 6: THE CIRCUIT DESCRIPTION



CHAPTER 6: THE CIRCUIT DESCRIPTION

6.1 General

These circuits are used to interface the exchange and subscriber sides along with the signal amplification.

6.2 Description.

These subscriber side and exchange side circuits perform following functions:-

6.2.1 Subscriber Side

- 2/4 Line conversion of the signals to and from the subscriber telephone.
- Transcoding of EM signaling.
- Detect on/off hook condition of subscriber telephone.
- Automatic subscriber loop current regulation.
- Adjustment of the signal gains.

6.2.2 Exchange Side

- To convert the signals from 2 wire into 4 wire and vice versa .
- Detect incoming ring from DMU-220.
- Detect on/off hook condition.
- Detect dialing signals from subscriber end both in DTMF and pulse modes.

6.2.4 Technical Data

Subscriber Side

Number of Channel	1
Impedance, 2 wire connection	600 balanced
2 wire return Loss	20 dB (input 0. 5V @1 kHz 600)
Transhybrid Loss	35 dB (input 0.5V 1 Khz 600)
Input Level 2 wire	0 dBm(nominal)
Output level 2 wire	-4.0 dBm (nominal)
Input level 4 wire	0 dBm (nominal)
Output level 4 wire	-1.0 dBm
Ringing signal to subscriber	80 V rms 25 Hz
Constant current line feed	24 to 28 mA
Dialing mode	Pulse and DTMF auto detection
Secondary protection	250 mA quick blow up fuse on both Tip and Ring.
Max loop length	22 Km typical
Line voltage	24 volts
Temperature range (operating)	O C to +70 C
Temperature range (storage)	20 C to 85 C

Exchange Side

Number of exchange	1
Inpedance, 2 wire connection	600 balanced
2 wire return loss	20 dB (input 0. 5V @1 kHz 600)
Transhybrid loss	20 dB (input 0.5V 1 Khz 600)
Input level 2 wire	0 dBm(nominal)
Output level 2 wire	-4.0 dBm (nominal)
Ring Voltage	80 v rms

Operating loop current	80 mA
Off-Hook DC Voltage	6 V rms 25 Hz

Table 13 Exchange And Subscriber Side Units

6.3 Description of the Block Diagram

6.3.1 Subscriber Side. Following are the basic functions of the unit:-

6.3.1.1 Protection Circuit. This protection circuit provides two distinct functions i.e high current and primary high voltage protection to the devices appearing on line side. To meet the safety requirement it is necessary to provide dependable current limiting 10 ohms resistance with 250 millivolt quick blow up fuse. It is obvious that smaller the current rating of the fuse, the better will be the performance. However, from a system performance point of view, it was undesirable to have the fuse of such a low current which blow due to intermittent transients that may appear on a routine basis. Therefore, 250 milliamp fuses have been used with current limiting resistance of 10 ohms (which cater for small transients). Surge protectors SK 14K130 prevent the modem from any surge appears on line side. These surge protector clamp the voltage by storing/dissipating the energy through ground. If the surge is large enough the surge protectors will burn and also short-circuit this voltage to ground immediately hence preventing the equipment from any possible damage.

6.3.1.3 **SLIC (Functional description)**.

The SLIC performs a transformer-less 2-wire to 4-wire conversion of the analog signal. The 2-wire circuit is the balanced line going to the subscriber loop while the 4-wire circuit is the audio signal going to and from encoder/decoder. The SLIC also provides a switch hook (SHK) status output, which goes high when the telephone is set off hook.

off hook will be detected by the SLIC when the loop impedance falls below 1200 ohms. The SHK output on SLIC can be monitored by the system.

6.3.1.2.1 Dialing. When a number is dialed in pulse mode the loop makes and breaks according to the number dialed. The SLIC detects these signals and sends the information to pulse filter through SHK. When a number is dialed in tone mode (DTMF), signals are transmitted through the massage channel (4 wire).

6.3.1.2.2 Current Limit. The Tip or Ring may accidentally short to ground. In such a case, current will only flow through the feed resistor. This high current will be sensed and reduced by the current limit circuit to a lower value to protect the internal circuitry.

6.3.1.2.3 Ring. Ringing signals are sent to the subscriber through the Tip and Ring pair of wires. When ringing signals are received on exchange side modem, it converts these ringing signals into logic level. This logical activates ring encoder circuit. In this way oscillator is connected to amplifier and a tone of 500 Hz is sent on line. From line these signals are received in ring decoder circuits on subscriber side and converted into logic level again. Then these logic levels are sent to ring detection circuit. When this circuit receives these signals turns “on” the relay. This relay connects ringing generator to SLIC, which connect these signals, to 2 wire (Tip and Ring).

6.3.1.3 Amplifier/High Pass Filter. The function of this block is to filter out dc and any low frequency noise generated due to fluctuation and also provide gain/loss to the incoming and out going signals (encoder/decoder) to meet the level plan as every encoder/decoder has its own level setting.

6.3.1.4 Pulse Filter, Off/On Hook Generation Circuit. This block is directly connected with the SHK pin of the SLIC. Since this pin only provide permanent high or low level signals to code this, an off/on hook generation circuit is used. When a subscriber set goes off hook, SHK become high and this generation circuit generate a pulse of 400 ms. When subscriber set goes on hook SHK become low and this circuit after detecting low level generate a pulse of 150 ms. These pulses are then fed to pulse encoder circuit which connects 1630Hz oscillator to amplifier stage and send 1630Hz tone on line for pulse remain high duration. The dial pulses are filtered and pass through the circuit as such and go directly to pulse encoder stage.

6.3.1.5 Ring Detection Circuit. A ringing signals are received in ring detection circuit from other end. This circuit detects the ringing signals and activates the ring controller circuit.

6.3.1.6 Call Processing. Refer to Fig-.

- To make a call the telephone is first lifted i.e off-hook and loop current start flowing in the circuit. This flow of current is detected by SLIC and it sends this signal to the off/on hook generator circuit. This circuit generates appropriate off/on hook signals and sends to pulse encoder, it converts this pulse into tone and from line this tone is received by pulse decoder on exch side and recovered from tone to pulse signals. This pulse signals are then send to exch. The dial tone from the exchange side is fed to the amplifier/high pass filter. This circuit amplifies the incoming dial tone and after filtering feed this dial tone to SLIC. SLIC through its TIP and RING connect this dial tone to line protection circuit, which is connected to the telephone. After receiving dial tone subscriber can dial any number.
- Subscriber can dial in both pulse and tone mode. In pulse mode loop makes and breaks according to the make and break ratio. The SLIC detects this make and breaks of loop current and sends these pulses to pulse filter. Pulse encoder circuit, which converts pluses into 1630Hz. These pulses are sent to the pulse encoder circuit which converts pulses into 1630Hz tone on/off. In tone mode the DTMF (Dual Tone Multiple Frequency) is send directly from the SLIC to amplifier/high pass filter.
- Speech from the exchange side is received in the amplifier/high pass filter. This circuit after necessary amplification and filtering feed these signals to SLIC. SLIC connect these signals to subscriber through line protection circuit.
- When subscriber places his handset the circuit breaks. SLIC after detecting circuit break inform the off/on hook generator circuit. This circuit generates appropriate signals and feeds these signals to pulse encoder and encoder converts these signals into 1630Hz tone and sends it through amplifier to exchange side.
- Incoming ring signals are coupled to ring detector circuit. When incoming ring signals come, relay is marked and output of ring generator is connected to the telephone through TIP and Ring of the SLIC.

6.3.2 Exchange Side Unit. Following are the basic functions of exchange side unit.

6.3.2.3 **Protection Circuit**.

This protection circuit provides two distinct functions i.e high current and primary high voltage protection to the devices appearing on line side. To meet the safety requirement it is necessary to provide dependable current limiting 10 ohms resistance with 250 millivolt quick blow up fuse. It is obvious that smaller the current rating of the fuse, the better will be the performance. However, from a system performance point of view, it will undesirable to have the fuse of such a low current which blow due to intermittent transients that may appear on a routine basis. Therefore, 250 millivolts fuses have been used with current limiting resistance of 10 ohms (which cater for small transients). Surge protectors SK14K130 prevent the modem from any surge appears on line side. These surge protector clamps the voltage by storing/dissipating the energy through ground. If the surge is large enough the surge protectors will burn and also short-circuit this voltage to ground immediately hence preventing the equipment from any possible damage.

6.3.2.4 **Data Access Arrangement**.

DAA is used to convert a balanced 2 wire loop to a ground referenced signal (4 wire) and it also provides a signaling link between an analog loop (central office) and 4 wire data equipment i.e Modems and telephone.

- **Line Termination**. When loop control (LC) is at logic 0, a line termination is applied across Tip and Ring. The device can be considered off hook and DC loop current will flow. The line termination consists of both a DC line termination and an AC input impedance. When LC is at logic 1, a dummy ringer is connected across Tip and Ring. The device can be considered on hook and negligible DC current will flow. The dummy ringer is an AC load, which represents a telephone mechanical ringer. If LC is applied and disconnected at the required rate, can be used to generate dial pulses.
- **Supervisory Features**. The device is capable of monitoring the line conditions across Tip and Ring. The Ringing voltage Loop Current detect pin (RVLC), indicates the status of the device. The RVLC output is at logic 0 when loop current flows, indicating that the DAA is in an off hook state. When the device is generating dial pulses, the RVLC pin outputs a TTL pulse at the same rate. An AC ringing voltage across Tip and Ring will cause RVLC to output a TTL pulse at double the ringing frequency with an envelope determined buy the ringing cadence.
- **On/Off Hook Detection Circuit**. When handset is resting on telephone DAA provide open circuit to central office (normally very high impedance). When HANDSET is picked up pulse encoder/decoder sends signals to DAA through off/on hook circuit. These signals are detected in the off/on hook detector circuit and it informs DAA that hand set is off hook. DAA inturn provides low impedance to the Tip and Ring, hence circuit is completed and central office provides dial tone to the DAA. DAA connect this dial tone to the high pass filter circuit. When subscriber places his handset, signals are generated in off/on hook circuit. These signals are then fed to pulse encoder. It sends these signals to pulse decoder on exchange side. On receipt these signals are fed to the off/on hook generator circuit. This off/on hook generator circuit informs DAA and handset is on hook. DAA now provide very high impedance (open circuit) to the central office, which disconnect the dial tone or message channel.
- **Ring Detection/Conversion Circuit**. When ringing voltage applied to the TIP and Ring of DAA, it produces the frequency that is double the ringing frequency. The ring pulse generator detected these frequencies and produce a high logic level till such time ring is received, as soon as ring disconnected ring pulse generator produce low logic level which is send to ring encoder circuit and this signals is transformed into logic level through ring decoder circuit on subscriber side.

- **Pulse Detection Circuit**. When at subscriber end a number is dialed in pulse mode the loop makes and breaks according to the number dialed. These pulses are generated at subscriber unit and send to the DAA through pulse encoder and pulse decoder. Before it connected to DAA these are filter in a pulse detector circuit that detect whether these are off/on hook pulses or they are dial pulses and accordingly informed DAA. When number is dialed in DTMF modes it does not follow the above-mentioned channel rather it pass through the massage channel.
- **Ring Encoder Circuit**. When it receives high logic level from ring detection circuit DAA, it connects 1110Hz oscillator to amplifier for that particular duration. Amplifier sends this tone to subscriber side modem.

6.4 Description of Detailed Circuit Diagram

6.4.1 Subscriber End.

6.4.1.1 Line Filter/Protection Circuit (2 Wire). Fuses F1 and F2 are 250 mA quick blowup fuses, which provide protection against any heavy current drainage due to short circuit. Varistors RV1 & RV2 are 130V, which protect the internal circuit from any surge voltage coming from loop side. R8 and R9 are 10 ohms current limiting resistance. These two lines terminate on SLIC Pin 9 & 10 that is TIP and Ring. U2 also provides the loop with constant 26 mA current to power the telephone set at 24 VDC.

6.4.1.3 **Amplifier/High Pass Filter (4 Wire)**

- **Rx Side**. Pin J2(3) is Rx line and Pin J2(4) is its ground C1 provide two functions one it stops DC input and secondly it filter the unnecessary low noise entering in the system. R1 and VR1 control the gain of the op-amp. U1 is set such that it should compensate attenuation offered by U2. U1 is high gain, frequency compensated op-amp, which not only amp but it also block DC amplification and protect U2 from any unusual signals. Output of U1 from Pin1 is connected to Pin3 of U2.
- **Tx Side**. Pin J2(1)&(2) is Tx line and Pin J2(4) is its ground. Output from U2 pin8 is connected to C3, R5 and VR2 is a gain control circuit for U1. Output of U1 pin7 is connected to Ax4.
- **Battery Feed**. VBAT (-24) is applied to the R2, R3 and VR3, which form potential divider circuit. VR3 is used for adjusting the required voltage at Pin4 of U2. R4 is used to limit the current. D1 is zener diode, which protect U2 from variation in VBAT. Doide D2, D3, D4 and D5 connected to U2 Pin15 and provide secondary protection to U2.

6.4.1.3 On /Off Hook Generation Circuit

- **Off Hook Generation**. When a subscriber set goes off-hook the local loop (loop side) is closed and a DC current flows. The SLIC monitors the loop current flow and indicates an off-hook condition when a specific threshold has been exceeded. The SHK (U2 Pin20), then extend ground to the FCC through R10. Initially VCC is connected to U3 pin3 through R10, R13 and U3 pin1 through R14 and R15 which makes potential divider. VCC is also connected to U3 Pin2 through C7, VR4 and R16. VR4 and R16 makes potential divider circuit and threshold level can be adjusted through veriable resistance VR5. When telephone set is on-hook capacitor C7 remain on charged condition (change path is VCC R10, R4, C7 and ground), as soon as set goes off-hook capacitor C7 discharges through R4 and SHK U2 pin20 .

- Since threshold level is adjustable through VR4 and it is adjusted to 2.3 Volts. When telephones goes off-hook voltage level at U3 pin3 varies due to discharge of capacitor C7 when it cross the threshold level as, the output at U3 pin1 changes from high to low. This output is fed directly to U4 pin1. Another input to U4 pin2 is directly fed from SHK. These two outputs are then XORed and a pulse of 200ms is produced at U4 pin3. This is fed to U6 pin1 through R19 and R20.
- **On Hook Generation**. Same circuit is used for the on-hook detection. When a subscriber set goes on hook the loop breaks and DC current stop flowing through the loop. This break is detected by the SLIC and the SHK goes to third state (float) because of this C7 charge through the R4. Voltages at U3 pin3 changes when it cross the threshold level and U3 become high.

6.4.1.4 Dialing Pulses Detection Circuit. When subscriber dials a number loop makes and breaks according to the make breaks ratio. The SLIC detects this make and break of loop current and its SHK respond accordingly. Since response of C7 is slower therefore output of U3 Pin1 remain high. Input of U4 Pin2, which is directly connected to SHK, changes its state according to the make and break.

6.4.1.5 Ring Detection Circuit. Normally PinAx11 is open but when ring received from exchange side, relay of encoder / decoder is marked and ground is extended. As the ground is extended, circuit for U6 Pin3 and Pin4 is completed through R21 and R22. Due to this VCC is connected to U5 Pin1 through U6 Pin6 and Pin5. R24 eliminates any chances of false ringing due to indeterminate state. U5 Pin1 remain high for time ring is received. This time depend on type of exch. When U5 Pin1 become high U5 Pin3 also become high as U5 Pin2 is directly connected to SHK. Therefore for the period telephone is on hook this pin will remain on high state and since AND gate is used output of U5 Pin3 will respond according to the incoming ring. The output U5 Pin3 is connected to the base of Q1 through R17 and to LED RED D22 through R18. When ring comes LED will glow for visual indication and Q1 will also go on conduction. Relay K1 will mark because Vcc is connected to K1 Pin1 and K1 Pin16 is connected to Q1 collector and emitter is connected to ground. D6, which is connected between K1 pin1 and 16, protect the coil from any damage. Output of Ring Generator is aval on pin Ax27, which is connected to the K1 Pin9 through R7. R7 controls the voltage of ringer. K1 is a DPDT relay K1 Pin11 is normally connected to K1 Pin13 hence connecting U2 Pin15 and Pin11. When relay is marked U2 Pin15 is disconnected and ringer output is connected to U2 Pin11 through K1 Pin13, resister R6 serves to provide battery feed to the subscriber loop during the transitional state. R7 also provide protection and to limit the surge of DC current when subscriber set goes off-hook. The ringing signal must be DC biased at the battery voltage in order for the SLIC to detect an off-hook condition, while ringing signal has been applied. The operations of the ringer at telephone end of the loop causes AC current to flow in the loop. This current may cause the device to indicate a false off-hook, in order to prevent, this from happening, a C5 is connected to U2 Pin19 and ground while the ringing signal is connected to the loop.

6.5 Power Supply

6.5.1 -24 Volt (VBAT). A –24 volt from main power supply is available at Pin P1(3). This –24 volt are initially filtered through C6 and directly fed to U2 Pin18 and The ground pin for –24 volts is P1(5).

6.6 Exchange End

6.6.1 Protection Circuit (2 Wire). A12 and A13 are connected to the fuse F1 and F2 respectively. Fuses F1 and F2 are 250mA quick blowup which provide primary protection against any heavy current drainage due to short circuit. Varistor RV1 and RV2 are 130V, which protect the internal circuit against any surge voltage produced due to lightening. R1 and R2 are 10 ohms resistance, which limit the current. These two lines terminate on (DAA) U1 Pin26 and 16, which is a balance 2 wire input/output.

6.6.2 High Pass Filter (4 Wire).

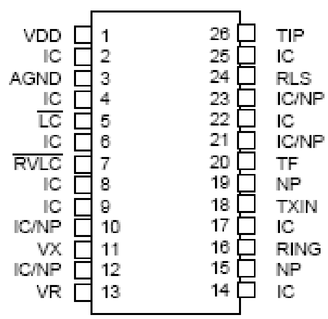
6.6.2.1 Rx Side. Pin 17 is Rx line and Pin 18 is its ground. C3 provide two functions one it stops DC input and secondly it filters the unnecessary low noise entering in the system. The capacitor is directly connected to U1 Pin 11.

6.6.2.2 Tx Side. Pin Bx4 is Tx line and Pin3 is its ground. Pin Bx4 is connected to the U1 Pin13 through capacitor C4.

6.6.2.2.1 Incoming Ring Detection. Ring from central office is received at TIP & Ring Pins on U1. U1 detect this ringing voltage and will cause RVLC to output a TTL pulse at double the ringing frequency. The output of RVCC is connected to U5 Pin4. This output is XORed with line status U1 Pin5, so as to remove any possibility of ring during off-hook conditions. The output of U5 Pin6 is inverted through U3 Pin11and Pin12. This inverted output is connected to U4 Pin3 (opto-coupler).

6.6.2.2.2 On/Off Hook Detection Circuit. When handset is resting on telephone DAA provide open circuit to central office (normally very high impedance). When HANDSET is picked up pulse encoder/decoder sends signals to DAA through off/on hook circuit. These signals are detected in the off/on hook detector circuit and it informs DAA that hand set is off hook. DAA inturn provides low impedance to the Tip and Ring, hence circuit is completed and central office provides dial tone to the DAA. DAA connect this dial tone to the high pass filter circuit. When subscriber places his handset, signals are generated in off/on hook circuit. These signals are then fed to pulse encoder. It sends these signals to pulse decoder on exchange side. On receipt these signals are fed to the off/on hook generator circuit. This off/on hook generator circuit informs DAA and handset is on hook. DAA now provide very high impedance (open circuit) to the central office, which disconnect the dial tone or message channel.

CHAPTER 7: THE MODULES



CHAPTER 7: THE MODULES
7.1 MH-88422
7.1.1 Features
- FAX and Modem interface (V29)
- Variants available with different line impedances
- Provides reinforced barrier to international PTT requirements
- Transformerless 2-4 Wire conversion
- Integral Loop Switch
- Dial Pulse and DTMF operation
- Line state detection outputs
- Loop current/Ringing outputs
- Single +5V operation, low on-hook power (5mW)
- Full duplex data transmission

7.1.2 Applications
Interface to Central Office or PABX line for:
- Modem
- FAX
- Telemetry

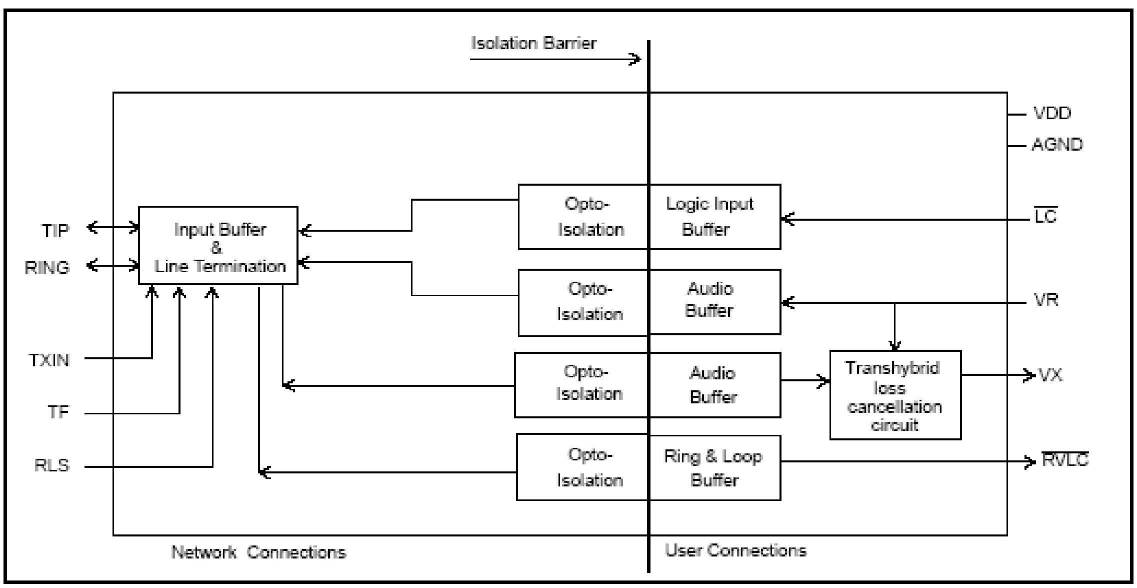


Figure 1 - Functional Block Diagram

Figure 7.1 Functional Block Diagram

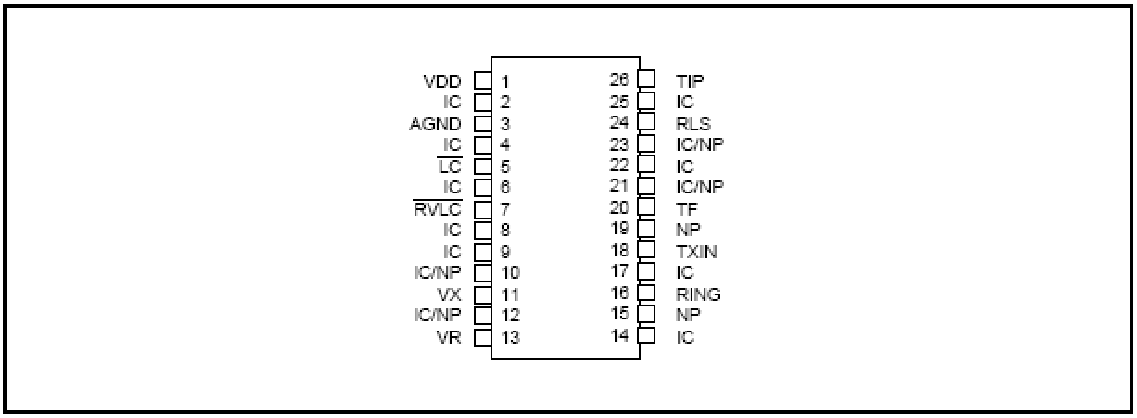


Figure 2 - Pin Connections

Figure 7.2 Pin Connections

7.1.3 Description

The Mitel MH88422 Data Access Arrangement (D.A.A) provides a complete interface between data transmission equipment and a telephone line. All functions are integrated into a single thick film hybrid module which provides high voltage isolation, very high reliability and optimum circuit design needing a minimum of external components.
A number of variants are available to meet particular country impedance requirements. The D.A.A has been designed to meet regulatory approvals requirements in these countries.

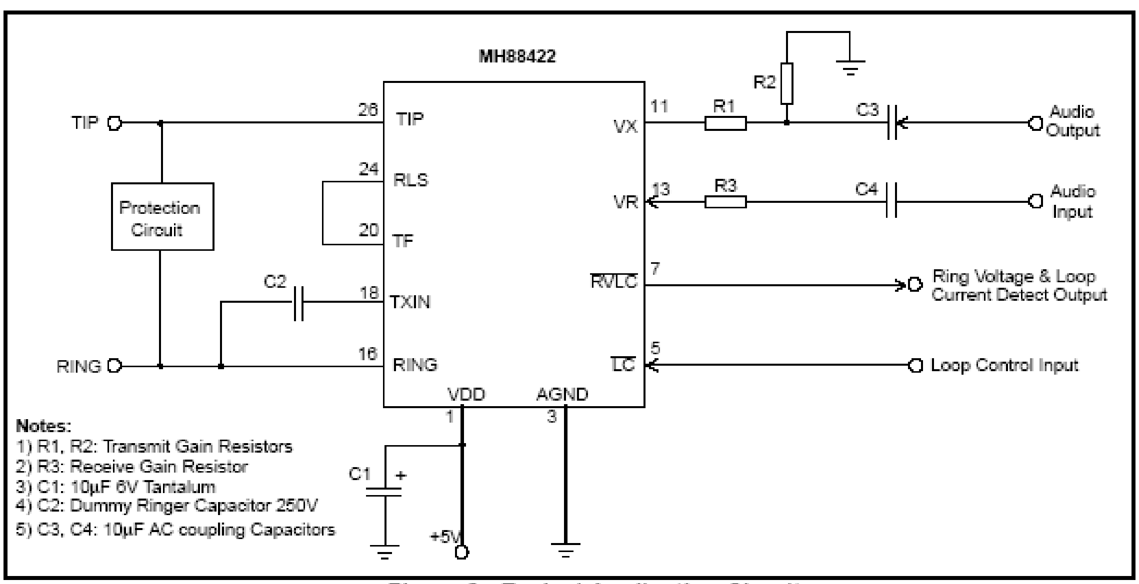


Figure 3 - Typical Application Circuit

Figure7.3 Application Circuit

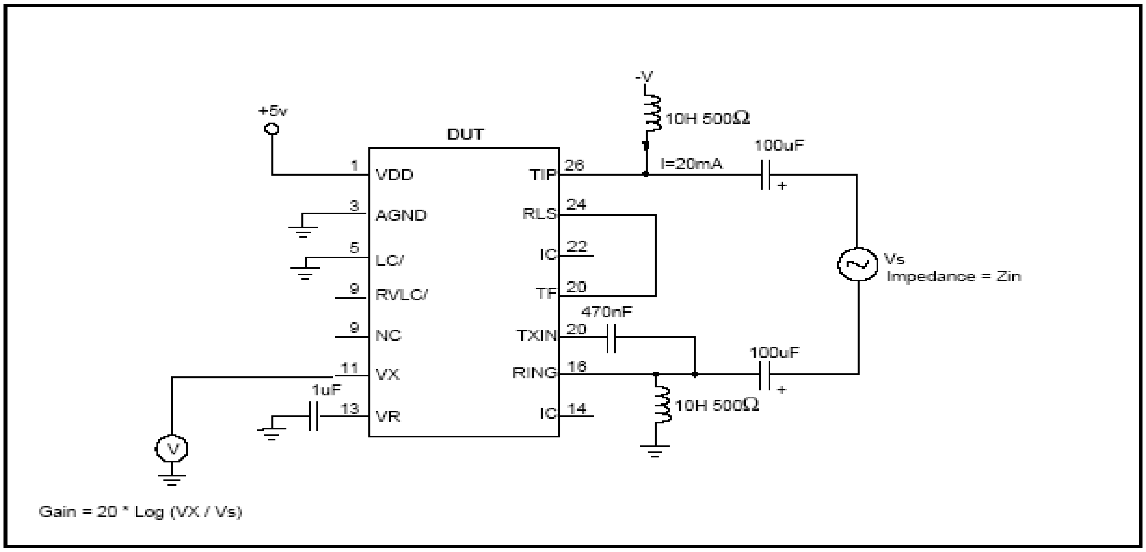


Figure 5 - Test Circuit 2

Figure7.4 Test Circuit2

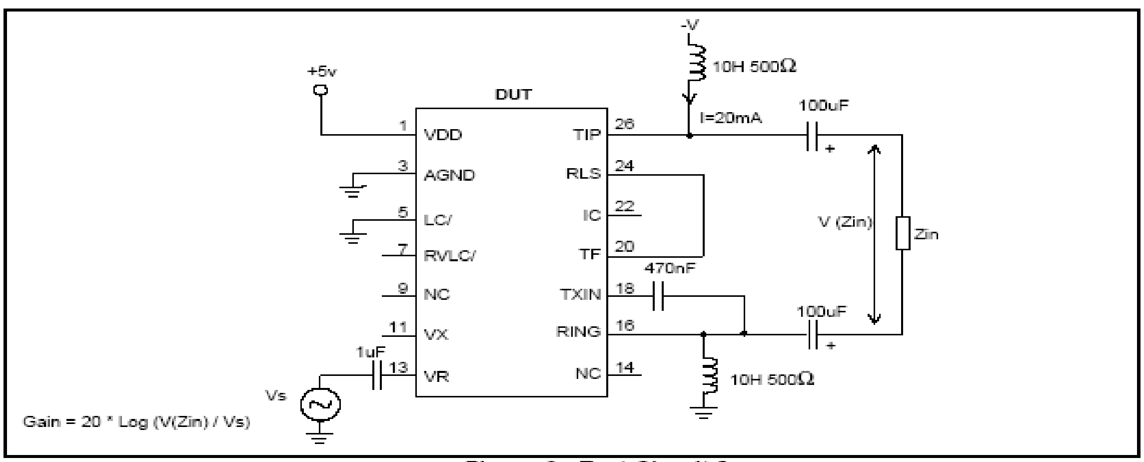


Figure 6 - Test Circuit 3

Figure7.5 Test Circuit3

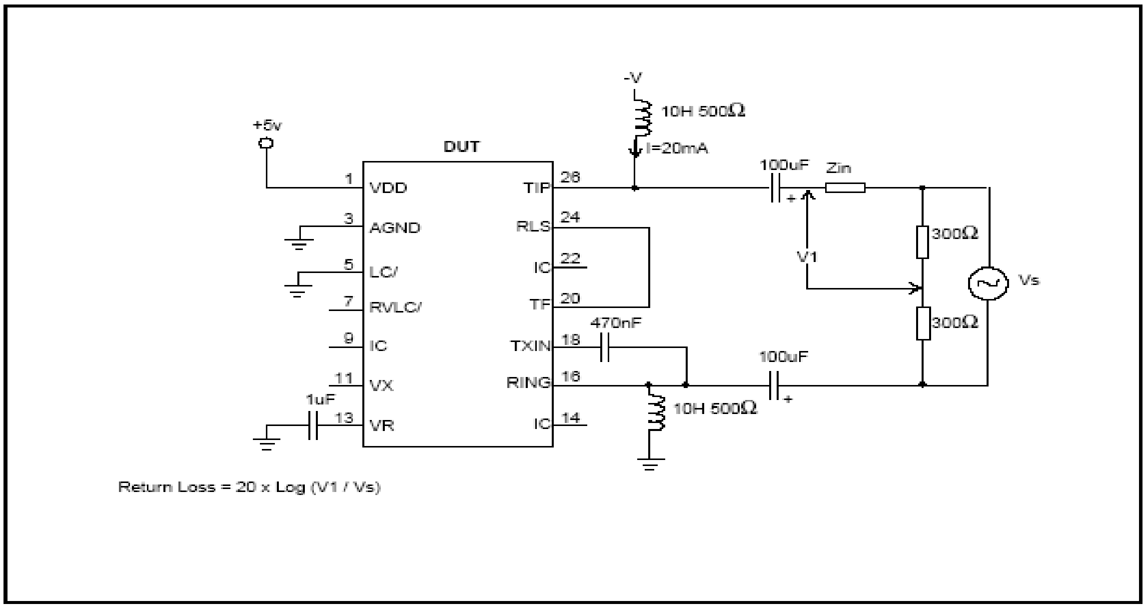


Figure 7 - Test Circuit 4

Figure 7.6 Test Circuit4

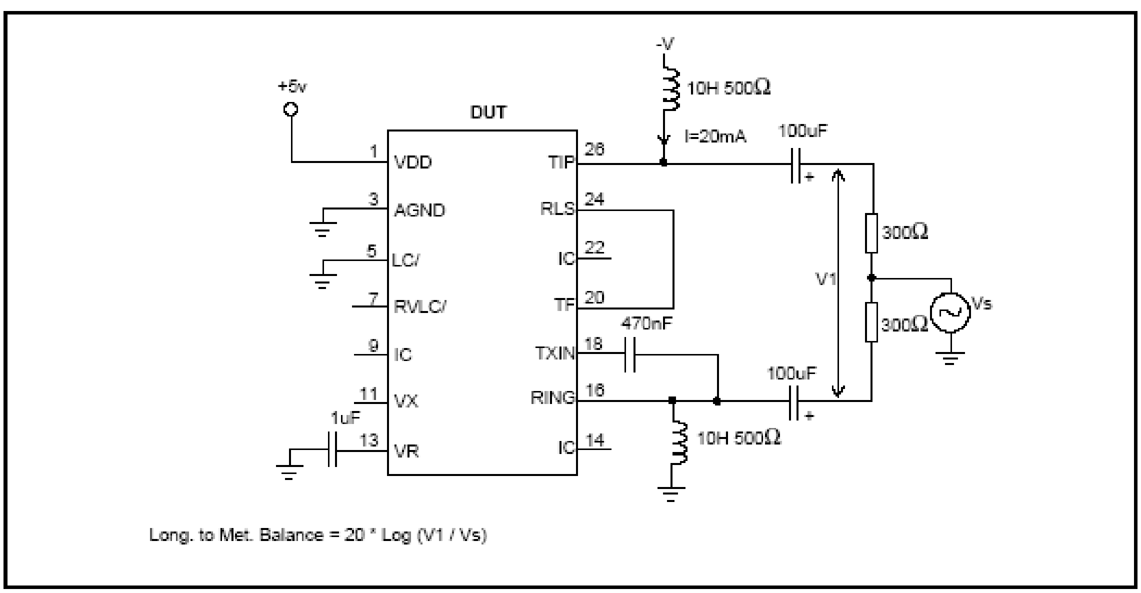


Figure 8 - Test Circuit 5

Figure 7.7 Test Circuit5

Pin Description

Pin #	Name	Description
1	VDD	**Positive Supply Voltage.** +5V.
2, 4, 6, 8, 9	IC	**Internal Connection.** This pin is cropped short.
3	AGND	**Analog Ground.** 4-Wire Ground. Normally connected to System Ground.
5	$\overline{\text{LC}}$	**Loop Control (Input).** A logic 0 activates internal circuitry which provides a line termination across Tip and Ring. Used for seizing the line and dial pulsing.
7	$\overline{\text{RVLC}}$	**Ringing Voltage and Current Detect (Output).** Indicates the status of loop current and ringing voltage.
10, 12	IC/NP	**Internal Connection or No Pin Fitted.** This pin is either cropped short or not fitted, depending on the variant. See Note 1
11	VX	**Transmit (Output).** Analog output to modem/fax chip set.
13	VR	**Receive (Input).** Analog input to modem/fax chip set.
14, 17	IC	**Internal Connection.** This pin is cropped short.
15, 19	NP	**No Pin Fitted.**
16	RING	**Ring Lead.** Connects to the "Ring" lead of a telephone line.
18	TXIN	**Dummy Ringer Connection.** Connects to the "Ring" lead of a telephone line through a dummy ringer capacitor.
20	TF	**Tip Feed.** Connects externally to the RLS pin.
21, 23	IC/NP	**Internal Connection or No Pin Fitted.** This pin is either cropped short or not fitted, depending on the variant. See Note 1
24	RLS	**Ringing Loop Sense.** Connects externally to the TF pin.
25	IC	**Internal Connection.** This pin is cropped short.
26	TIP	**Tip Lead.** Connects to the "Tip" lead of a telephone line.

Table 14 Pin Connections

7.1.4 Functional Description. The device is a Data Access Arrangement (D.A.A). It is used to correctly terminate a 2-Wire analog loop. It provides a signalling link and a 2-4 Wife line interface between an analog loop and subscriber data transmission equipment such as Modems, Facsimiles (Fax's), Remote Metering.

7.1.5 Isolation Barrier. The device provides an Isolation barrier implemented by using optocouplers. This is a reinforced barrier for an instantaneous power surge of up to 3kV r.m.s., for example a lightning strike. It also provides full isolation for a continuous AC voltage level of up to 250V rms.

7.1.6 External Protection Circuit. Should the input voltage from the line exceed that isolated by the optocoupler, an External Protection Circuit assists in preventing damage to the device and the subscriber equipment.

7.1.7 Line Termination. When Loop Control (LC) is at a logic 0, a line termination is applied across Tip and Ring. The device can be considered off-hook and DC loop current will flow. The line termination consists of both a DC line termination and an AC input impedance. When LC is at a logic 1, a Dummy Ringer is applied across Tip and Ring. The device can be considered on-hook and negligible DC current will flow. The dummy ringer is an AC load, which represents a telephone's mechanical ringer.

7.1.8 DC Line Termination. When LC is at a logic 0, an active termination is applied across Tip and Ring, at which time it can be considered to be in an off-hook state.

7.1.9 Input Impedance. The MH88422 is available in a number of different variants each of which has its own fixed Tip-Ring AC input impedance (Zin).

7.1.10 Dummy Ringer. This device supports a dummy ringer option which can be configured by the inclusion of external components. Further details relating to component values and configuration can be obtained from MSAN-154. For example, Figure 3 shows capacitor C2 which if set to 1.8uF would meet the New Zealand dummy ringer requirements.

7.1.11 4 Wire Conversion. The device converts the balanced 2-Wire input, presented by the line at Tip and Ring, to a ground referenced signal at VX, as required by modem/fax chip sets.Conversely the device converts the ground referenced signal input at VR, to a balanced 2-Wire signal across Tip and Ring.

During full duplex transmission, the signal at Tip and Ring consists of both the signal from the device to the line and the signal from the line to the device. The signal input at VR, being sent to the line, must not appear at the output VX. In order to prevent this, the device has an internal cancellation circuit. The measure of attenuation is Transhybrid Loss (THL).

The Transmit (VX) and Receive (VR) signals are ground referenced (AGND), and biased to 2.5 V. The device must be in the off-hook condition for transmission or reception to take place.

7.1.12 Transmit Gain. The transmit Gain of the MH88422 is the gain from the differential signal across Tip and Ring to the ground referenced signal at VX. The internal Transmit Gain of the device is fixed and depends on the variant as shown in the AC Electrical Characteristics table. For the correct gain, the Input Impedance of the MH88422 variant used, must match the specified line impedance.

7.1.13 Receive Gain. The Receive Gain of the MH88422 is the gain from the ground referenced signal at VR to the differential signal across Tip and Ring. The internal Receive Gain of the device is fixed as shown in the AC Electrical Characteristics table. For the correct gain, the Input Impedance of the MH88422 variant used, must match the specified line impedance.

7.1.14 Supervisory Features. The device is capable of monitoring the line conditions across Tip and Ring, this is shown in Figure 7.2. The Ringing Voltage Loop Current detect pin (RVLC), indicates the status of the device. The RVLC output is at logic 0 when loop current flows, indicating that the MH88422 is in an off hook state.

When the device is generating dial pulses, the RVLC pin outputs a TTL pulse at the same rate.

7.1.15 Absolute Maximum Ratings* - All voltages are with respect to AGND unless otherwise specified.

	Parameter	Symbol	Min	Max	Units
1	DC Supply Voltage	V_{DD}	-0.3	6	V
2	Storage Temperature	T_S	-55	+125	°C
3	DC Loop Voltage	V_{BAT}	-110	+110	V
4	Ringing Voltage - 2 variant - all other variants	V_R V_R	- -2	150 120	Vrms Vrms
5	Loop Current	I_{Loop}	-	90	mA

*Exceeding these values may cause permanent damage. Functional operation under these conditions is not implied.

Recommended Operating Conditions

	Parameter	Sym	Min	Typ‡	Max	Units	Test Conditions
1	DC Supply Voltages	V_{DD}	4.75	5.0	5.25	V	
2	Operating Temperatures	T_{OP}	0	25	70	°C	
3	Ringing Voltage	V_R		75	90	Vrms	150 Vrms for -2 variant

‡ Typical figures are at 25°C with nominal +5V supply and are for design aid only

Loop Electrical Characteristics †

	Characteristics	Sym	Min	Typ‡	Max	Units	Test Conditions
1	Ringing Voltage	VR					Externally Adjustable - See MSAN-154
	-1 Variant Only No Detect				17	Vrms	
	Detect		35			Vrms	
	BD-1 Variant Only No Detect				15	Vrms	
	Detect		32			Vrms	
	All other Variants No Detect				7	Vrms	
	Detect		14			Vrms	
2	Ringing Frequency						
	BD-1 Variant Only		23		28	Hz	
	All other Variants		15		68	Hz	
3	Operating Loop Current						
	BD-1 Variant Only		20		80	mA	
	All other Variants		15		80	mA	
4	Off-Hook DC Voltage						Test circuit as Fig 4
	-1 Variant		6.0			V	I_{Loop}=19mA (See Note 1)
					28.8	V	I_{Loop}=60mA
	-2 Variant				6.0	V	I_{Loop}=15mA
			2.4		6.0	V	I_{Loop}=20mA (See Note 2)
			3.1		7.8	V	I_{Loop}=26mA
	-3 Variant				9.0	V	I_{Loop}=15mA (See Note 3)
			6.0		14.0	V	I_{Loop}=90mA
	BD-1 Variant		6.0		10.8	V	I_{Loop}=20mA (See Note 4)
			6.0		27	V	I_{Loop}=50mA

Table 15 Loop Electrical Characteristics

DC Electrical Characteristics †

		Characteristics	Sym	Min	Typ‡	Max	Units	Test Conditions
1		Supply Current	I_{DD}		1	5	mA	V_{DD} = 5.0V, On-hook
2	$\overline{RVLC}$	Low Level Output Voltage High Level Output Voltage	V_{OL} V_{OH}	 2.4		0.4	V V	I_{OL} = 4mA I_{OH} = 0.4mA
3	$\overline{LC}$	Low Level Input Voltage High Level Input Voltage Low Level Input Current High Level Input Current	V_{IL} V_{IH} I_{IL} I_{IH}	 2.0		0.8 -60 60	V V µA µA	 V_{IL} = 0.0V V_{IH} = 5.0V

AC Electrical Characteristics † - MH88422 All Variants

	Characteristics	Sym	Min	Typ‡	Max	Units	Test Conditions
1	Input Impedance VR			47k		Ω	
2	Output Impedance at VX			10		Ω	
3	Receive Gain (VR to 2-Wire)		2.5	3.5	4.6	dB	Test circuit as Fig 6 Input 0.5V at 1kHz
4	Frequency Response Gain (relative to Gain @ 1kHz) All Variants		-1 -1	0 0	+1 +1	dB dB	300Hz 3400Hz
5	Signal Output Overload Level at 2-Wire at Vx		+2.0 +2.0	+3.0 +3.0		dBm dBm	THD ≤ 5% @ 1kHz I_{Loop} = 20 to 40mA
6	Total Harmonic Distortion BD-1 Variant at 2-Wire All other Variants at 2-Wire All Variants at VX	THD		1.2 1.2 1.2	2.0 2.5 2.0	% % %	Input -3.5dBm at 1kHz
7	Power Supply Rejection Ratio BD-1 Variant at 2-Wire at VX All other Variants at 2-Wire at VX	PSRR	18 18 12 12	40 40 20 20		dB dB dB dB	Ripple 0.1Vrms 1kHz on V_{DD}
8	Transhybrid Loss	THL	6	20		dB	Test circuit as Fig 6 Input -3.5dBm, 300-3400Hz at V_R

AC Electrical Characteristics† - MH88422-1

	Characteristics	Sym	Min	Typ‡	Max	Units	Test Conditions
1	Return Loss at 2-Wire (220Ω + 820Ω //120nF)	RL	 20 20 20	 22 24 26		 dB dB dB	Test circuit as Fig 7 300-500Hz 500-2500Hz 2500-3400Hz
2	Longitudinal to Metallic Balance		 40 55 53	 65 60 60		 dB dB dB	Test circuit as Fig 8 50-300Hz 300-1000Hz 1000-4000Hz
3	Idle Channel Noise at 2-Wire at VX	Nc		 -79 -73	 -72 -58	 dBmp dBmp	
4	Transmit Gain (2-Wire to Vx)		 -1.4	 -0.4	 0.9	 dB	Test circuit as Fig 5 Input 0.5V @ 1kHz Off -Hook
5	Frequency Response Gain (relative to Gain @ 1kHz)		-1.8 -2.1	-0.6 -0.5	0.4 0.9	dB dB	300Hz 3400Hz

AC Electrical Characteristics† - MH88422-2

	Characteristics	Sym	Min	Typ‡	Max	Units	Test Conditions
1	Return Loss at 2-Wire (Reference 600Ω)	 ERL SFRL	 20 14	 30 19		 dB dB	Test circuit as Fig 7 500-2500Hz 200-3200Hz
2	Longitudinal to Metallic Balance Metallic to Longitudinal Balance		 58 53 60 40	 60 55		 dB dB dB dB	Test circuit as Fig 8 200-1000Hz 1000-3000Hz Test circuit as Fig 9 200-1000Hz 1000-4000Hz
3	Idle Channel Noise at 2-Wire at VX	Nc		 13 13	 20 20	 dBrnC dBrnC	
4	Transmit Gain (2-Wire to Vx)		-1.4	-0.4	0.9	dB	Test circuit as Fig 5 Input 0.5V @ 1kHz Off- Hook
5	Frequency Response Gain (relative to Gain @ 1kHz)		-1.6 -2.1	-1.3 -0.5	0.4 0.9	dB dB	200Hz 3400Hz

AC Electrical Characteristics† - MH88422-3

	Characteristics	Sym	Min	Typ‡	Max	Units	Test Conditions
1	Return Loss at 2-Wire (370Ω + 620Ω // 310nF)	RL	16	20		dB	Test circuit as Fig 7 200-4000Hz
2	Longitudinal to Metallic Balance		50	60		dB	Test circuit as Fig 8 300-3400Hz
3	Idle Channel Noise at 2-Wire at VX	Nc		 -80 -80	 -70 -68	 dBmp dBmp	
4	Transmit Gain (2-Wire to Vx)		-1.4	-0.4	0.9	dB	Test circuit as Fig 5 Input 0.5V @ 1kHz Off-Hook
5	Frequency Gain (relative to gain @ 1kHz)		-1.6 -2.1	-1.3 -0.5	0.4 0.9	dB dB	300Hz 3400Hz

7.2 MH-88610 SLIC (Subscriber Line Interface Card)

7.2.1 Features

- Transformerless 2-wire to 4-wire conversion
- Battery and ringing feed to line
- Off-hook and dial pulse detection
- Ring ground over-current protection
- Loop length detection
- Constant current feed

7.2.2 Applications

Line interface for:

- PABX
- Intercoms
- Key Telephone Systems
- Control Systems

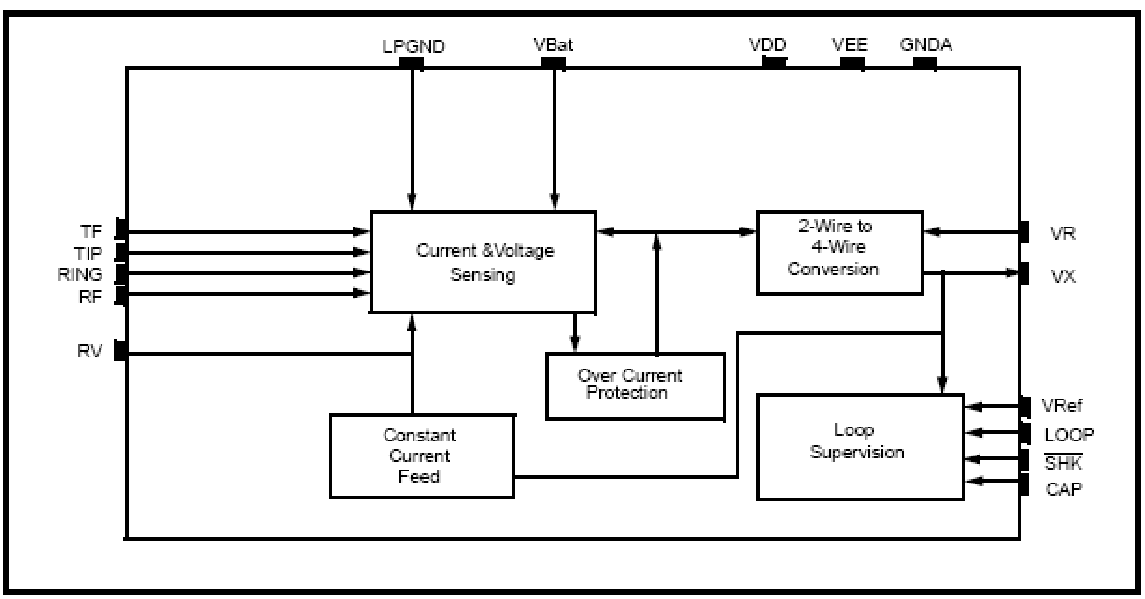


Figure 1 - Functional Block Diagram

Figure 7.8 Functional Block Diagram

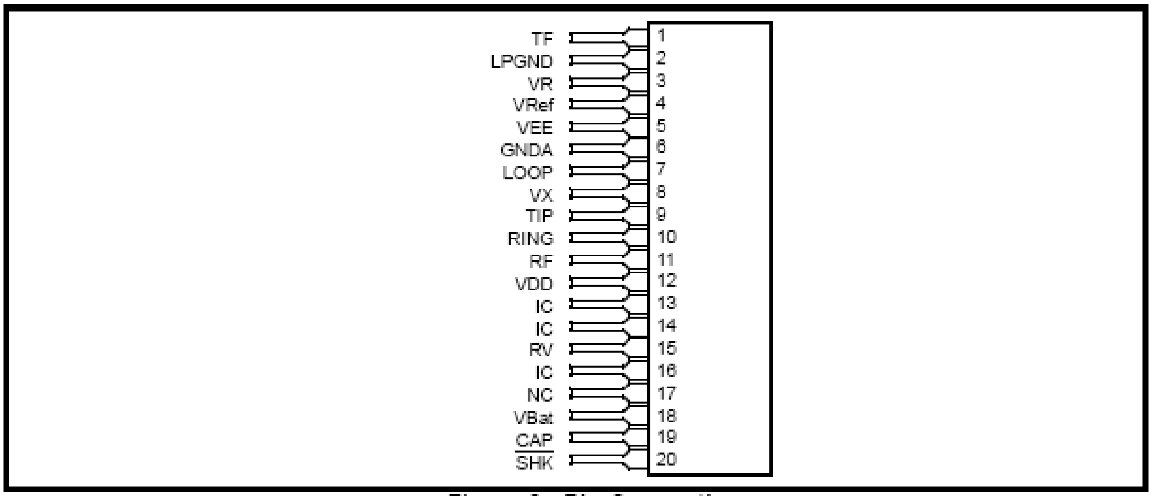


Figure 2 - Pin Connections

Figure 7.9 Pin Connections

7.2.3 Description

The Mitel MH88610 Subscriber Line Interface Circuit provides a complete interface between a switching system and a subscriber loop. Functions provided include battery feed and ringing feed to the subscriber line. 2-Wire to 4-Wire hybrid interfacing, constant current, loop length and dial pulse detection. The device is fabricated using thick film hybrid technology in a 20-pin single in-line package.

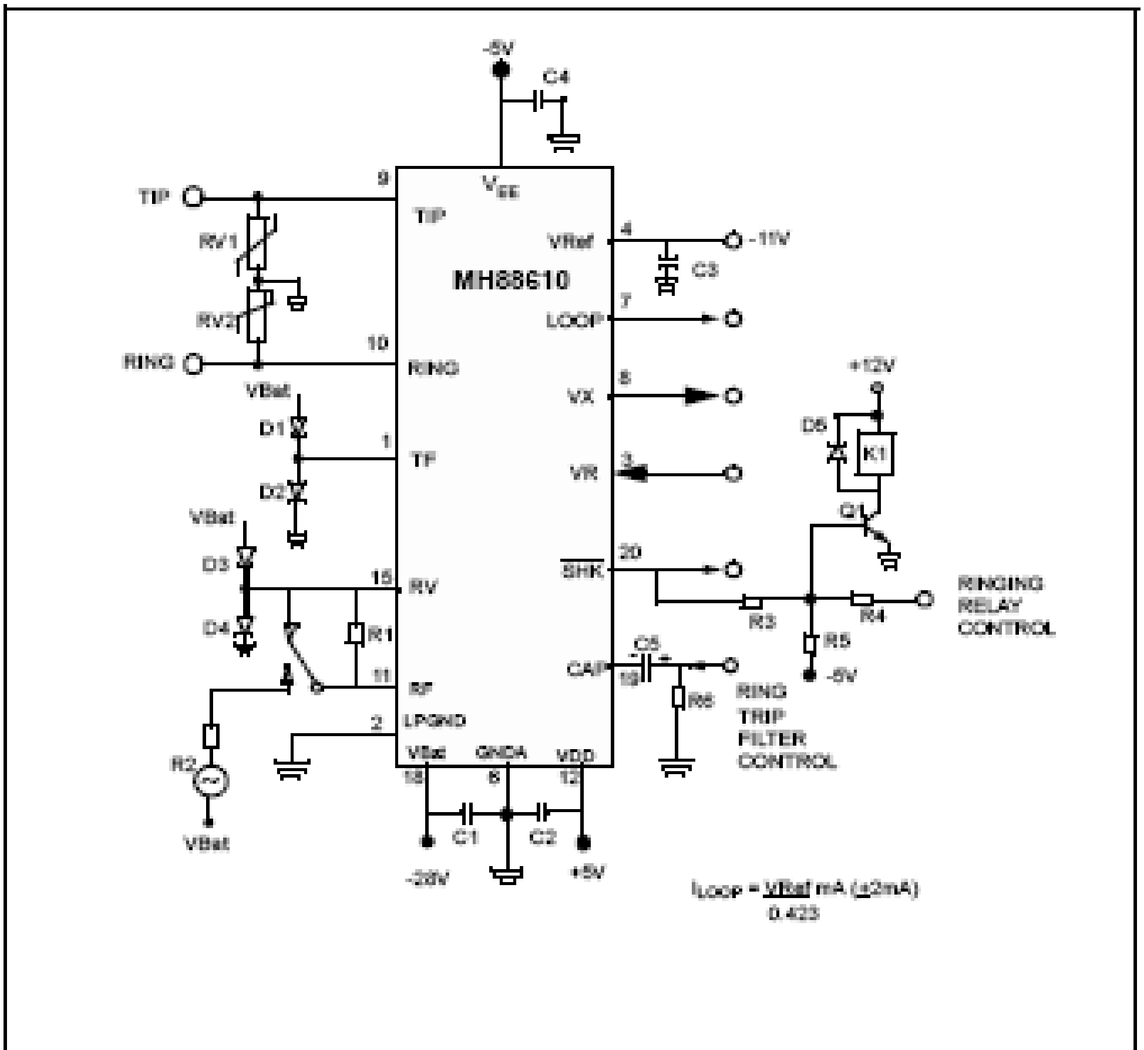


Figure 3 - Application Circuit

Figure 7.10 Application Circuit

7.2.4 Functional Description

The MH88610 performs a transformerless 2-wire to 4-wire conversion of the analog signal. The 2-wire circuit is the balanced line going to the subscriber loop, while the 4-2 wire circuit is the audio signal going to an from devices such as the voice codec or switching circuit. The SLIC also provides two status signals, switch hook (SHK) and loop length (Loop). The Loop signal is an analog voltage which is proportional to the loop length and the SHK goes low when the telephone set is off-hook.

Pin Description

Pin #	Name	Description
1	TF	**TF Tip Feed.** Internal connection. Normally connects a pair of external diodes for protection.
2	LPGND	**Loop Ground.** is the system ground reference with respect to VBat.
3	VR	**Voice Receive (input)** is the 4 wire analog signal to the SLIC.
4	V_{Ref}	**Voltage Reference (Input)** to set the line current feed to the subscriber line.
5	V_{EE}	**Negative Power Supply Voltage (-5V).**
6	GNDA	**Analog Ground (0V).**
7	LOOP	**Loop Monitor Voltage (Output).** is proportional to the loop length.
8	VX	**Voice Transmit (Output)** is the 4-wire analog signal from the SLIC.
9	TIP	Connects to the "Tip" lead of the telephone line .
10	RING	Connects to the "Ring" lead of the telephone line.
11	RF	**Ring Feed (Input)** is normally connected to Ring relay for negative battery feed voltage and ringing voltage input.
12	V_{DD}	**Positive Power Supply Voltage.**
13	IC	**Internal Connection.** Pin cut short.
14	IC	**Internal Connection.** Pin cut short.
15	RV	**Ring Feed Voltage** connects to pin 11 (RF) through a normally closed ring relay.
16	IC	**Internal Connection.** Pin cut short.
17	NC	**No Connection.**
18	V_{Bat}	**Negative Battery Feed Supply Voltage.**
19	CAP	Connects external capacitor and resistor to ground for ring trip filter control.
20	$\overline{SHK}$	**Switch Hook Detect (Output).** Digital output of an open-collector comparator. This output will go low (V_{EE}) when the subscriber line resistance falls below a set threshold value indicating that the telephone set has gone off-hook. This output can be monitored for dial pulse collection.

Table 16 Pin Descriptions

7.2.5 Constant Current Feed

The MH88610 employs a complex feedback circuit to supply a constant feed current to the line. This is done by sensing the sum of the voltages across the internal feed resistors and comparing it to an input reference voltage (Vref) that determines the constant feed current. This gives the loop current as:

$$I_{Loop} = 25- \frac{(Vref)}{1.25} \text{ mA } (\pm 2 \text{ mA})$$

7.2.6 Switch Hook Detection

When the DC current exceeds an internal threshold level, the switch hook (SHK) will go low. If the loop resistance is so high that V_{Bat} can no longer supply the required amount of loop current as determined by constant current supply circuit, the output of the switch hook (SHK) will go high impedance (open collector ouput) to indicate that the loop resistance is too high and the line is on hook.

7.2.7 Ringing and Ring Trip Detection

In Figure 7.10 a ringing signal is applied to the line by disconnecting pin 15 (RV) from pin 11(RF), and connecting the ringing voltage at pin 11 (RF) by use of the relay K1.The SLIC can detect an off-hook condition during ringing but there is a large AC component which must be filtered out to give a true off-hook condition at SHK.A 1.0uF capacitor connected from pin 19 (CAP) to ground will provide adequate attenuation when ringing is applied. Once an off-hook condition has been detected an external circuit will deactivate the relay (K1) to disconnect the ringing voltage from pin 11 and reconnect to pin 15. At that time the SLIC will revert to constant current feed operation.

During off-hook conditions (closed loop), the capacitor should be switched out. This can be performed using a transistor, relay or system drive output of a codec. Applying GNDA to the Ring Trip Filter Control pin will switch in the filter, whilst removing GNDA, (with the switch in a tristate condition), will switch out the filter.For applications using DTMF signalling, the capacitor can be permanently connected to ground.

7.2.8 Current Limit

The Tip or Ring may accidentally short to ground. In such a case, current will only flow through the feed resistor. This high current will be sensed and reduced by the current limit circuit to a lower value to protect the internal circuitry.

Absolute Maximum Ratings*

	Parameter	Symbol	Min	Max	Units
1	DC Supply Voltage	V_{DD}		+15	V
		V_{EE}	-15		V
	LPGND=GNDA	V_{Bat}	-60		V
2	Storage Temperature	T_S	-40	100	°C
3	Package Power Dissipation	PD		2	W

* Exceeding these values may cause permanent damage. Functional operation under these conditions is not implied.

Recommended Operating Conditions

	Parameter	Sym	Min	Typ†	Max	Units	Comments
1	Operating Supply Voltage	V_{DD}	4.75	5.0	5.25	V	
		V_{EE}	-5.25	-5.0	-4.75	V	
		V_{Ref}	-23	-11		V	
		V_{Bat}		-28		V	
2	Operating Temperature	T_O	0		70	°C	

† Typical figures are at 25°C and are for design aid only.

DC Electrical Characteristics† - Voltages are with respect to GNDA unless otherwise stated.

	Characteristics	Sym	Min	Typ‡	Max	Units	Test Conditions
1	Supply Current V_{DD} V_{EE}	I_{DD} I_{EE}		64 -3.4	7.6 -5.0	mA mA	
2	Power Consumption	P_C			212 1110	mW mW	Standby Active
3	Constant Current Line Feed	I_{Loop}	24	26	28	mA	
4	Operating Loop Resistance	R_{Loop}	800			Ω	V_{Bat} = -28V
5	Off-Hook Threshold			1200		Ω	V_{Bat} = -28V
6	Ring Ground Over-Current protection			33	42	mA	
7	Output High Voltage Loop (On-hook)		V_{DD}-2		V_{DD}	V	No Load
8	Output High Source Current Loop (on-hook)		15			mA	R_{LOOP} = 2.5V
9	Output Low Voltage $\overline{SHK}$ Loop (off-hook)		V_{EE} 1.9		V_{EE}+1.5 2.4	V V	10kΩ pull-up to 5V No Load
10	Output Low Sink Current $\overline{SHK}$ Loop (off-hook)		6 10	16 20		mA mA	V $\overline{SHK}$ = 1.5V V_{Loop} = 2.5V

AC Electrical Characteristics

	Characteristics	Sym	Min	Typ*	Max	Units	Test Conditions
1	Ringing Voltage (rms)	V_R			105	V_{rms}	
2	Ring Frequency		17		25	Hz	
3	Ringer Equivalence Number	REN			3		
4	Ring Trip Detect time				200	ms	
5	Input AC Impedance 2-wire	Zin		600		Ω	
6	Input Impedance at V_R			230		kΩ	
7	Output Impedance at Vx			1		Ω	
8	Gain 2-wire to Vx		0.60	0.62	0.70	dB	Input 6dBm at 2-wire
9	Gain VR to 2-wire		-6.75	-6.69	-6.65	dB	Input 1.0V at VR 600Ω termination
10	2-wire Return Loss		20			dB	Input 0.5 V 1kHz 600Ω
11	Transhybrid Loss	THL	40			dB	Input 0.5 V, 1kHz at V_R 600Ω
12	Longitudinal Balance		45			dB	Input 0.5V, 1kHz at metallic output voltage
13	Total Harmonic Distortion	THD					
	at Vx			0.1	1.0	%	Input 6dBm at 2-wire
	at Tip and Ring			0.1	1.0	%	Input 1.0V at V_R
14	Common Mode Rejection Ratio 2-wire to Vx	CMRR	40			dB	Input 0.5Vrms, 1KHz at metallic output voltage
15	Idle channel Noise (at Vx)	Nc			15	dBmC	C- Message
16	Power supply rejection ratio	PSRR					
	V_{DD}		39			dB	At V_X, ripple at Vpp, 1kHz
	V_{DD}		37			dB	At 2-Wire, ripple at 1Vpp, 1kHz
	V_{EE}		23			dB	At V_X, ripple at 1Vpp, 1kHz
	V_{BAT}		23			dB	At 2-Wire, ripple at 1Vpp, 1kHz

Table 17 AC Electrical Characteristics

7.3 LM258N

- Internally frequency compensated
- Large DC voltage gain: 100dB
- Wide bandwidth (unity gain): 1.1mHz (temperature compensated)
- Very low supply current/op (500μA) essentially independent of supply voltage
- Low input bias current: 20nA (temperature compensated)
- Low input offset voltage: 2mV
- Low input offset current: 2nA
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Large output voltage swing 0V to (Vcc - 1.5V)

Pin Connections (top view)

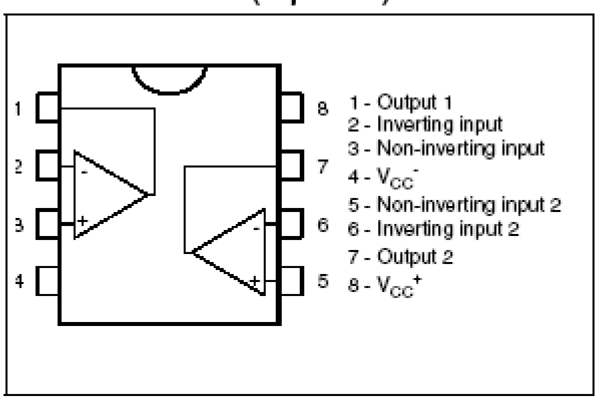


Figure 7.11 Pin Connections

7.4 2N3904

NPN switching transistor 2N3904

FEATURES

- Low current (max. 200 mA)
- Low voltage (max. 40 V).

APPLICATIONS

- High-speed switching.

DESCRIPTION

NPN switching transistor in a TO-92; SOT54 plastic package. PNP complement: 2N3906.

PINNING

PIN	DESCRIPTION
1	collector
2	base
3	emitter

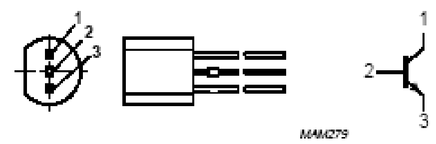
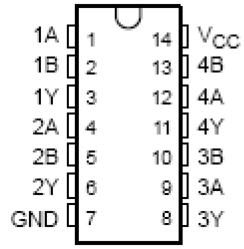


Fig.1 Simplified outline (TO-92; SOT54) and symbol.

7.5 CD74ACT08E

- Inputs Are TTL-Voltage Compatible
- Speed of Bipolar F, AS, and S, With Significantly Reduced Power Consumption
- Balanced Propagation Delays
- Buffered Inputs
- ±24-mA Output Drive Current
  - Fanout to 15 F Devices
- SCR-Latchup-Resistant CMOS Process and Circuit Design
- Exceeds 2-kV ESD Protection Per MIL-STD-883, Method 3015

CD54ACT08 . . . F PACKAGE
CD74ACT08 . . . E OR M PACKAGE
(TOP VIEW)



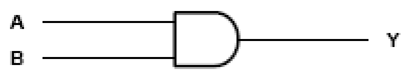
description

The 'ACT08 devices are quadruple 2-input positive-AND gates. These devices perform the Boolean function $Y = A \bullet B$ or $Y = \overline{A + B}$ in positive logic.

FUNCTION TABLE
(each gate)

INPUTS		OUTPUT
A	**B**	**Y**
H	H	H
L	X	L
X	L	L

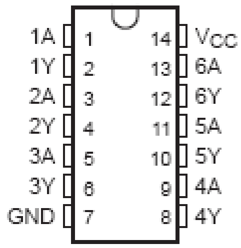
logic diagram, each gate (positive logic)



7.6 CD74ACT14E

- Inputs Are TTL-Voltage Compatible
- Speed of Bipolar F, AS, and S, With Significantly Reduced Power Consumption
- Greater Noise Immunity Than Standard Inverters
- Operates With Much Slower Than Standard Input Rise and Fall Slew Rates
- ±24-mA Output Drive Current
  – Fanout to 15 F Devices
- SCR Latchup-Resistant CMOS Process and Circuit Design
- Exceeds 2-kV ESD Protection Per MIL-STD-883, Method 3015

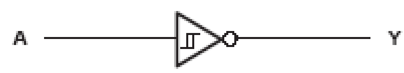
E OR M PACKAGE
(TOP VIEW)



FUNCTION TABLE
(each inverter)

INPUT A	OUTPUT Y
H	L
L	H

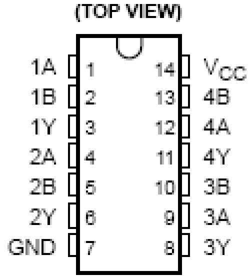
logic diagram, each inverter (positive logic)



7.7 CD74ACT86E

- Inputs Are TTL-Voltage Compatible
- Speed of Bipolar F, AS, and S, With Significantly Reduced Power Consumption
- Balanced Propagation Delays
- ±24-mA Output Drive Current
  – Fanout to 15 F Devices
- SCR-Latchup-Resistant CMOS Process and Circuit Design
- Exceeds 2-kV ESD Protection Per MIL-STD-883, Method 3015

CD54ACT86 . . . F PACKAGE
CD74ACT86 . . . E OR M PACKAGE
(TOP VIEW)



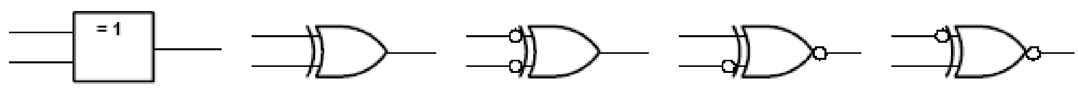
FUNCTION TABLE
(each gate)

INPUTS		OUTPUT
A	B	Y
L	L	L
L	H	H
H	L	H
H	H	L

exclusive-OR logic

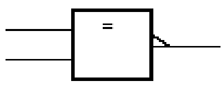
An exclusive-OR gate has many applications, some of which can be represented better by alternative logic symbols.

EXCLUSIVE OR



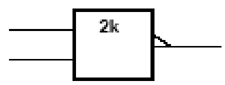
These are five equivalent exclusive-OR symbols valid for an CD74AC86 gate in positive logic; negation may be shown at any two ports.

LOGIC-IDENTITY ELEMENT



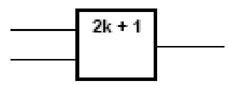
The output is active (low) if all inputs stand at the same logic level (i.e., A = B).

EVEN-PARITY ELEMENT



The output is active (low) if an even number of inputs (i.e., 0 or 2) are active.

ODD-PARITY ELEMENT



The output is active (high) if an odd number of inputs (i.e., only 1 of the 2) are active.

7.8 IN4001A

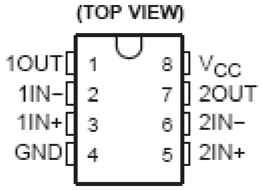
FEATURES

* High reliability
* Low leakage
* Low forward voltage drop
* High current capability

MECHANICAL DATA

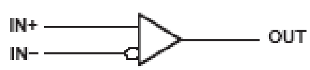
* Case: Molded plastic
* Epoxy: UL 94V-0 rate flame retardant
* Lead: MIL-STD-202E, Method 208 guaranteed
* Polarity: Color band denotes cathode end
* Mounting position: Any
* Weight: 0.22 gram

7.9 LM2903

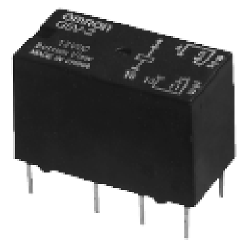


- Single Supply or Dual Supplies
- Wide Range of Supply Voltage:
  Max Rating . . . 2 V to 36 V
  Tested . . . 2 V to 30 V Non-V Devices
  Tested . . . 2 V to 32 V V-Suffix Devices
- Low Supply-Current Drain Independent of Supply Voltage . . . 0.4 mA Typ Per Comparator
- Low Input Bias Current . . . 25 nA Typ
- Low Input Offset Current . . . 3 nA Typ (LM193)
- Low Input Offset Voltage . . . 2 mV Typ
- Common-Mode Input Voltage Range Includes Ground
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . ±36 V
- Low Output Saturation Voltage
- Output Compatible With TTL, MOS, and CMOS
- For Single Version in SOT23-5, See TL331 Data Sheet

symbol (each comparator)



7.10 RELAY DPCO 5V



- Suitable for handling low signals in computer peripherals, telecommunications and security equipment
- Capable of switching loads up to 2 A
- Conforms to FCC part 68 1500 V surge withstand
- Reliable bifurcated crossbar contacts
- Fully-sealed construction

CHAPTER 8: THE DESIGN APPROACHES

CHAPTER 8: THE DESIGN APPROACHES

8.1 One attempt to resolve this problem is simply to raise the signal level at the transmitting end to so high a level that, in spite of the attenuation, the receive signal substantially overrides the noise. Such a solution is hardly feasible on the grounds that the signal power and consequent voltage levels at the transmitter would be difficult to handle. For example, at 1 kHz, a telephone cable may be expected to produce attenuation of the order of 1 dB per mile. For a 3000-mile run, even if we were satisfied with a received signal of 1 mV, the voltage at the transmitting end would have to be 10,147 volts.

8.2 An amplifier at the receiver will not help the situation, since at the point both signal and noise levels will be increased together.

8.3 Repeater (repeater is the term used for an amplifier in a communications channel) be located at the midpoint of the long communications path. This repeater will raise the signal level; in addition, it will raise the level of only the noise introduced in the first half of the communications path. Hence, such a midway repeater, as contrasted with an amplifier at the receiver, has the advantage to improving the received signal-to-noise ratio. This midway repeater will relieve the burden imposed on transmitter and cable due to higher power requirement when the repeater is not used.

The next step is of course, to use additional repeaters, say initially at the one quarter and three quarter points and thereafter at points in between the added repeater serves to lower the maximum power level encountered on the communications link and each repeater improves the signal-to-noise ratio over what would result if the corresponding gain were introduced at the receiver.

In the limit we might, conceptually at least, use an infinite number of repeaters. We could even adjust the gain of each repeater to be infinitesimally greater than unity by just the amount to overcome the attenuation in the infinitesimal section between repeaters. In the end we would thereby have constructed a channel which had no attenuation. The signal at the receiving terminal of the channel would then be the unattenuated transmitted signal. We would then, in addition, have at the receiving end all the noise introduced at all points of the channel. This noise is also received without attenuation, no matter howe far away from the receiving end the noise was introduced.

This situation is actually somewhat more dismal than has just been intimated since each repeater (transistor amplifier) introduces some noise on its own accord. Hence, as more repeaters are cascaded, each repeater must be designed to more exacting standards with respect to noise figure (see Sec 14.10). This limitation of the system we have been describing for communicating over long channels is that once noise has been introduced any place along the channel, we are “stuck” with it.

8.4 The Operation Of A Hybrid

A hybrid, for telephone work (at voice frequency), is a transformer. For a simplified description, a hybrid may be viewed as a power splitter with four sets of wire pair connections.

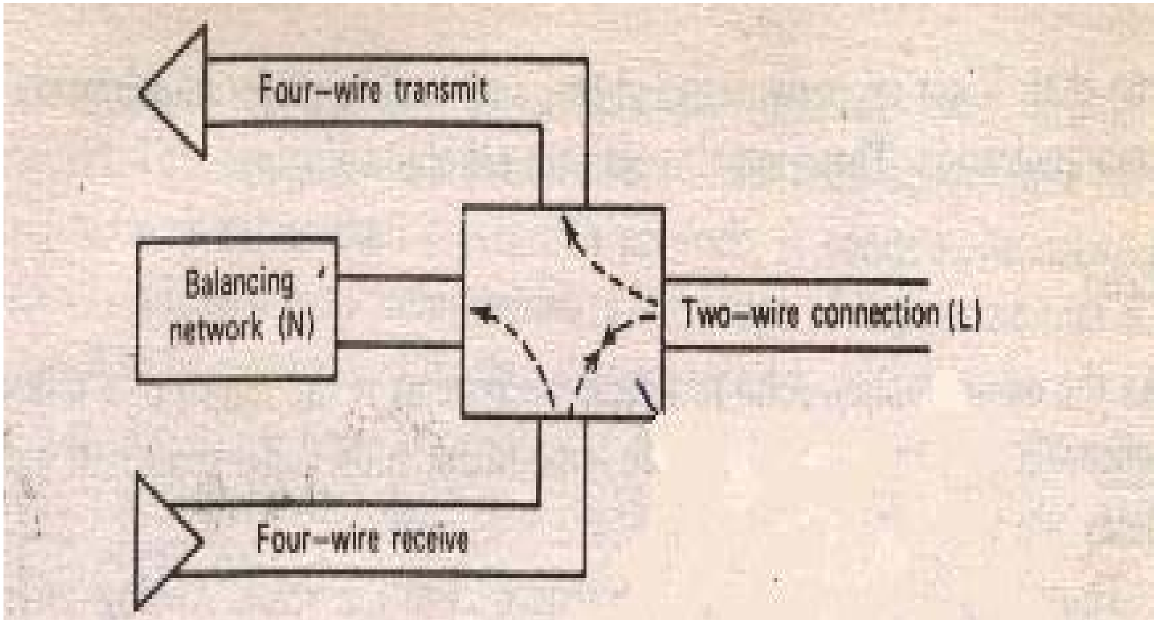


Figure 8.1 Operation of a hybrid transformer

A functional block diagram of a hybrid device is shown in Figure 8.1. Two of these wire pair connections belong to the four-wire path, which consists of a transmit pair and a receive pair. The third pair is the connection to the two-wire link to the subscriber subset. The last wire pair connects the hybrid to a resistance-capacitance balancing network, which electrically balances the hybrid with the two-wire connection to the subscriber's subset over the frequency range of the balancing network. An artificial line may also be used for this purpose.

The hybrid function permits signals to pass from any pair through the transformer to both adjacent pairs but blocks signals to the opposite pair. Signal energy entering from the four-wire side divides equally, half dissipating into the balancing network and half going to the desired two-wire connection. Ideally no signal energy in this path crosses over the four-wire transmit side.

Signal energy entering from the two-wire subset connection divides equally, half of it dissipating in the impedance of the four wire side receive path, and half going to the four-wire side transmit path. Here the ideal situation is that no energy is to be dissipated by the balancing network (i.e., there is a perfect balance). The balancing network is supposed to display the characteristic impedance of the two-wire line (subscriber connection) to the hybrid.

8.6 Repeaters for Signal Transmission

Analog repeaters are basically amplifiers that are generally used in telephone wireline channels and microwave LOS radio channels to boost the signal level and, thus, to offset the effect of signal attenuation in transmission through the channel.

8.7 Vf Repeaters

VF repeaters in telephone terminology imply the use of unidirectional amplifiers at voice frequency on VF trunks. On a two-wire trunk two amplifiers must be used on each pair with a hybrid in and a hybrid out.

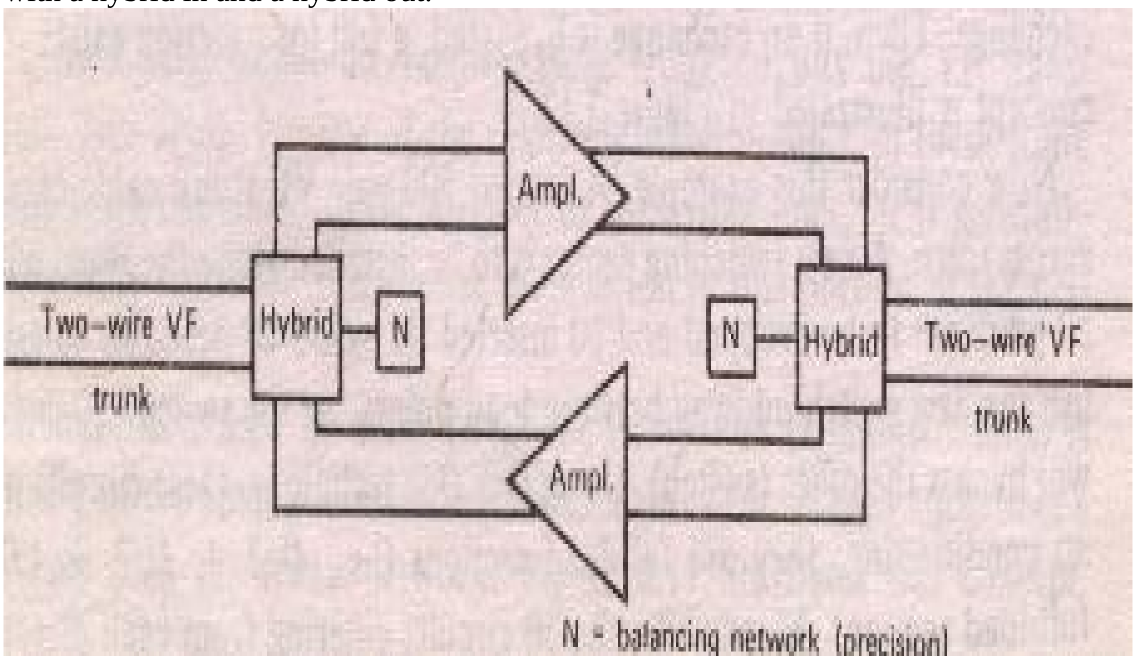


Figure 8.2 VF repeater

The gain of a VF repeater can be run up as high as 20 or 25 dB, and originally they were used on 50-mi, 19 gauge loaded cable in the long distance (toll) plant. Today they are seldom found on long-distance circuits, but do have application on local trunk circuits, where the gain requirements are considerably less. Trunks using VF repeaters have the repeater’s gain adjusted to the equivalent loss of the circuit minus the 4-dB loss to provide the necessary singing margin. In practice a repeater is installed at each end of the trunk circuit to simplify maintenance and power feeding. Gains may be as high as 6-8 dB. An important consideration with VF repeaters is the balance at the hybrids. Hence precision balancing networks may be used instead of the compromise networks employed at the two-wire, four-wire interface. It is common to achieve a 21-dB return loss, 27 dB is also possible, and theoretically, 35 dB can be reached.

8.7 Loading

In many situations it is desirable to extend subscriber loop lengths beyond the limits. Common methods to attain longer loops without exceeding loss limits are the following:

- **Increase conductor diameter.**
- **Use amplifiers and/or loop extenders.***
- **Use inductive loading.**

Loading a particular voice pair loop consists of inserting series inductances (loading coils) into the loop at fixed intervals. Adding load coils tends to

- **Decrease the velocity of propagation.**
- **Increase impedance**

A loop extender is a device that increases battery voltage on a loop extending signaling range. It may also contain an amplifier, thereby extending transmission loss limits.

REFERENCES

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2. www.atmel.com/literature
3. www.hpinfotech.ro
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5 .“A Comparison of differential Termination Techniques”, Joe Vo, National Semiconductor, Application Note AN903
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8. “Application Guidance for TIA/EIA-485-A, TIA?EIA Telecommunication Systems bulletin” Telecommunication Industry Association 1998.
9.”Analog Transmission Line Circuits Data book”, Texas Instrument, Literature No . SLLD 001, 1998.
10.” Electrical Characteristics of Receivers for use in balanced Analog multipoint systems ”,TIA/EIA/485-A,TSB-89
11. “Application Guidelines for TIA/EIA485-A,TSB91”.
12.”Comparian EIA 4845 and EIAS 422 –A Line drivers and receivers in multipoint application”, John Goldie, National Semiconductor, Application Note AN759
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14. “Analogue and Digital Communication.” By “B P Lathi”.
15.”Telecommunication Hand book” By “Freeman.”

APPENDIX

2N3903, 2N3904

2N3903 is a Preferred Device

General Purpose Transistors

NPN Silicon

NPN switching transistor — 2N3904

FEATURES

- Low current (max. 200 mA)
- Low voltage (max. 40 V).

APPLICATIONS

- High-speed switching.

DESCRIPTION

NPN switching transistor in a TO-92; SOT54 plastic package. PNP complement: 2N3906.

PINNING

PIN	DESCRIPTION
1	collector
2	base
3	emitter

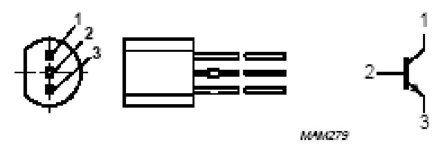
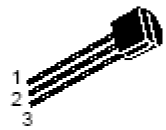


Fig.1 Simplified outline (TO-92; SOT54) and symbol.

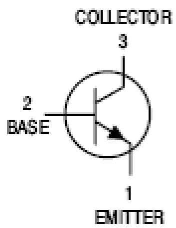
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector−Emitter Voltage	V_{CEO}	40	Vdc
Collector−Base Voltage	V_{CBO}	60	Vdc
Emitter−Base Voltage	V_{EBO}	6.0	Vdc
Collector Current − Continuous	I_C	200	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	625 5.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.5 12	W mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	−55 to +150	°C

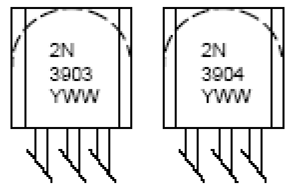
Maximum ratings are those values beyond which device damage can occur. Maximum ratings applied to the device are individual stress limit values (not normal operating conditions) and are not valid simultaneously. If these limits are exceeded, device functional operation is not implied, damage may occur and reliability may be affected.



TO−92
CASE 29
STYLE 1



MARKING DIAGRAMS



THERMAL CHARACTERISTICS (Note 1)

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction−to−Ambient	$R_{\theta JA}$	200	°C/W
Thermal Resistance, Junction−to−Case	$R_{\theta JC}$	83.3	°C/W

1. Indicates Data in addition to JEDEC Requirements.

2N3903, 2N3904

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector−Emitter Breakdown Voltage (Note 2) (I_C = 1.0 mAdc, I_B = 0)	$V_{(BR)CEO}$	40	−	Vdc
Collector−Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	$V_{(BR)CBO}$	60	−	Vdc
Emitter−Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	$V_{(BR)EBO}$	6.0	−	Vdc
Base Cutoff Current (V_{CE} = 30 Vdc, V_{EB} = 3.0 Vdc)	I_{BL}	−	50	nAdc
Collector Cutoff Current (V_{CE} = 30 Vdc, V_{EB} = 3.0 Vdc)	I_{CEX}	−	50	nAdc

ON CHARACTERISTICS

DC Current Gain (Note 2)		h_{FE}			–
(I_C = 0.1 mAdc, V_{CE} = 1.0 Vdc)	2N3903		20	–	
	2N3904		40	–	
(I_C = 1.0 mAdc, V_{CE} = 1.0 Vdc)	2N3903		35	–	
	2N3904		70	–	
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	2N3903		50	150	
	2N3904		100	300	
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc)	2N3903		30	–	
	2N3904		60	–	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	2N3903		15	–	
	2N3904		30	–	
Collector−Emitter Saturation Voltage (Note 2)		$V_{CE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)			–	0.2	
(I_C = 50 mAdc, I_B = 5.0 mAdc			–	0.3	
Base−Emitter Saturation Voltage (Note 2)		$V_{BE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)			0.65	0.85	
(I_C = 50 mAdc, I_B = 5.0 mAdc)			–	0.95	

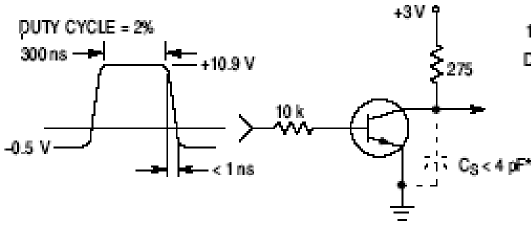
SMALL−SIGNAL CHARACTERISTICS

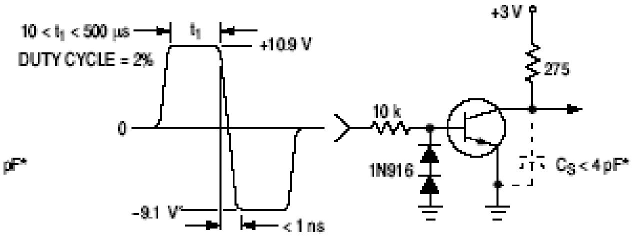
Current−Gain − Bandwidth Product		f_T			MHz
(I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N3903		250	–	
	2N3904		300	–	
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)		C_{obo}	–	4.0	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)		C_{ibo}	–	8.0	pF
Input Impedance		h_{ie}			k Ω
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3903		1.0	8.0	
	2N3904		1.0	10	
Voltage Feedback Ratio		h_{re}			X 10^{-4}
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3903		0.1	5.0	
	2N3904		0.5	8.0	
Small−Signal Current Gain		h_{fe}			–
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3903		50	200	
	2N3904		100	400	
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{oe}	1.0	40	μmhos
Noise Figure		NF			dB
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc, R_S = 1.0 k Ω, f = 1.0 kHz)	2N3903		–	6.0	
	2N3904		–	5.0	

SWITCHING CHARACTERISTICS

Delay Time	(V_{CC} = 3.0 Vdc, V_{BE} = 0.5 Vdc, I_C = 10 mAdc, I_{B1} = 1.0 mAdc)		t_d	–	35	ns
Rise Time			t_r	–	35	ns
Storage Time	(V_{CC} = 3.0 Vdc, I_C = 10 mAdc, I_{B1} = I_{B2} = 1.0 mAdc)	2N3903	t_s	–	175	ns
		2N3904		–	200	
Fall Time			t_f	–	50	ns

2. Pulse Test: Pulse Width ≤ 300 μs; Duty Cycle ≤ 2%.





* Total shunt capacitance of test jig and connectors

Figure 1. Delay and Rise Time Equivalent Test Circuit

Figure 2. Storage and Fall Time Equivalent Test Circuit

TYPICAL TRANSIENT CHARACTERISTICS

——— T_J = 25°C
— — T_J = 125°C

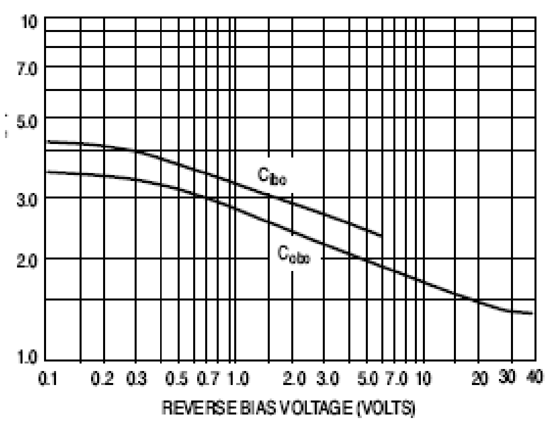


Figure 3. Capacitance

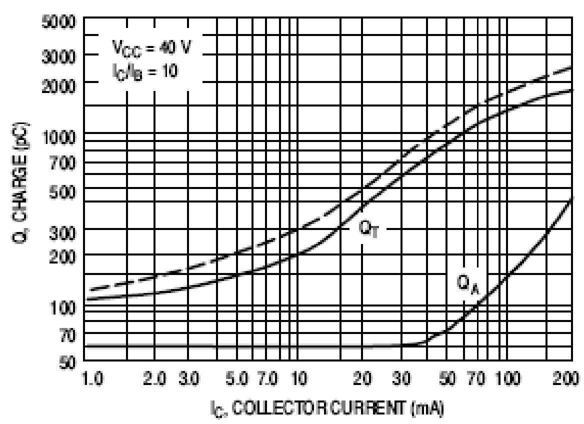


Figure 4. Charge Data

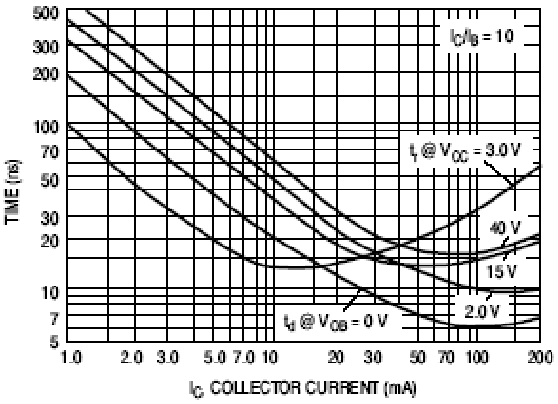


Figure 5. Turn−On Time

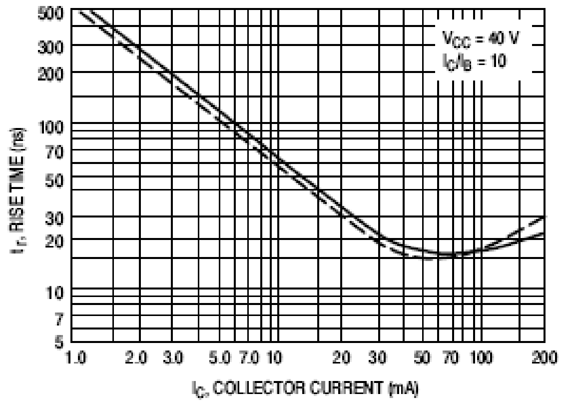
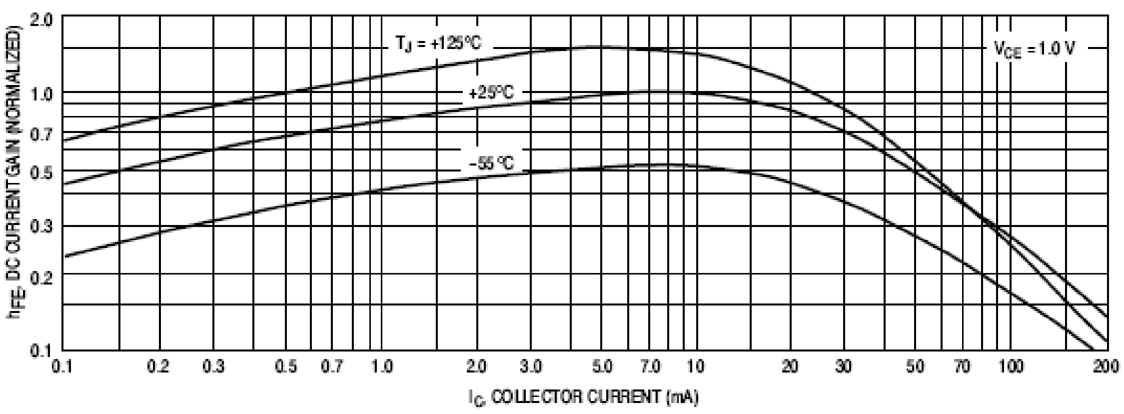


Figure 6. Rise Time

2N3903, 2N3904

TYPICAL STATIC CHARACTERISTICS



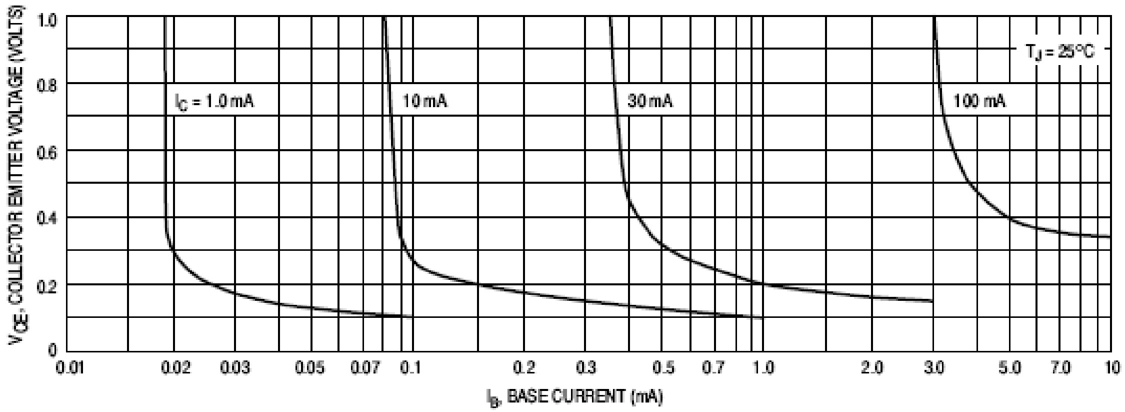
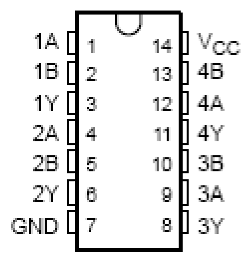


Figure 16. Collector Saturation Region

CD54ACT08, CD74ACT08
QUADRUPLE 2-INPUT POSITIVE-AND GATES

- Inputs Are TTL-Voltage Compatible
- Speed of Bipolar F, AS, and S, With Significantly Reduced Power Consumption
- Balanced Propagation Delays
- Buffered Inputs
- ±24-mA Output Drive Current
  – Fanout to 15 F Devices
- SCR-Latchup-Resistant CMOS Process and Circuit Design
- Exceeds 2-kV ESD Protection Per MIL-STD-883, Method 3015

CD54ACT08 . . . F PACKAGE
CD74ACT08 . . . E OR M PACKAGE
(TOP VIEW)



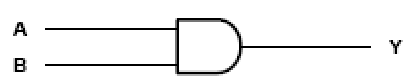
description

The ’ACT08 devices are quadruple 2-input positive-AND gates. These devices perform the Boolean function $Y = A \bullet B$ or $Y = \overline{\overline{A} + \overline{B}}$ in positive logic.

FUNCTION TABLE
(each gate)

INPUTS		OUTPUT
A	B	Y
H	H	H
L	X	L
X	L	L

logic diagram, each gate (positive logic)



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

TEXAS INSTRUMENTS

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

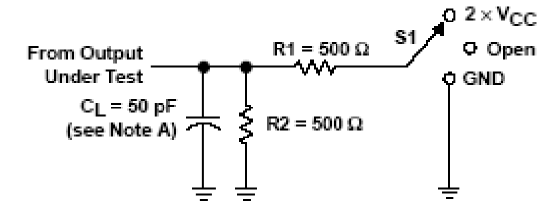
Supply voltage range, V_{CC} .... –0.5 V to 6 V
Input clamp current, I_{IK} ($V_I < 0$ or $V_I > V_{CC}$) (see Note 1) .... ±20 mA
Output clamp current, I_{OK} ($V_O < 0$ or $V_O > V_{CC}$) (see Note 1) .... ±50 mA
Continuous output current, I_O ($V_O = 0$ to V_{CC}) .... ±50 mA
Continuous current through V_{CC} or GND .... ±100 mA
Package thermal impedance, θ_{JA} (see Note 2): E package .... 80°C/W
M package .... 86°C/W
Storage temperature range, T_{stg} .... –65°C to 150°C

recommended operating conditions (see Note 3)

		T_A = 25°C		–40°C TO 85°C		–55°C TO 125°C		UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	
V_{CC}	Supply voltage	4.5	5.5	4.5	5.5	4.5	5.5	V
V_{IH}	High-level input voltage	2		2		2		V
V_{IL}	Low-level input voltage		0.8		0.8		0.8	V
V_I	Input voltage	0	V_{CC}	0	V_{CC}	0	V_{CC}	V
V_O	Output voltage	0	V_{CC}	0	V_{CC}	0	V_{CC}	V
I_{OH}	High-level output current		–24		–24		–24	mA
I_{OL}	Low-level output current		24		24		24	mA
$\Delta t/\Delta v$	Input transition rise or fall rate		10		10		10	ns/V

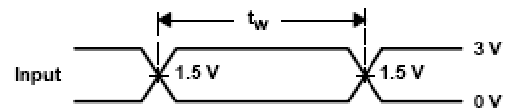
NOTE 3: All unused inputs of the device must be held at V_{CC} or GND to ensure proper device operation. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, literature number SCBA004.

PARAMETER MEASUREMENT INFORMATION

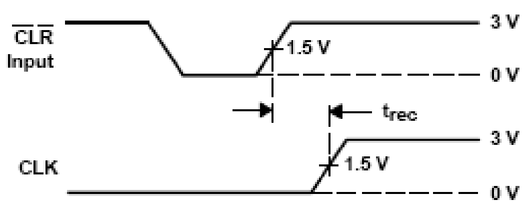


LOAD CIRCUIT

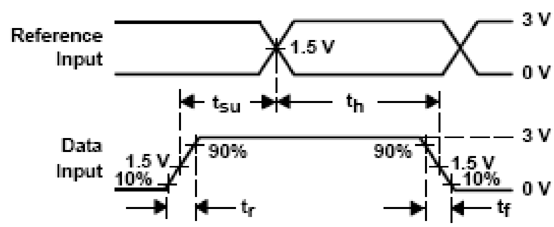
TEST	S1
t_{PLH}/t_{PHL}	Open
t_{PLZ}/t_{PZL}	2 × V_{CC}
t_{PHZ}/t_{PZH}	GND



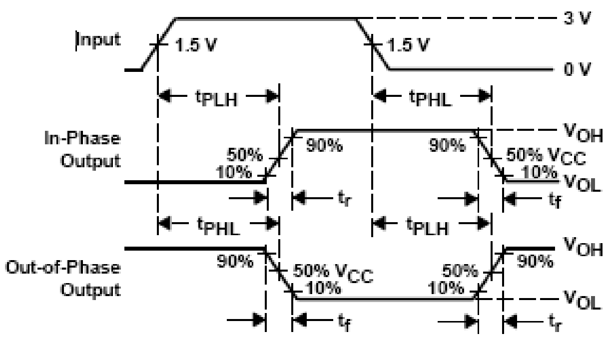
VOLTAGE WAVEFORMS
PULSE DURATION



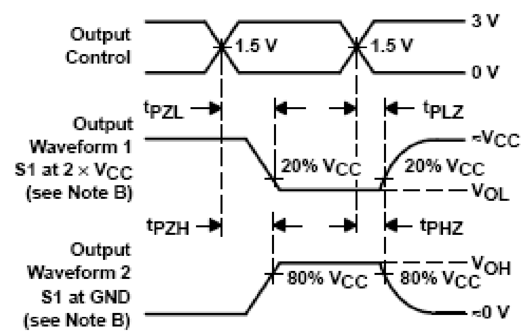
VOLTAGE WAVEFORMS
RECOVERY TIME



VOLTAGE WAVEFORMS
SETUP AND HOLD AND INPUT RISE AND FALL TIMES



VOLTAGE WAVEFORMS
PROPAGATION DELAY AND OUTPUT TRANSITION TIMES

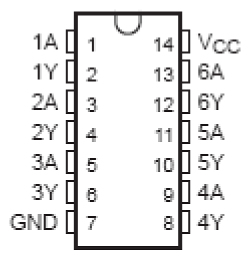


VOLTAGE WAVEFORMS
OUTPUT ENABLE AND DISABLE TIMES

CD74ACT14
HEX SCHMITT-TRIGGER INVERTER

- Inputs Are TTL-Voltage Compatible
- Speed of Bipolar F, AS, and S, With Significantly Reduced Power Consumption
- Greater Noise Immunity Than Standard Inverters
- Operates With Much Slower Than Standard Input Rise and Fall Slew Rates
- ±24-mA Output Drive Current
  - Fanout to 15 F Devices
- SCR Latchup-Resistant CMOS Process and Circuit Design
- Exceeds 2-kV ESD Protection Per MIL-STD-883, Method 3015

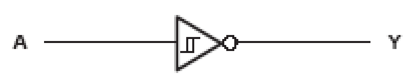
E OR M PACKAGE
(TOP VIEW)



FUNCTION TABLE
(each inverter)

INPUT A	OUTPUT Y
H	L
L	H

logic diagram, each inverter (positive logic)



CD74ACT14
HEX SCHMITT-TRIGGER INVERTER

SCHS319A – NOVEMBER 2002 – REVISED NOVEMBER 2004

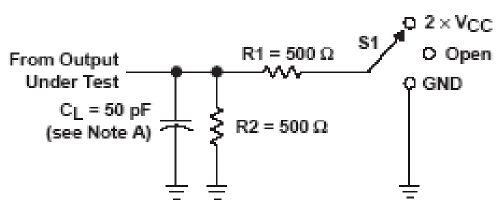
absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage range, V_{CC} . . . . −0.5 V to 6 V
Input clamp current, I_{IK} (V_I < 0 or V_I > V_{CC}) (see Note 1) . . . . ±20 mA
Output clamp current, I_{OK} (V_O < 0 or V_O > V_{CC}) (see Note 1) . . . . ±50 mA
Continuous output current, I_O (V_O = 0 to V_{CC}) . . . . ±50 mA
Continuous current through V_{CC} or GND . . . . ±100 mA
Package thermal impedance, θ_{JA} (see Note 2): E package . . . . 80°C/W
M package . . . . 86°C/W
Storage temperature range, T_{stg} . . . . −65°C to 150°C

CD74ACT14
HEX SCHMITT-TRIGGER INVERTER

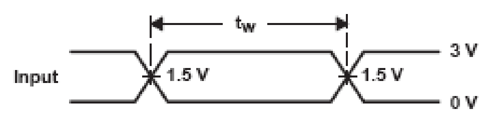
SCHS319A – NOVEMBER 2002 – REVISED NOVEMBER 2004

PARAMETER MEASUREMENT INFORMATION

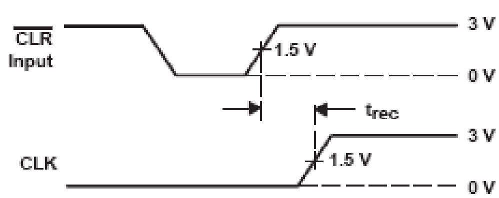


LOAD CIRCUIT

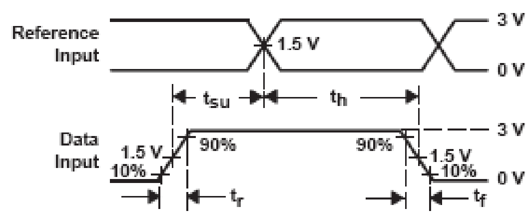
TEST	S1
t_{PLH}/t_{PHL}	Open
t_{PLZ}/t_{PZL}	2 × V_{CC}
t_{PHZ}/t_{PZH}	GND



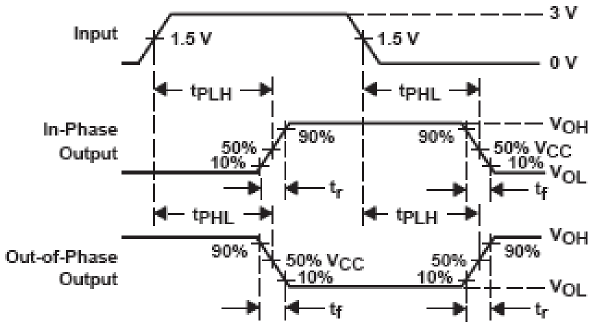
VOLTAGE WAVEFORMS
PULSE DURATION



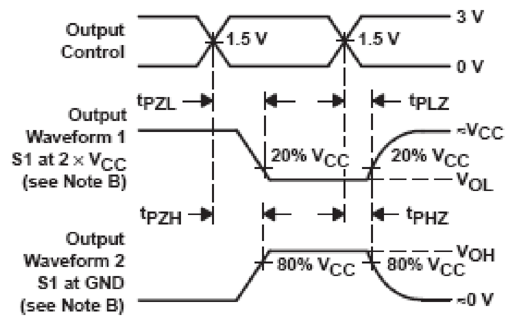
VOLTAGE WAVEFORMS



VOLTAGE WAVEFORMS



VOLTAGE WAVEFORMS
PROPAGATION DELAY AND OUTPUT TRANSITION TIMES

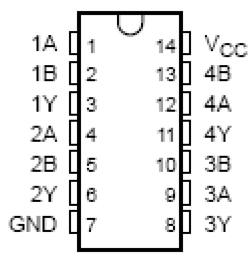


VOLTAGE WAVEFORMS
OUTPUT ENABLE AND DISABLE TIMES

CD54ACT86, CD74ACT86
QUADRUPLE 2-INPUT EXCLUSIVE-OR GATES

- Inputs Are TTL-Voltage Compatible
- Speed of Bipolar F, AS, and S, With Significantly Reduced Power Consumption
- Balanced Propagation Delays
- ±24-mA Output Drive Current
  – Fanout to 15 F Devices
- SCR-Latchup-Resistant CMOS Process and Circuit Design
- Exceeds 2-kV ESD Protection Per MIL-STD-883, Method 3015

CD54ACT86 . . . F PACKAGE
CD74ACT86 . . . E OR M PACKAGE
(TOP VIEW)



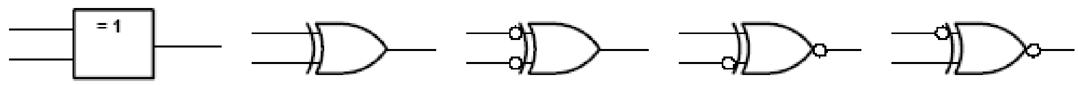
FUNCTION TABLE
(each gate)

INPUTS		OUTPUT
A	B	Y
L	L	L
L	H	H
H	L	H
H	H	L

exclusive-OR logic

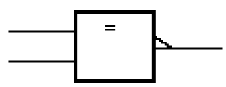
An exclusive-OR gate has many applications, some of which can be represented better by alternative logic symbols.

EXCLUSIVE OR



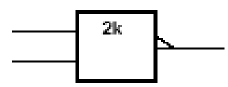
These are five equivalent exclusive-OR symbols valid for an CD74AC86 gate in positive logic; negation may be shown at any two ports.

LOGIC-IDENTITY ELEMENT



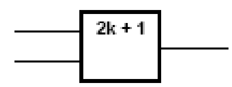
The output is active (low) if all inputs stand at the same logic level (i.e., A = B).

EVEN-PARITY ELEMENT



The output is active (low) if an even number of inputs (i.e., 0 or 2) are active.

ODD-PARITY ELEMENT



The output is active (high) if an odd number of inputs (i.e., only 1 of the 2) are active.

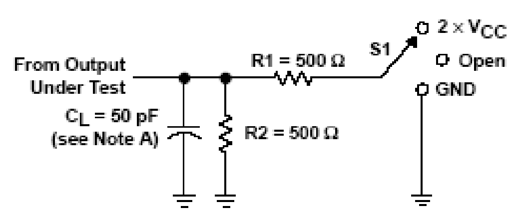
CD54ACT86, CD74ACT86
QUADRUPLE 2-INPUT EXCLUSIVE-OR GATES

SCHS322 – JANUARY 2003

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

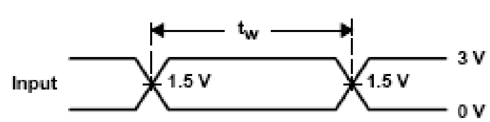
PARAMETER	TEST CONDITIONS		V_{CC}	T_A = 25°C		–55°C to 125°C		–40°C to 85°C		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
V_{OH}	$V_I = V_{IH}$ or V_{IL}	I_{OH} = –50 µA	4.5 V	4.4		4.4		4.4		V
		I_{OH} = –24 mA	4.5 V	3.94		3.7		3.8		
		I_{OH} = –50 mA†	5.5 V			3.85				
		I_{OH} = –75 mA†	5.5 V					3.85		
V_{OL}	$V_I = V_{IH}$ or V_{IL}	I_{OL} = 50 µA	4.5 V		0.1		0.1		0.1	V
		I_{OL} = 24 mA	4.5 V		0.36		0.5		0.44	
		I_{OL} = 50 mA†	5.5 V				1.65			
		I_{OL} = 75 mA†	5.5 V						1.65	
I_I	$V_I = V_{CC}$ or GND		5.5 V		±0.1		±1		±1	µA
I_{CC}	$V_I = V_{CC}$ or GND,	$I_O = 0$	5.5 V		4		80		40	µA
ΔI_{CC}‡	$V_I = V_{CC} - 2.1$ V		4.5 V to 5.5 V		2.4		3		2.8	mA
C_i					10		10		10	pF

PARAMETER MEASUREMENT INFORMATION

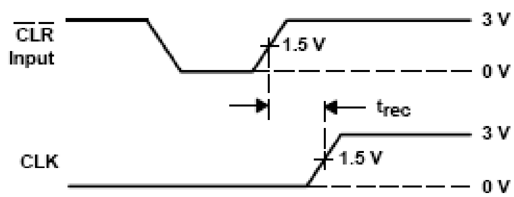


LOAD CIRCUIT

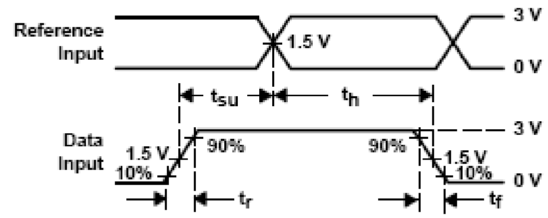
TEST	S1
t_{PLH}/t_{PHL}	Open
t_{PLZ}/t_{PZL}	2 × V_{CC}
t_{PHZ}/t_{PZH}	GND



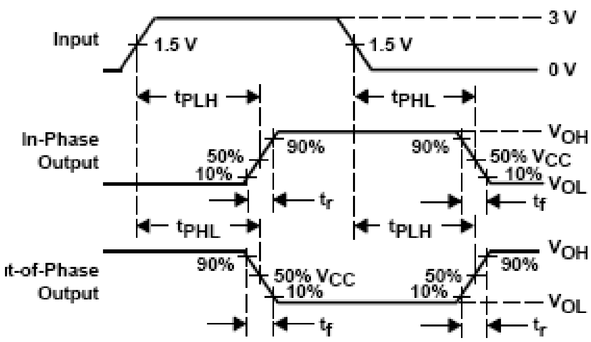
VOLTAGE WAVEFORMS
PULSE DURATION



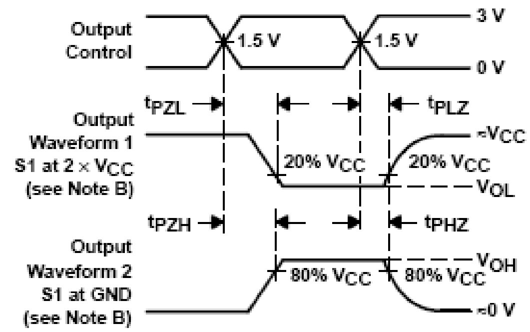
VOLTAGE WAVEFORMS
RECOVERY TIME



VOLTAGE WAVEFORMS
SETUP AND HOLD AND INPUT RISE AND FALL TIMES



VOLTAGE WAVEFORMS
PROPAGATION DELAY AND OUTPUT TRANSITION TIMES



VOLTAGE WAVEFORMS
OUTPUT ENABLE AND DISABLE TIMES

DC COMPONENTS CO., LTD. RECTIFIER SPECIALISTS		1N 4001A / RL 101 THRU 1N 4007A / RL 107

TECHNICAL SPECIFICATIONS OF SILICON RECTIFIER

VOLTAGE RANGE - 50 to 1000 Volts CURRENT - 1.0 Ampere

FEATURES

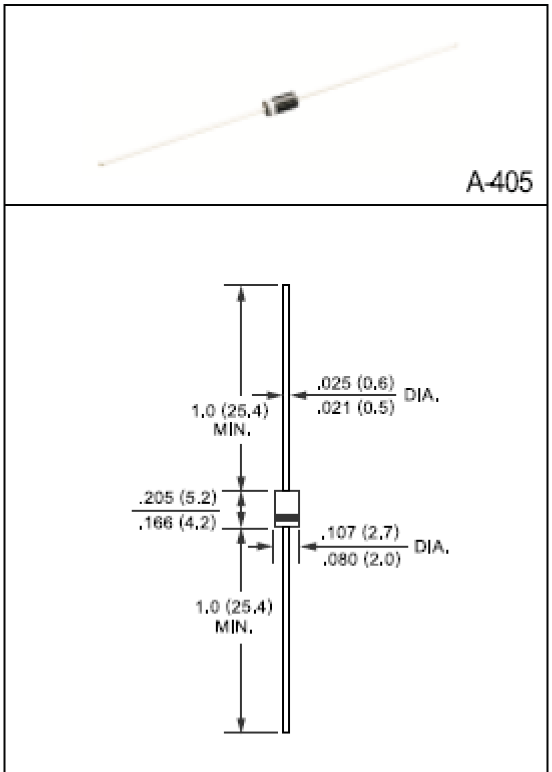
* High reliability
* Low leakage
* Low forward voltage drop
* High current capability

MECHANICAL DATA

* Case: Molded plastic
* Epoxy: UL 94V-0 rate flame retardant
* Lead: MIL-STD-202E, Method 208 guaranteed
* Polarity: Color band denotes cathode end
* Mounting position: Any
* Weight: 0.22 gram

MAXIMUM RATINGS AND ELECTRICAL CHARACTERISTICS

Ratings at 25°C ambient temperature unless otherwise specified.
Single phase, half wave, 60 Hz, resistive or inductive load.
For capacitive load, derate current by 20%.



Dimensions in inches and (millimeters)

		SYMBOL	1N4001A RL101	1N4002A RL102	1N4003A RL103	1N4004A RL104	1N4005A RL105	1N4006A RL106	1N4007A RL107	UNITS
Maximum Recurrent Peak Reverse Voltage		V_{RRM}	50	100	200	400	600	800	1000	Volts
Maximum RMS Voltage		V_{RMS}	35	70	140	280	420	560	700	Volts
Maximum DC Blocking Voltage		V_{DC}	50	100	200	400	600	800	1000	Volts
Maximum Average Forward Rectified Current at T_A = 55°C		I_O	1.0							Amps
Peak Forward Surge Current, 8.3 ms single half sine-wave superimposed on rated load (JEDEC Method)		I_{FSM}	30							Amps
Maximum Instantaneous Forward Voltage at 1.0A DC		V_F	1.1							Volts
Maximum DC Reverse Current at Rated DC Blocking Voltage	@T_A = 25°C	I_R	5.0							uAmps
	@T_A = 100°C		500							
Maximum Full Load Reverse Current Average, Full Cycle .375"(9.5mm) lead length at T_L = 75°C			30							uAmps
Typical Junction Capacitance (Note)		C_J	15							pF
Typical Thermal Resistance		$R_{\theta JA}$	50							°C/W
Operating and Storage Temperature Range		T_J, T_{STG}	-65 to + 175							°C

NOTES : Measured at 1 MHz and applied reverse voltage of 4.0 volts

RATING AND CHARACTERISTIC CURVES

(1N4001A RL101 THRU 1N4007A RL107)

FIG. 1 - TYPICAL FORWARD CURRENT DERATING CURVE

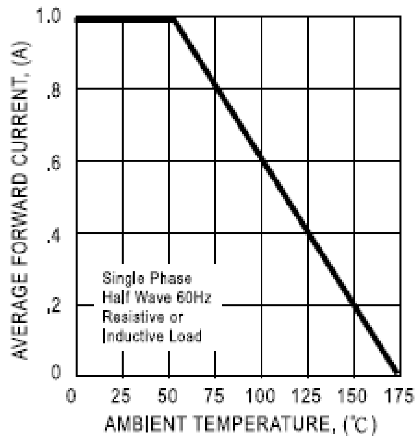


FIG. 2 - TYPICAL INSTANTANEOUS FORWARD CHARACTERISTICS

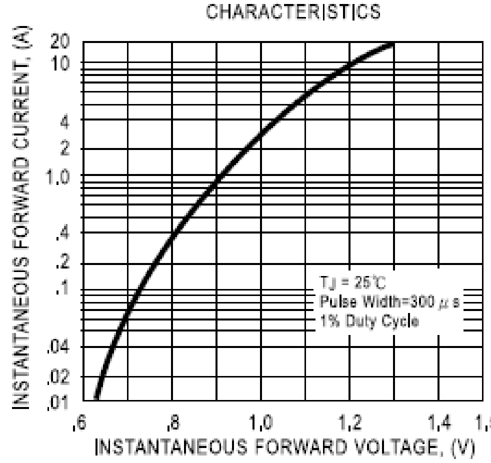


FIG. 3 - MAXIMUM NON-REPETITIVE FORWARD SURGE CURRENT

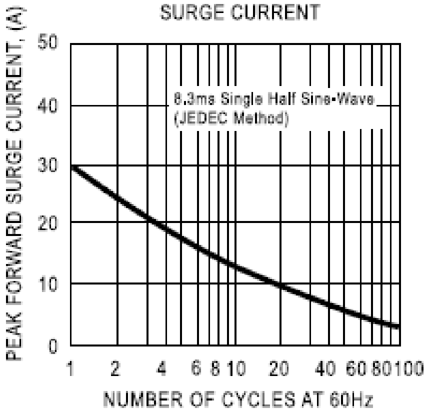


FIG. 4 - TYPICAL REVERSE CHARACTERISTICS

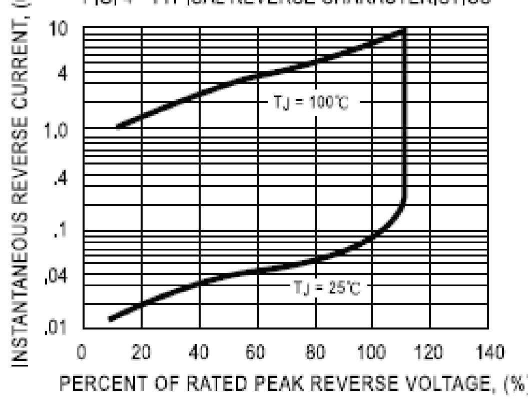
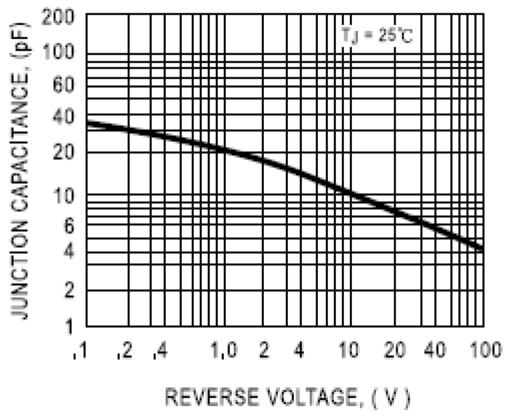


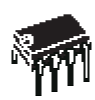
FIG. 5 - TYPICAL JUNCTION CAPACITANCE



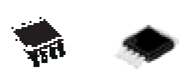
DC COMPONENTS CO., LTD.

LM158, LM258, LM358
LM158A, LM258A, LM358A

- **Internally frequency compensated**
- **Large DC voltage gain: 100dB**
- **Wide bandwidth (unity gain): 1.1mHz**
  (temperature compensated)
- **Very low supply current/op (500µA) essentially independent of supply voltage**
- **Low input bias current: 20nA**
  (temperature compensated)
- **Low input offset voltage: 2mV**
- **Low input offset current: 2nA**
- **Input common-mode voltage range includes ground**
- **Differential input voltage range equal to the power supply voltage**
- **Large output voltage swing 0V to (Vcc - 1.5V)**



N
DIP-8
(Plastic Package)



D & S
SO-8 & mini SO-8
(Plastic Micropackage)

P
TSSOP8
(Thin Shrink Small Outline Package)

Pin Connections (top view)

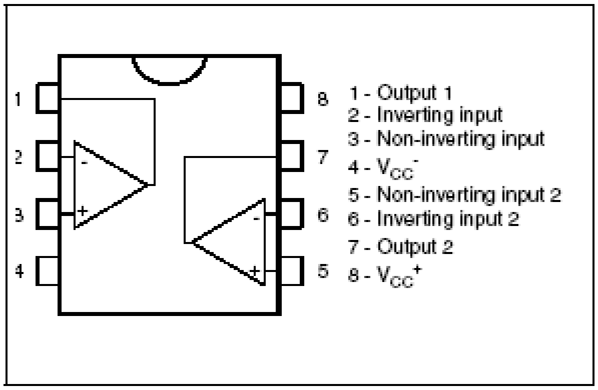
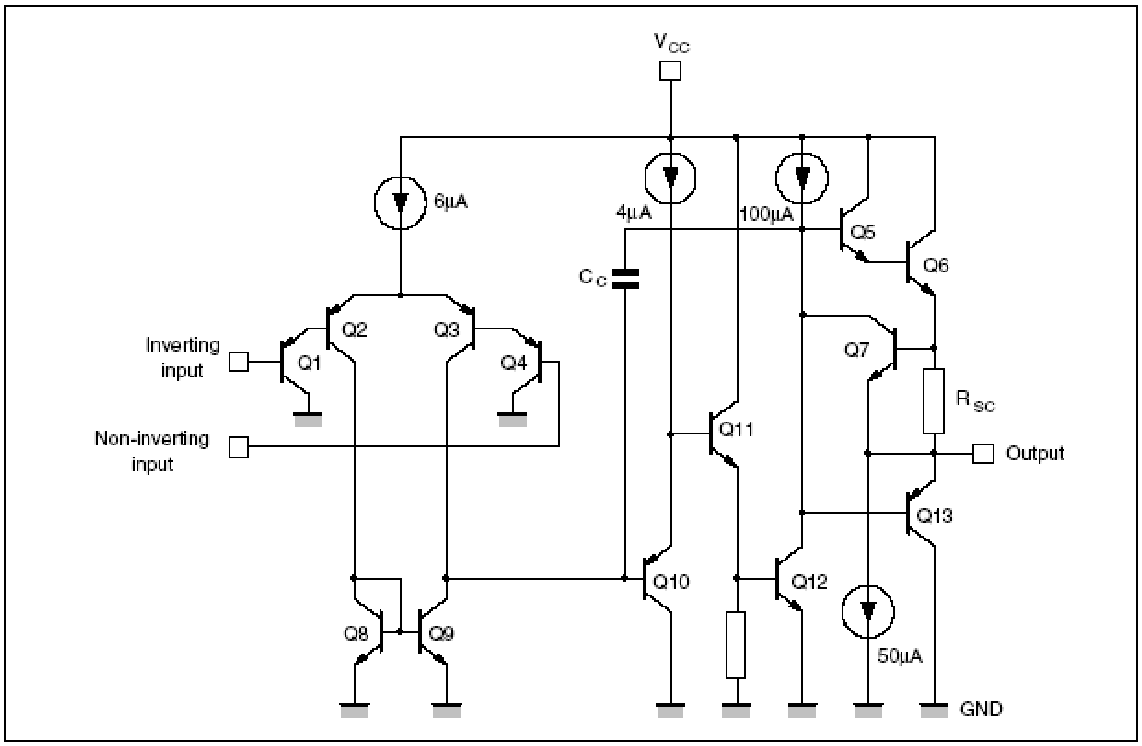


Figure 1. Schematic diagram (1/2 LM158)



1 Absolute Maximum Ratings

Table 1. Key parameters and their absolute maximum ratings

Symbol	Parameter	LM158,A	LM258,A	LM358,A	Unit
VCC	Supply voltage	+/-16 or 32			V
Vi	Input Voltage	-0.3 to +32			V
V_{id}	Differential Input Voltage	+32			V
P_{tot}	Power Dissipation [1]	500			mW
	Output Short-circuit Duration [2]	Infinite			
I_{in}	Input Current [3]	50			mA
T_{oper}	Operating Free-air Temperature Range	-55 to +125	-40 to +105	0 to +70	°C
T_{stg}	Storage Temperature Range	-65 to +150			°C
T_j	Maximum Junction Temperature	150			°C
R_{thja}	Thermal Resistance Junction to Ambient[4] SO8 TSSOP8 DIP8 miniSO8	 125 120 85 190			°C/W

LM158, LM258, LM358, LM158A, LM258A, LM358A **Electrical Characteristics**

Figure 2. Open loop frequency response

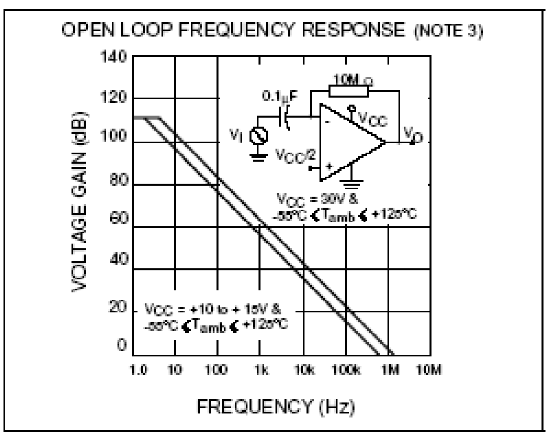


Figure 5. Voltage follower pulse response

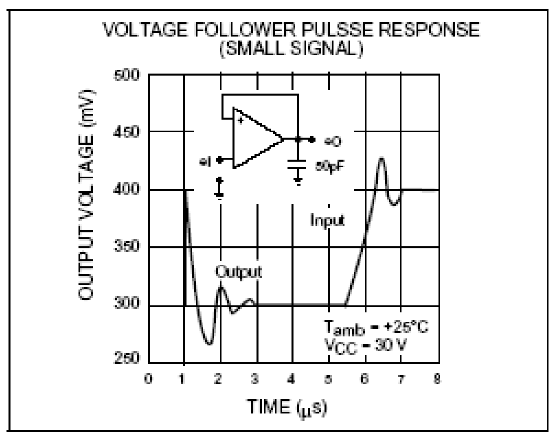


Figure 8. Output characteristics

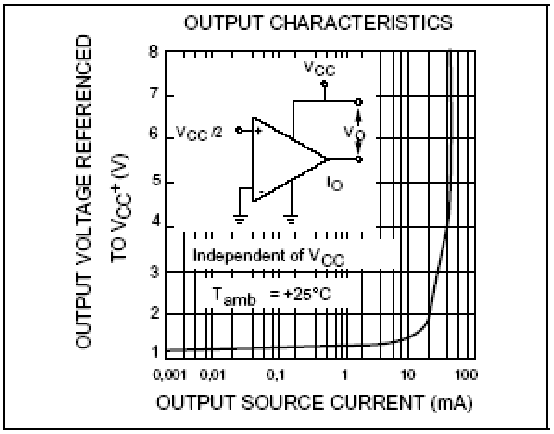


Figure 11. Positive supply voltage

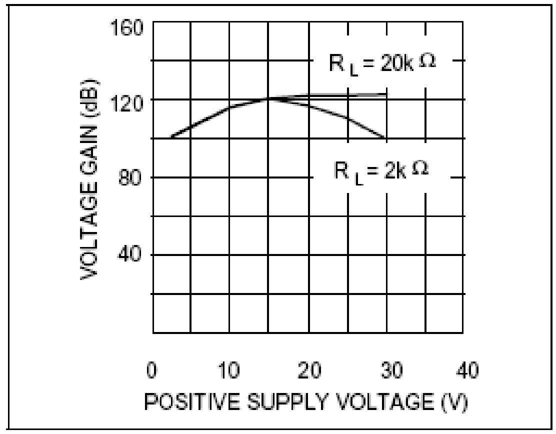


Figure 10. Input voltage range

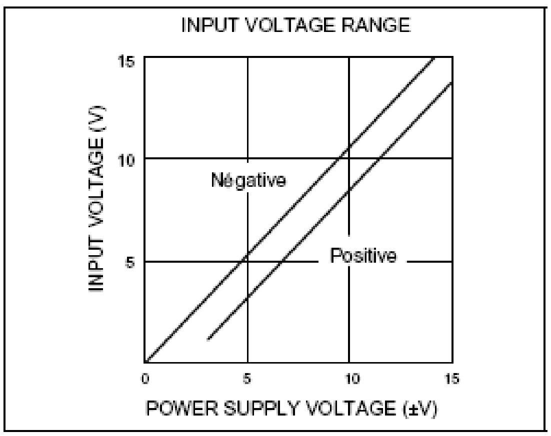
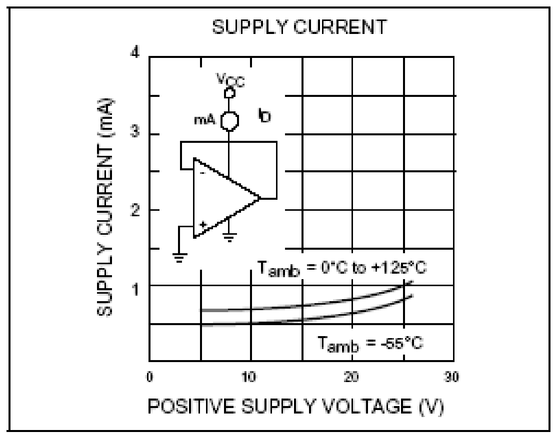
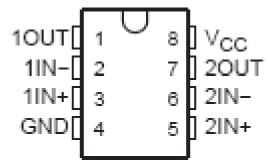


Figure 13. Supply current



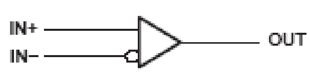
LM193, LM293, LM293A
LM393, LM393A, LM2903
DUAL DIFFERENTIAL COMPARATORS

(TOP VIEW)

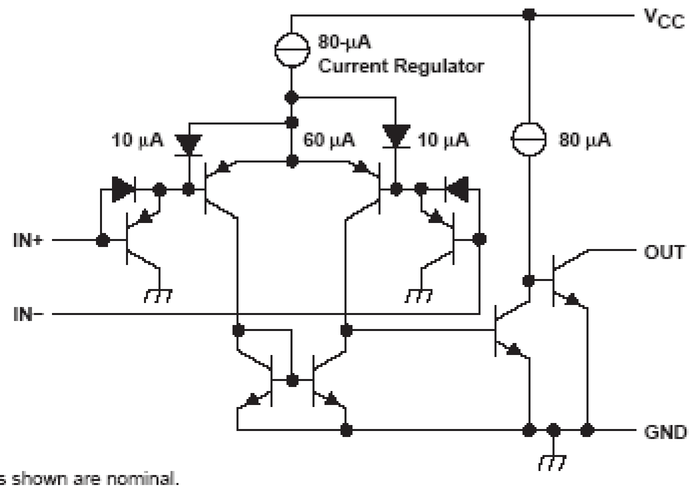


- **Single Supply or Dual Supplies**
- **Wide Range of Supply Voltage:**
  Max Rating . . . 2 V to 36 V
  Tested . . . 2 V to 30 V Non-V Devices
  Tested . . . 2 V to 32 V V-Suffix Devices
- **Low Supply-Current Drain Independent of Supply Voltage . . . 0.4 mA Typ Per Comparator**
- **Low Input Bias Current . . . 25 nA Typ**
- **Low Input Offset Current . . . 3 nA Typ (LM193)**
- **Low Input Offset Voltage . . . 2 mV Typ**
- **Common-Mode Input Voltage Range Includes Ground**
- **Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . ±36 V**
- **Low Output Saturation Voltage**
- **Output Compatible With TTL, MOS, and CMOS**
- **For Single Version in SOT23-5, See TL331 Data Sheet**

symbol (each comparator)



schematic (each comparator)



COMPONENT COUNT	
Epi-FET	1
Diodes	2
Resistors	2
Transistors	30

Current values shown are nominal.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V_{CC} (see Note 1)		36 V
Differential input voltage, V_{ID} (see Note 2)		±36 V
Input voltage range, V_I (either input)		−0.3 V to 36 V
Output voltage, V_O		36 V
Output current, I_O		20 mA
Duration of output short-circuit to ground (see Note 3)		Unlimited
Package thermal impedance, θ_{JA} (see Notes 4 and 5):	D package	97°C/W
	DGK package	172°C/W
	P package	85°C/W
	PS package	95°C/W
	PW package	149°C/W
Package thermal impedance, θ_{JC} (see Notes 6 and 7):	FK package	5.61°C/W
	JG package	14.5°C/W
Operating virtual junction temperature, T_J		150°C
Case temperature for 60 seconds: FK package		260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package		300°C
Storage temperature range, T_{stg}		−65°C to 150°C

electrical characteristics at specified free-air temperature, V_{CC} = 5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	LM293A LM393A			LM2903			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	V_{CC} = 5 V to MAX‡, V_O = 1.4 V, $V_{IC} = V_{IC(min)}$	25°C		1	2		2	7	mV
			Full range			4			15	
I_{IO}	Input offset current	V_O = 1.4 V	25°C		5	50		5	50	nA
			Full range			150			200	
I_{IB}	Input bias current	V_O = 1.4 V	25°C		−25	−250		−25	−250	nA
			Full range			−400			−500	
V_{ICR}	Common-mode input voltage range§		25°C	0 to V_{CC}−1.5			0 to V_{CC}−1.5			V
			Full range	0 to V_{CC}−2			0 to V_{CC}−2			
A_{VD}	Large-signal differential-voltage amplification	V_{CC} = 15 V, V_O = 1.4 V to 11.4 V, R_L ≥ 15 kΩ to V_{CC}	25°C	50	200		25	100		V/mV
I_{OH}	High-level output current	V_{OH} = 5 V, V_{ID} = 1 V	25°C		0.1	50		0.1	50	nA
		$V_{OH} = V_{CC}$ MAX, V_{ID} = 1 V	Full range			1			1	μA
V_{OL}	Low-level output voltage	I_{OL} = 4 mA, V_{ID} = −1 V	25°C		150	400		150	400	mV
			Full range			700			700	
I_{OL}	Low-level output current	V_{OL} = 1.5 V, V_{ID} = −1 V	25°C	6			6			mA
I_{CC}	Supply current	R_L = ∞, V_{CC} = 5 V	25°C		0.8	1		0.8	1	mA
		R_L = ∞, V_{CC} = MAX	Full range			2.5			2.5	

FAIRCHILD
SEMICONDUCTOR®

www.fairchildsemi.com

LM2903/LM2903I,LM393/LM393A, LM293/LM293A

Dual Differential Comparator

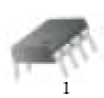
Features

- Single Supply Operation: 2V to 36V
- Dual Supply Operation: ± 1V to ±18V
- Allow Comparison of Voltages Near Ground Potential
- Low Current Drain 800µA Typ.
- Compatible with all Forms of Logic
- Low Input Bias Current 25nA Typ.
- Low Input Offset Current ±5nA Typ.
- Low Offset Voltage ±1mV Typ.

Description

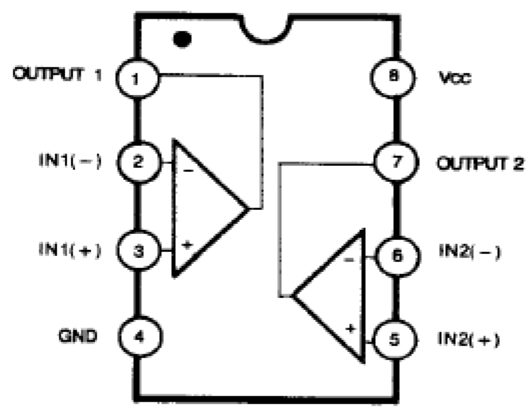
The LM2903/LM2903I, LM393/LM393A, LM293/LM293A consist of two independent voltage comparators designed to operate from a single power supply over a wide voltage range.

8-DIP

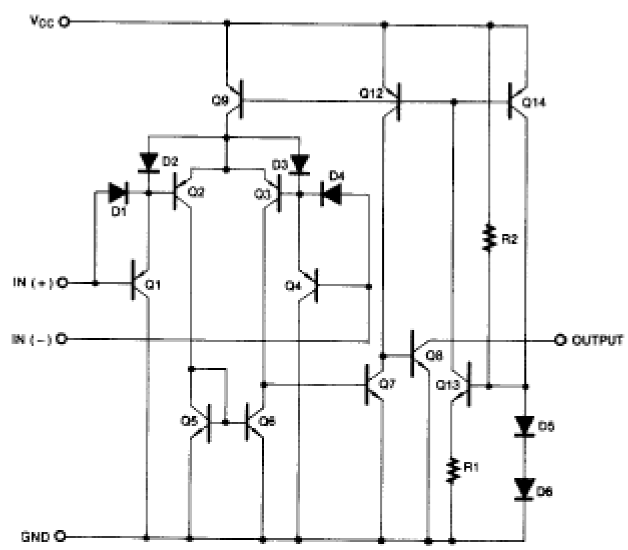


8-SOP

Internal Block Diagram



Schematic Diagram



Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Power Supply Voltage	V_{CC}	±18 or 36	V
Differential Input Voltage	$V_{I(DIFF)}$	36	V
Input Voltage	V_I	- 0.3 to +36	V
Output Short Circuit to GND	-	Continuous	-
Power Dissipation, Ta = 25°C 8-DIP 8-SOP	P_D	 1040 480	mW
Operating Temperature LM393/LM393A LM2903 LM2903I LM293/LM293A	T_{OPR}	 0 ~ +70 - 40 ~ +85 -40 ~ +105 -25 ~ +85	°C
Storage Temperature	T_{STG}	- 65 ~ +150	°C

Typical Performance Characteristics

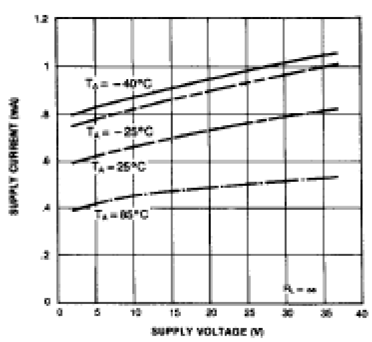


Figure 1. Supply Current vs Supply Voltage

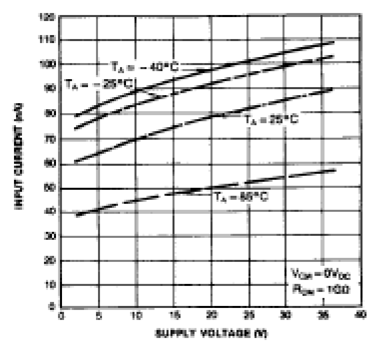


Figure 2. Input Current vs Supply Voltage

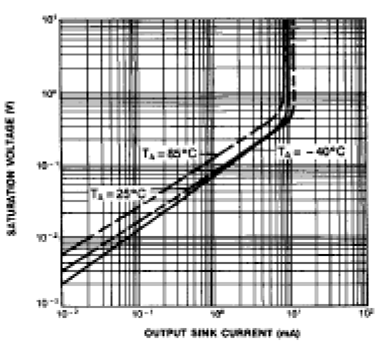


Figure 3. Output Saturation Voltage vs Sink Current

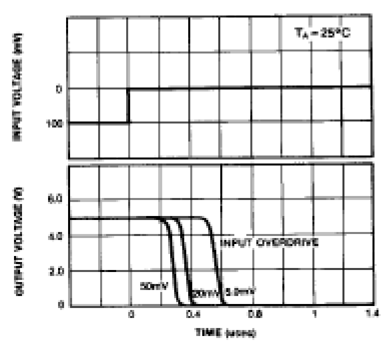


Figure 4. Response Time for Various Input Overdrive-Negative Transition

OMRON

Low Signal Relay — G5V-2

- Suitable for handling low signals in computer peripherals, telecommunications and security equipment
- Capable of switching loads up to 2 A
- Conforms to FCC part 68 1500 V surge withstand
- Reliable bifurcated crossbar contacts
- Fully-sealed construction

Specifications

CONTACT DATA

Load	Resistive load (p.f. = 1)
Rated load	0.50 A at 125 VAC 2 A at 30 VDC
Contact material	Ag (Au clad)
Carry current	2 A
Max. operating voltage	125 VAC 125 VDC
Max. operating current	2 A
Max. switching capacity	62.50 VA 60W
Min. permissible load	10 µA, 10 mVDC

COIL DATA

Standard type

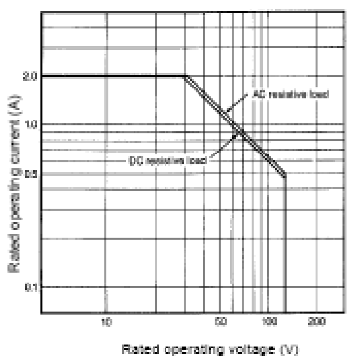
Rated voltage (VDC)	Rated current (mA)	Coil resistance (Ω)	Coil inductance (Ref. value) (H)		Pick-up voltage	Dropout voltage	Maximum voltage	Power consumption (mW)
			Armature OFF	Armature ON	% of rated voltage			
3	166.70	18	0.04	0.05	75% max.	5% min.	120% max. at 65°C (149°F)	Approx. 500
5	100	50	0.09	0.11				
6	83.30	72	0.16	0.19				
9	55.60	162	0.31	0.49				
12	41.70	288	0.47	0.74				
24	20.80	1,152	1.98	2.68				
48	12	4,000	—	—			110% max. at 60°C (140°F)	Approx. 580

■ CHARACTERISTICS

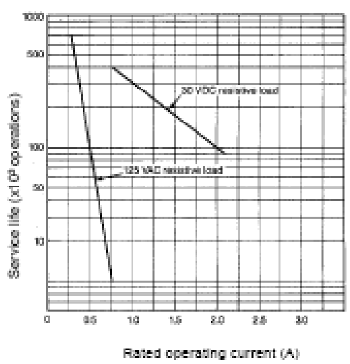
Contact resistance		50 mΩ max. G5V-2, G5V-2-H, 100 mΩ max. G5V-2-H1
Operate time		7 ms max. (mean value: approx. 3.5 ms)
Release time		3 ms max. (mean value: approx. 0.8 ms)
Bounce time	Operate	Mean value: approx. 0.5 ms
	Release	Mean value: approx. 3.5 ms
Operating frequency	Mechanical	36,000 operations/hour
	Electrical	1,800 operations/hour (under rated load)
Insulation resistance		1,000 MΩ min (at 500 VDC)
Dielectric strength		1,000 VAC, 50/60 Hz for 1 minute between coil and contacts 1,000 VAC, 50/60 Hz for 1 minute between contacts of different poles 750 VAC, 50/60 Hz for 1 minute between contacts of same poles (500 VAC, 50/60 Hz for 1 minute between contacts of same poles for ultra-sensitive type)
Surge withstand voltage		1,500 V 10 X 160 µs (conforms to part 68 of FCC rules)
Vibration	Mechanical durability	10 to 55 Hz, 1.50 mm (0.59 in) double amplitude
	Malfunction durability	
Shock	Mechanical durability	1,000 m/s² (approx. 100 G)
	Malfunction durability	200 m/s² (approx. 20 G)
Ambient temperature	Operating/storage	-25º to 70ºC (-13º to 158ºF)
Humidity		35% to 85% RH
Service life	Mechanical	15 million operations min. (at operating frequency of 36,000 operations/hour)
	Electrical	See "Characteristic Data"
Weight		6 g (0.21 oz)

■ CHARACTERISTIC DATA

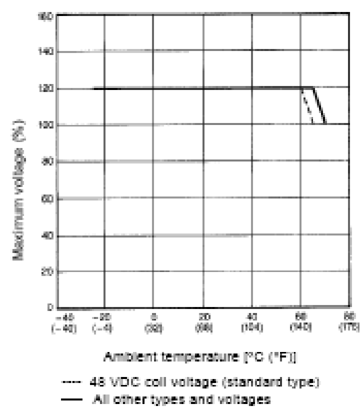
Maximum switching capacity



Electrical service life



Ambient temperature vs. maximum voltage

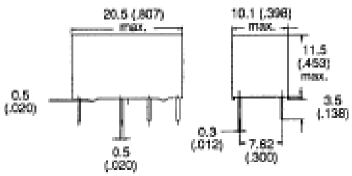


Dimensions

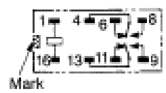
Unit: mm (inch)

■ RELAYS

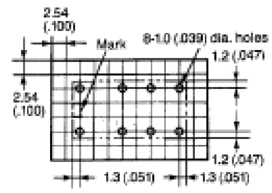
Fully-sealed



Terminal arrangement/Internal (bottom view)



Mounting holes (bottom view)



MH88610

Subscriber Line Interface Circuit (SLIC)

Preliminary Information

Features

- Transformerless 2-wire to 4-wire conversion
- Battery and ringing feed to line
- Off-hook and dial pulse detection
- Ring ground over-current protection
- Loop length detection
- Constant current feed

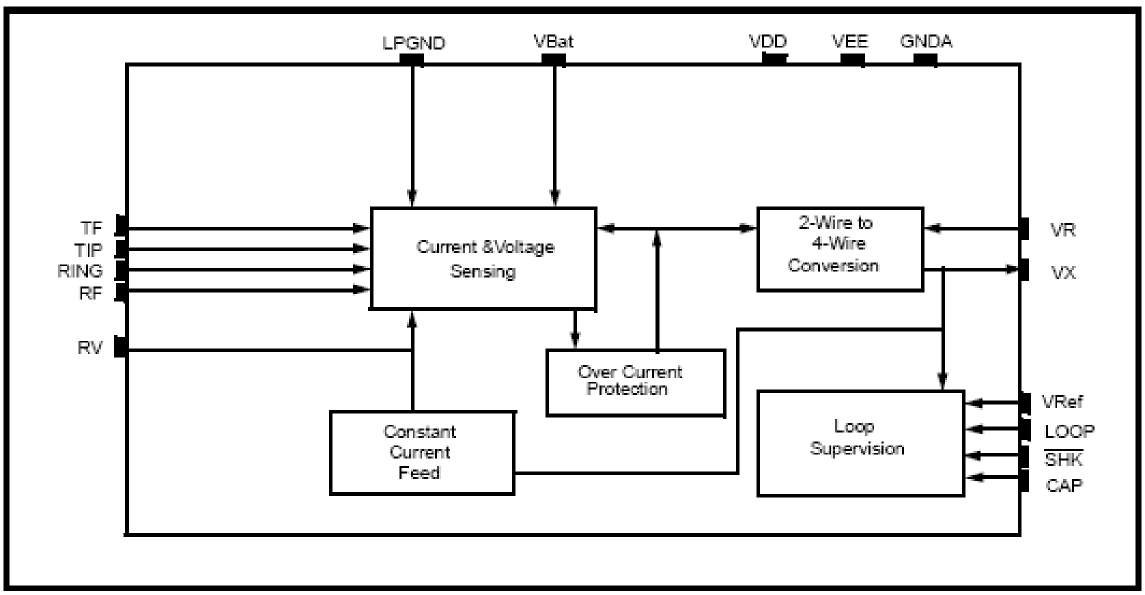


Figure 1 - Functional Block Diagram

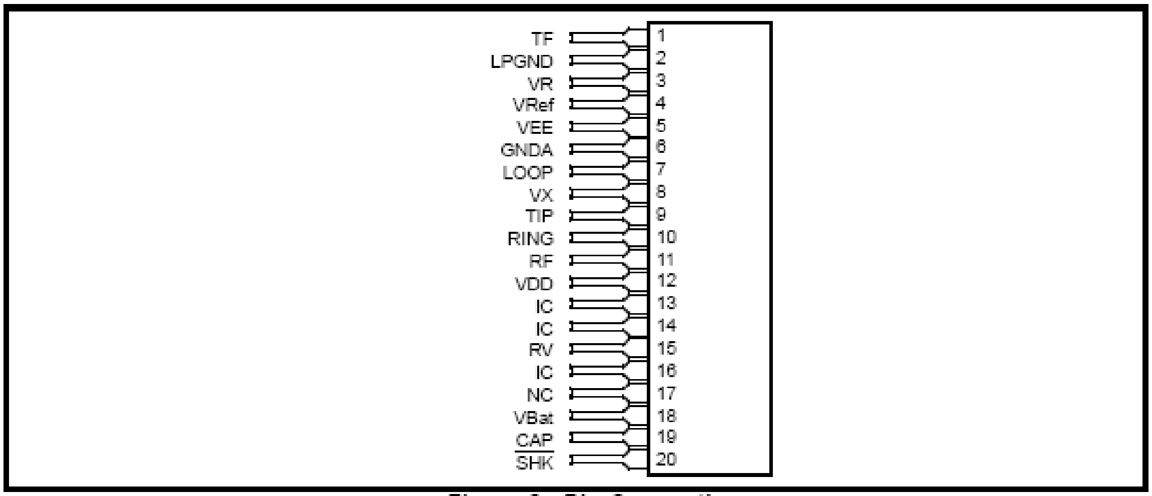


Figure 2 - Pin Connections

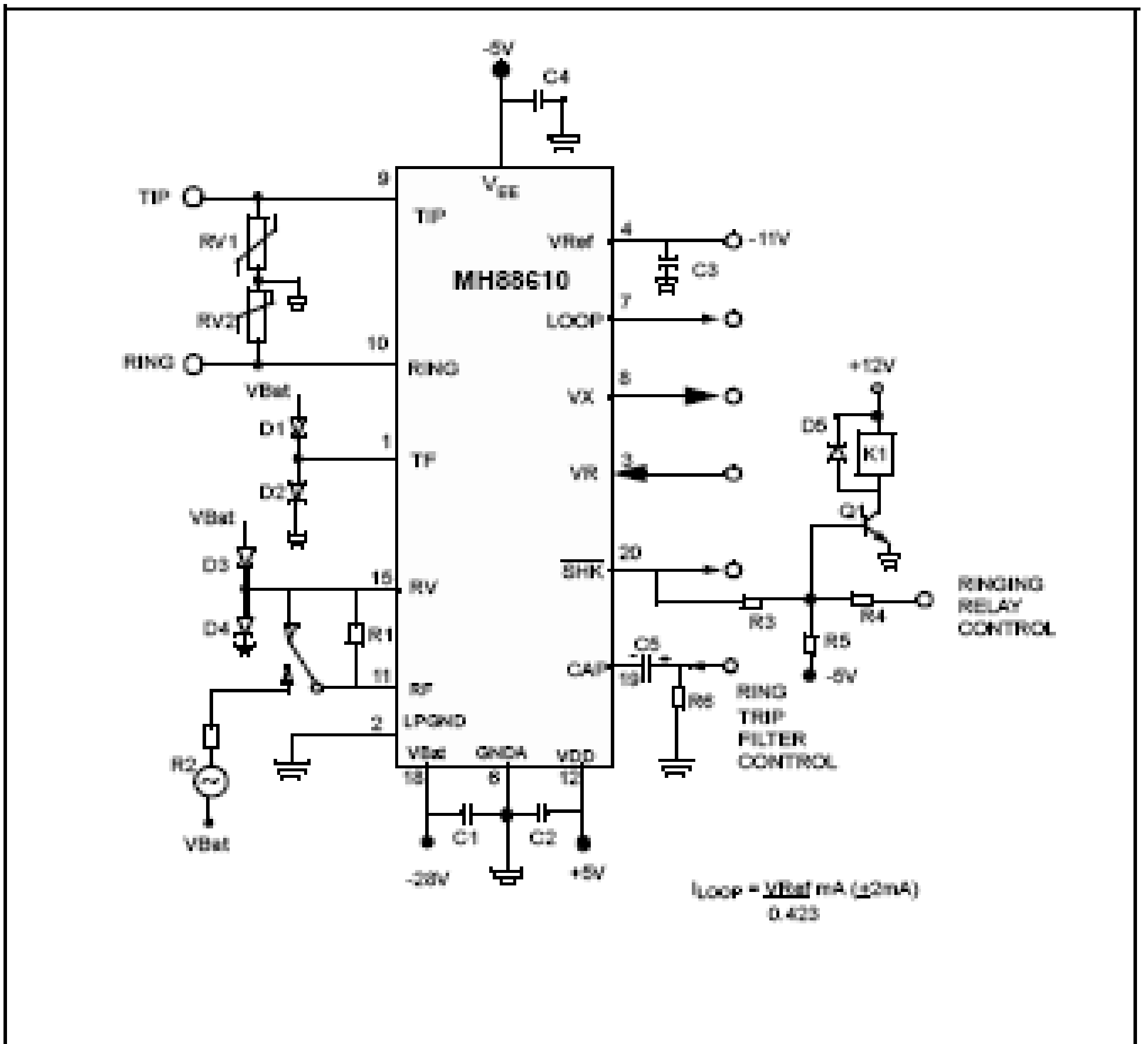


Figure 3 - Application Circuit

MITEL SEMICONDUCTOR

MH88422

Data Access Arrangement

Preliminary Information

Features

- FAX and Modem interface (V29)
- Variants available with different line impedances
- Provides reinforced barrier to international PTT requirements
- Transformerless 2-4 Wire conversion.
- Integral Loop Switch
- Dial Pulse and DTMF operation
- Line state detection outputs
- Loop current/ringing outputs
- Single +5V operation, low on-hook power (5mW)
- Full duplex data transmission

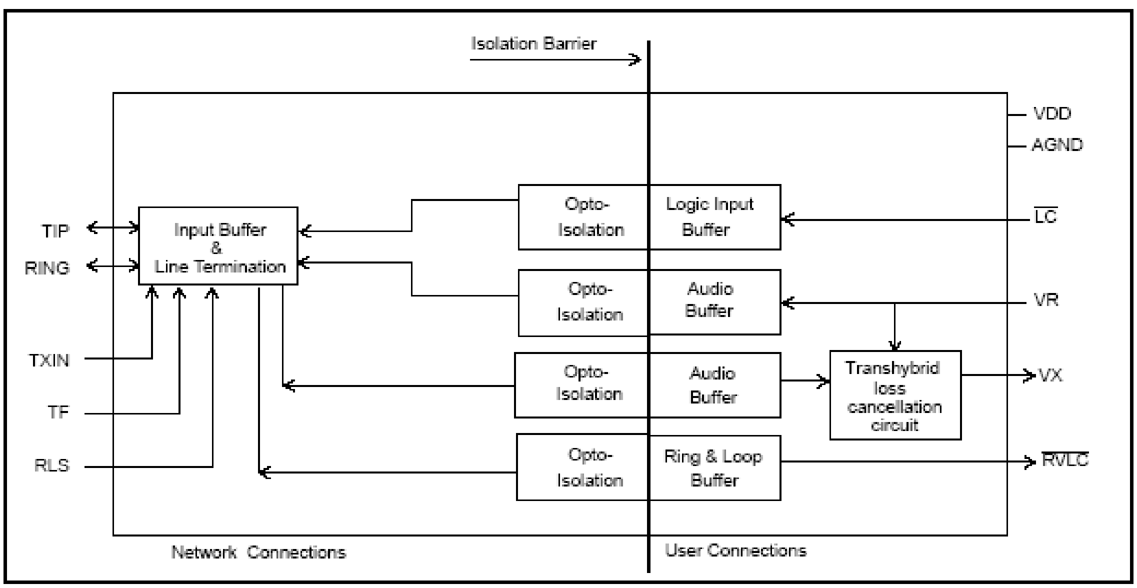


Figure 1 - Functional Block Diagram

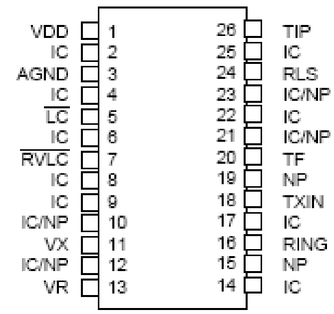


Figure 2 - Pin Connections

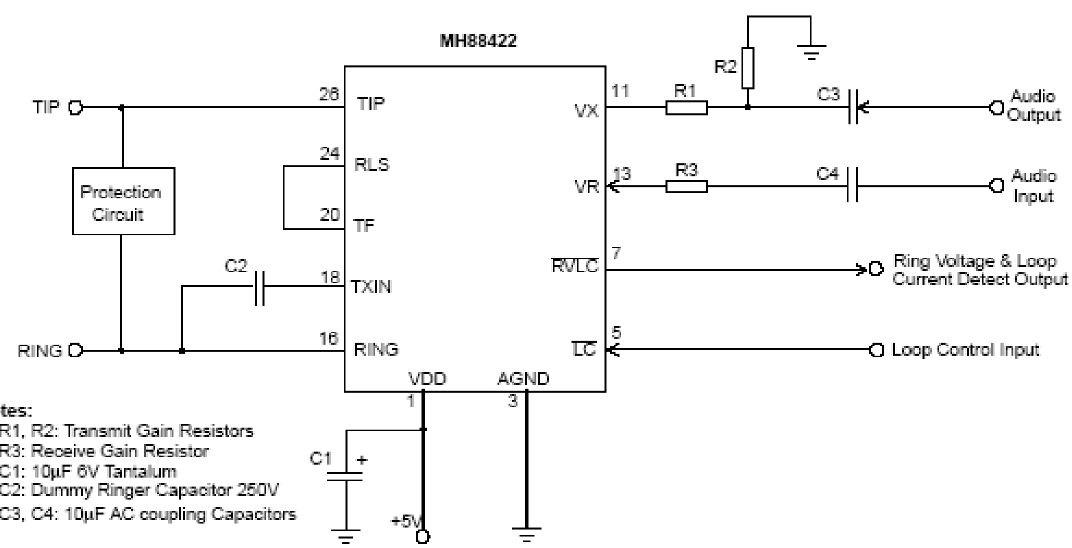


Figure 3 - Typical Application Circuit

MITEL SEMICONDUCTOR