

FX004 Voice Band Inverter

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Features

- Fixed Frequency Inversion
- CTCSS Compatible
- Choice of Three Audio Bandwidths and Inversion Frequencies
- μ P Compatible Interface
- Automatic Private/Clear Switching

Applications

- Private Mobile Radio
- Community Repeaters
- Interconnect Systems
- Cordless Telephones
- Telephony



Island Labs

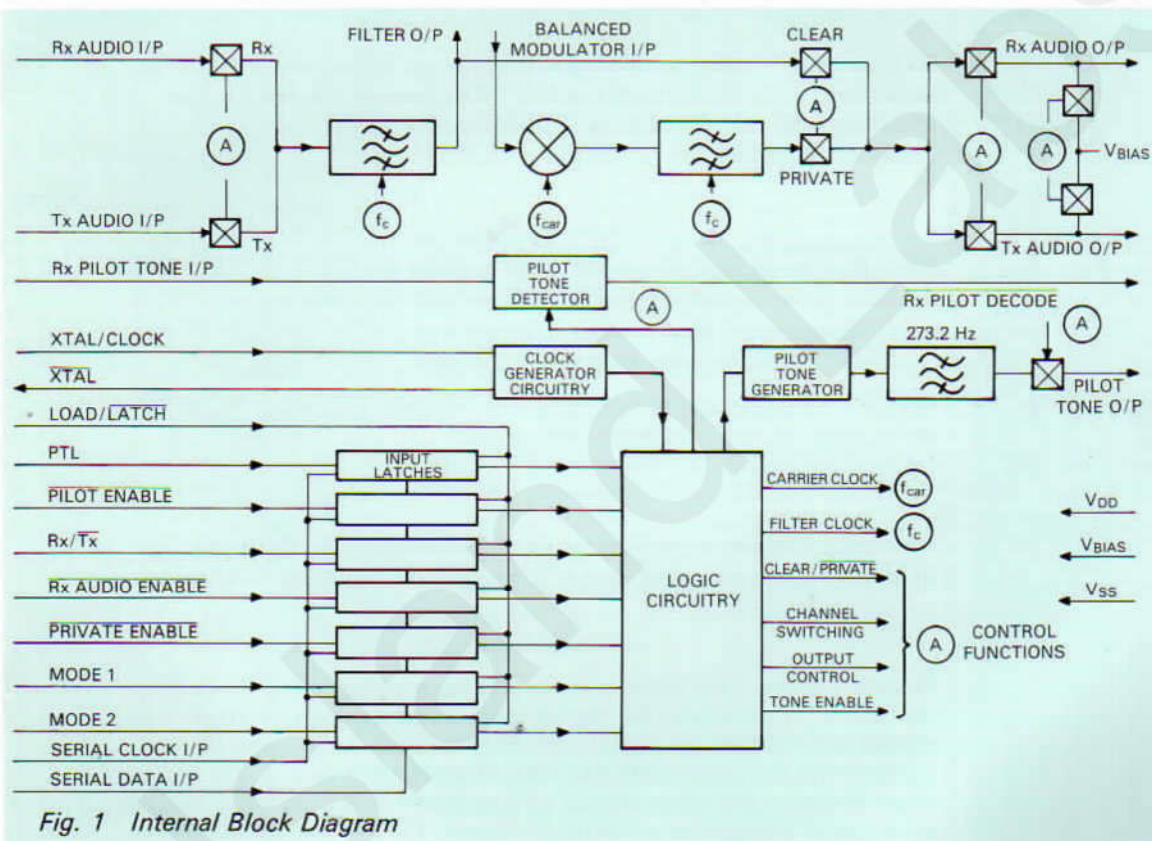


Fig. 1 Internal Block Diagram

FX004

Brief Description

The FX004 is designed to protect speech privacy in Private Mobile Radio and other common channel radio systems. It uses "FIXED FREQUENCY INVERSION" techniques which exchange the low and high frequencies of the transmitted voiceband signal to render the message unintelligible to eavesdropping.

Sharp cut-off in the internal voiceband filters permits operation with CTCSS and similar sub-audio signalling schemes and ensures the high quality of the recovered audio. The device incorporates a programmable clock divider which controls the carrier frequency and filter cut-off frequencies, thus permitting

the selection of one of three scrambling codes and transmission bandwidths. A pilot tone generator and detector are used to operate the automatic clear/private facility in mixed equipment systems. Control of the Rx/ \bar{T} x, PTL and privacy functions is by pin selection or use of serial/parallel microprocessor interfaces.

The FX004 operates from a single 5V supply and uses a 1MHz crystal oscillator to ensure correct pitch of the recovered speech. Signal coupling and supply decoupling are the only external components needed and a choice of DIL or SMD packages is available.

Pin Number

Function

DIL FX004J	Quad Plastic FX004LG	PLCC FX004LH	
1	1	2	Filter Output: This is the audio bandpass filtered signal and is coupled externally to the Balanced Modulator Input pin via capacitor C ₆ . See Fig. 2.
2	2	3	Load/Latch: This pin is used for controlling input latches in both Parallel and Serial loading modes. In Parallel, a logic "1" makes the latches transparent and the following inputs operate directly, PTL, Pilot Enable, Rx/Tx, Rx Audio Enable, Private Enable, Mode 1 and Mode 2. When at logic "0", the data present is latched in. During Serial loading, Load/Latch should be kept low until data is completely loaded then the pin strobed 0-1-0, latching the new data in. Internal 1MΩ pullup. See Fig. 4.
3	3	4	PTL: A logic '1' level at this input enables the Audio Output in Rx mode when Rx Audio Enable is at logic '1'. This feature enables channel checking without intercepting a private conversation. Internal 1MΩ pullup.
4	4	5	Pilot Enable: A logic '0' at this input enables the 273.2 Hz pilot tone at the Tx Pilot Tone Output when in Tx mode. Internal 1MΩ pullup.
5	5	6	Rx/Tx: This input selects the receive or transmit operating mode. Logic '1' is Rx, logic '0' is Tx. Internal 1MΩ pullup.
6	6	7	Rx Audio Enable: A logic '0' at this input enables the Rx Audio path in Rx mode. May be connected to a CTCSS decoder. Internal 1MΩ pullup.
7	7	8	Private Enable: This input controls the input action of the balanced modulator by switching the carrier clock (refer to Table 1). When audio signals are inverted the signal path gain is adjusted automatically to compensate for upper sideband loss. Internal 1MΩ pullup. For an 'Auto-Clear' function this input should be connected to the Rx Pilot Decode pin via external integrating components R ₂ and C ₉ , see Fig. 2.
8	8	9	Mode 1 } These two inputs control Audio band frequency, Carrier frequency and Loading control mode. See Table 2. Internal Mode 2 } 1MΩ pullups.
9	9	10	
10	10	13	Rx Pilot Tone Input: This pin is the input to the Rx pilot tone decoder. Signals should be A.C. coupled. See Fig. 2. The tone decoder is disabled in Tx mode.
11	11	14	Rx Audio Input: This is the audio input pin in Rx mode. Signals should be A.C. coupled. See Fig. 2.

Pin Number

Function

DIL FX004J	Quad Plastic FX004LG	PLCC FX004LH	
12	12	15	V_{SS} : Negative supply (GND).
13	13	16	Tx Audio Input : This is the audio input pin in Tx mode (mic). Signals should be A.C. coupled. See Fig. 2.
14	14	17	Rx Audio Output : This is the audio output in Rx mode, internally biased at $V_{DD}/2$ in Tx mode.
15	15	18	Tx Audio Output : This is the audio output in Tx mode, internally biased at $V_{DD}/2$ when Rx mode is selected.
16	16	20	Tx Pilot Tone Output : This pin outputs the 273.2Hz pilot tone and would normally be summed with the Tx Audio Output to modulate the transmitter. When not enabled or in Rx this output is open circuit (high-impedance).
17	17	21	Rx Pilot Decode : This pin is the output of the pilot tone detector, it outputs a logic '0' when a valid 273.2Hz tone is input. Has high impedance load to V_{DD} for wired 'OR' connection to other pins. For an 'Auto-Clear' function this input should be connected to the Private Enable pin via external integrating components R_2 and C_9 , see Fig. 2.
18	18	22	V_{BIAS} : This is the bias pin and is set internally to $V_{DD}/2$. It should be externally decoupled using a capacitor of 1.0 μ F (minimum) to V_{SS} . See Fig. 2.
19	19	23	Serial Data Input : Data present at this input is clocked into the input register by the "0-1" clock transition of the Serial Clock Input. See Fig. 4. Internal 1M Ω pullup.
20	20	24	Serial Clock Input : The timing clock pulses for serial loading are input here. Internal 1M Ω pullup.
21	21	25	Xtal : Output of the clock oscillator inverter.
22	22	26	Xtal/Clock : This is the input to the clock oscillator inverter. 1MHz Xtal input or externally derived clock can be injected into this input.
23	23	28	V_{DD} : Positive supply. A single +5V power supply is required.
24	24	1	Balanced Modulator Input : This pin should be connected to the Filter Output pin via capacitor C_6 , see Fig. 2. It is internally biased at $V_{DD}/2$.
		11, 12 19, 27	No Internal Connection.

External Conditions

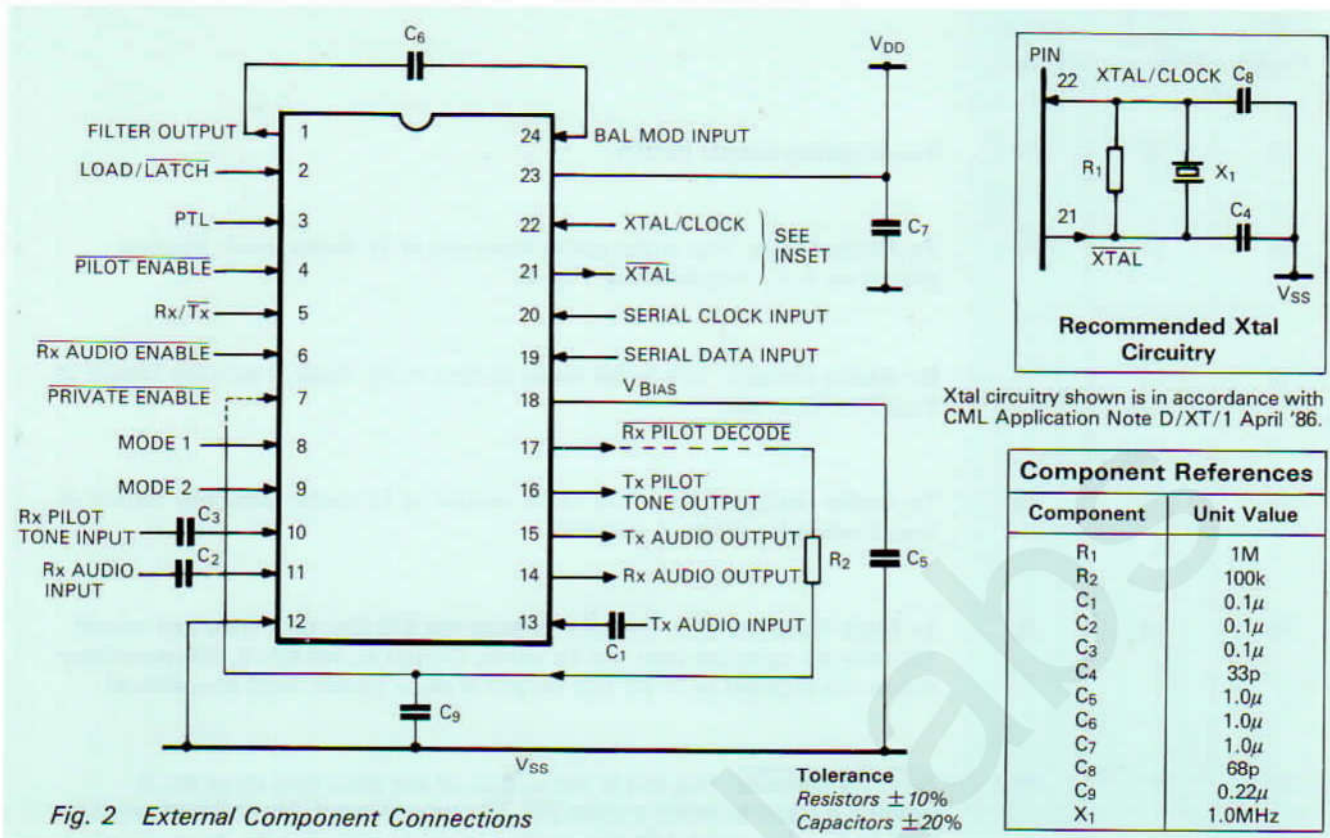


Fig. 2 External Component Connections

Private Enable (Auto-Clear)

To minimise the effect of noise and signal strength fluctuations on the 'Auto-Clear' function, the use of external integrating components between the Rx Pilot Decode output and the Private Enable input is required. Components R₂ and C₉, having a time constant of 20ms are recommended, as shown in figure 2.

Audio Quality

If it is necessary to install the FX004 Voice Band Inverter before the transmitter's existing pre-emphasis stage, an additional pre-emphasis stage before the FX004 followed by a de-emphasis stage after the FX004 will enhance the audio quality. At the receiver the FX004 should be installed between the demodulator and existing de-emphasis stage.

Input and Output Pin Conditions									
Rx/Tx	PTL	Private Enable	Pilot Enable	Rx Audio Enable	Assumed Rx I/P	Tx I/P	Rx O/P	Tx O/P	Tx Pilot O/P
1	0	X	X	1	X	X	V _{DD} /2	V _{DD} /2	O/C
1	1	X	X	1	Signal	X	Non Inverted	V _{DD} /2	O/C
1	X	0	X	0	Frequency Inverted	X	Clear (Passband Invert)	V _{DD} /2	O/C
1	X	1	X	0	Clear	X	Clear	V _{DD} /2	O/C
0	X	1	1	X	X	Signal	V _{DD} /2	Clear (Passband Non-Invert)	O/C
0	X	1	0	X	X	Signal	V _{DD} /2	Clear (Passband Non-Invert)	Tone
0	X	0	0	X	X	Signal	V _{DD} /2	Inverted (Passband Invert)	Tone
0	X	0	1	X	X	Signal	V _{DD} /2	Inverted (Passband Invert)	O/C

Table 1 Control Truth Table (X = don't care)

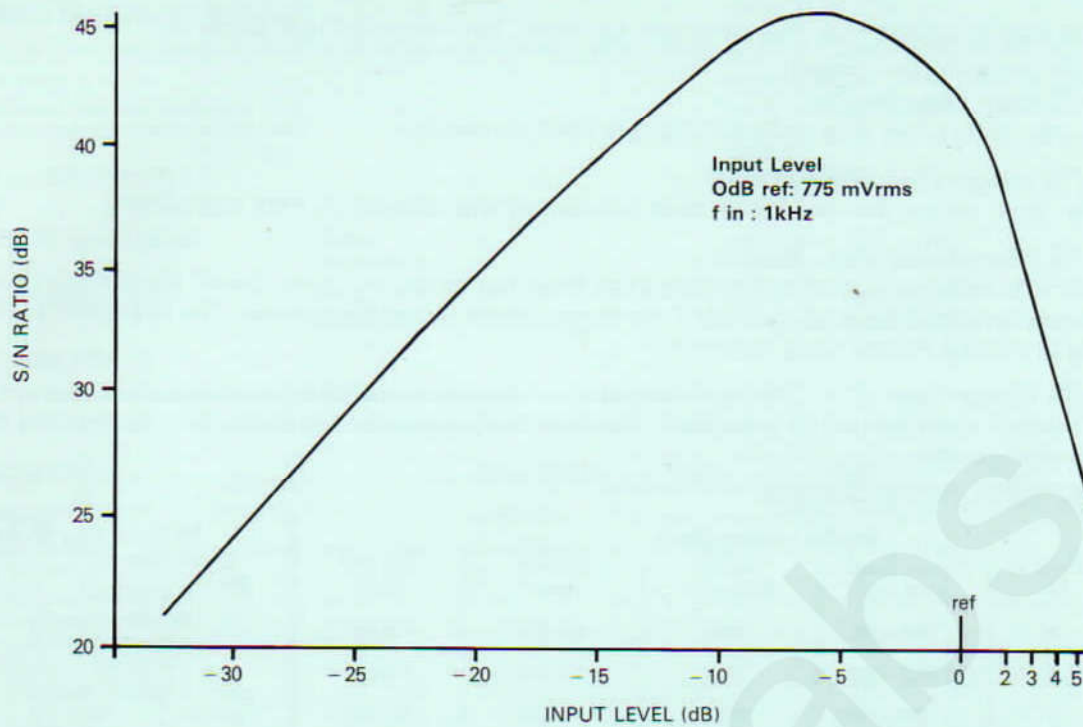
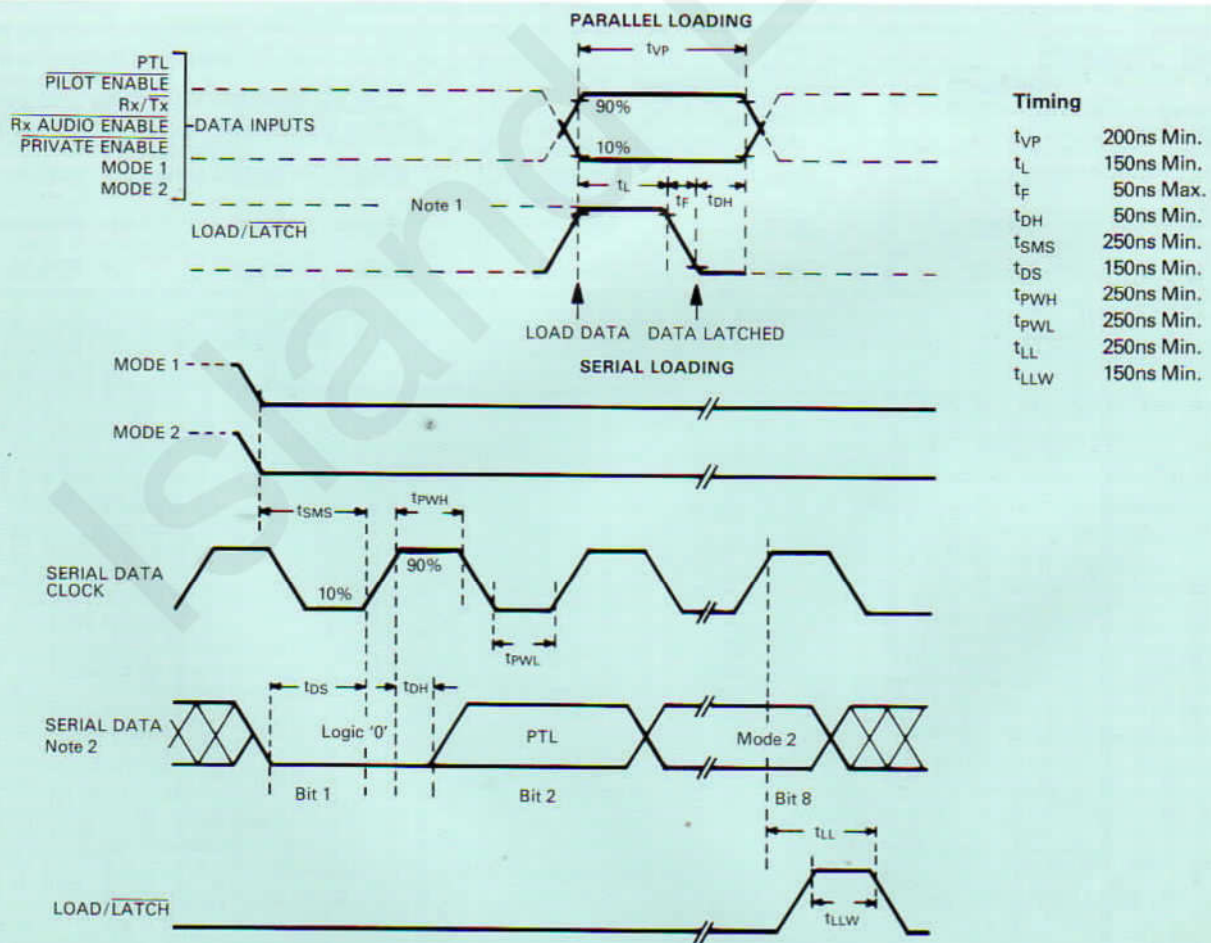


Fig. 3 Typical S/N Ratio Vs Input Level



- NOTES:** 1. With $\overline{\text{LOAD/LATCH}}$ at Logic '1' latches are transparent and data acts directly.
 2. Serial Data Loading Sequence: - Logic '0' - PTL - PILOT ENABLE - Rx/Tx - Rx AUDIO ENABLE - PRIVATE ENABLE - MODE 1 - MODE 2.

Fig. 4 Loading Timing Diagrams

Audio Frequency Bands

Band Usage

Any Audio Band may be selected for clear or private functions, but "intended" use would be:

- Band A Rx/ $\overline{\text{T}}\text{x}$ Private (333 – 3370Hz)**
Band B Rx/ $\overline{\text{T}}\text{x}$ Clear (300 – 3033Hz)
 Compatible with 'Auto Clear' pilot tone, CTCSS and PMR bandwidths.
- Band A Rx/ $\overline{\text{T}}\text{x}$ Private/Clear (333 – 3370Hz)**
 This is similar to (1) except that clear audio does not comply with mandatory PMR bandwidths.
- Band B Rx/ $\overline{\text{T}}\text{x}$ Private/Clear (300 – 3033Hz)**
 This complies with mandatory PMR bandwidths at all times but its use in "Auto -Clear" Mode (with Pilot Tone) is not recommended because the Pilot Tone is not filtered out at the receiver. This is suitable for fixed mode Private or manual Private/Clear operation.
- Band C Rx/ $\overline{\text{T}}\text{x}$ Private/Clear (273 – 2757Hz)** Required for time-compressed applications where loss of recovered "Private" voice bandwidth is avoided. The Pilot Tone could be used in the time-compressed mode if injected after compression.

Parallel Loading Mode						Serial Loading Mode		
Mode 1 I/P	Mode 2 I/P	Audio Band-Freq. (Hz)	Carrier Freq. (Hz)	Divisor ($f_{\text{clk}/x}$)	Control Mode	Serial Data In Bit 7	Serial Data In Bit 8	Audio Band
0	1	C 273 – 2757	3030	X = 330	Parallel	0	1	C
1	0	A 333 – 3370	3703	X = 270	Parallel	1	0	A
1	1	B 300 – 3033	3333	X = 300	Parallel	1	1	B
0	0	—	—	—	Serial	0	0	B

Audio Bands

The audio band/modulation frequency relationships with their division ratios are shown in Table 2 and are produced with a Xtal/clock frequency (f_{clk}) of 1MHz. The modulation frequency and band limits will alter proportionally with Xtal frequency.

Audio Band	Stopband @ $\geq -42\text{dB}$. F max	Passband		Attenuation at Carrier Frequency	Stopband @ $\geq -42\text{dB}$. F min.
		Lower Bound	Upper Bound		
A	278Hz	333Hz	3370Hz	3703Hz 20dB	4036Hz
B	250Hz	300Hz	3033Hz	3333Hz 20dB	3633Hz
C	227Hz	273Hz	2757Hz	3030Hz 20dB	3302Hz

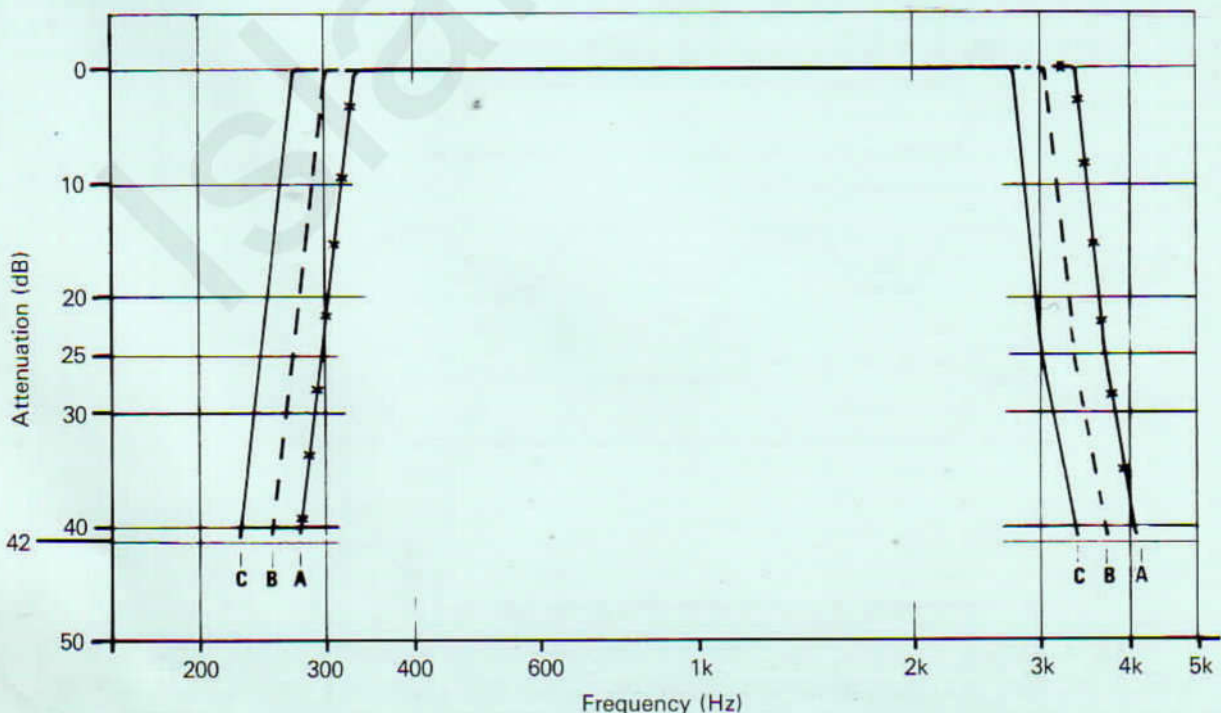


Fig. 5 Typical Audio Bandpass Filter Responses (1 Filter)

Specification

Absolute Maximum Ratings

Exceeding the maximum rating can result in device damage. Operation of the device outside the operating limits is not implied.

Supply voltage		-0.3V to 7.0V
Input voltage at any pin (ref $V_{SS} = 0V$)		-0.3V to ($V_{DD} + 0.3V$)
Output sink/source current (supply pins)		$\pm 30mA$
(other pins)		$\pm 20mA$
Total device dissipation @ 25°C		800mW Max.
Derating		10mW/°C
Operating temperature range:	FX004J	-30°C to +85°C (Cerdip)
	FX004LG/LH	-30°C to +70°C (Plastic)
Storage temperature range:	FX004J	-55°C to +125°C (Cerdip)
	FX004LG/LH	-40°C to +85°C (Plastic)

Operating Limits

All characteristics measured using the following parameters unless otherwise specified:

$V_{DD} = +5V$, $T_{amb} = 25°C$, Xtal/Clock (f_{clk}) = 1MHz, 0dB ref: 775mVrms.

Characteristics	See Note	Min.	Typ.	Max.	Unit
Static Values					
Supply Voltage	1	4.5	5.0	5.5	V
Supply Current		—	8.0	—	mA
Audio Input Impedance		—	500	—	k Ω
Audio Output Impedance		—	500	—	Ω
Logic Input Impedance		—	1	—	M Ω
Logic Output Impedance		—	—	—	—
(Rx Pilot Decode) To V_{DD}		—	100	—	k Ω
To V_{SS}		—	500	—	Ω
Input Logic '1'	1	3.5	—	—	V
Input Logic '0'	1	—	—	1.5	V
Output Logic '1'	1	4	—	—	V
Output Logic '0'	1	—	—	1	V
Dynamic Values:					
Audio Input Levels Rx/Tx	8	—	-8	—	dB
Audio Output Levels Rx/Tx		—	-8	—	dB
Audio Bandpass Filter (in clear)					
Passband Frequencies Band A	2	333	—	3370	Hz
Passband Frequencies Band B	2	300	—	3033	Hz
Passband Frequencies Band C	2	273	—	2757	Hz
Passband Gain	5	—	0	—	dB
Passband Ripple	5	—	± 1	—	dB
Output Noise Level	3	—	-50	—	dB
Insertion Loss		—	0	—	dB
Total Harmonic Distortion	9	—	2	5	%
Pilot Tone Detector					
Sensitivity		—	13	—	mVrms
Response Time	6	—	50	—	ms
Talk off and Falsing	4	—	—	—	—
Pilot Tone Output					
Tone Output Level		-2	0	+2	dB
Distortion		—	—	5	%
Tone Frequency	7	—	273.2	—	Hz
Parallel/Serial Inputs (Fig. 4)					
Parallel Data Valid Time (t_{VP})		200	—	—	ns
Parallel Load Time (t_L)		150	—	—	ns
Pulse Fall Time (t_F)		—	—	50	ns
Data Hold Time (t_{DH})		50	—	—	ns
Serial Mode Set Up Time (t_{SMS})	—	250	—	—	ns
Data Set Up Time (t_{DS})		150	—	—	ns
Clock 'High' Pulse Width (t_{PWH})		250	—	—	ns
Clock 'Low' Pulse Width (t_{PWL})		250	—	—	ns
Load/Latch Set Up Time (t_{LL})		250	—	—	ns
Load/Latch Pulse Width (t_{LLW})		150	—	—	ns

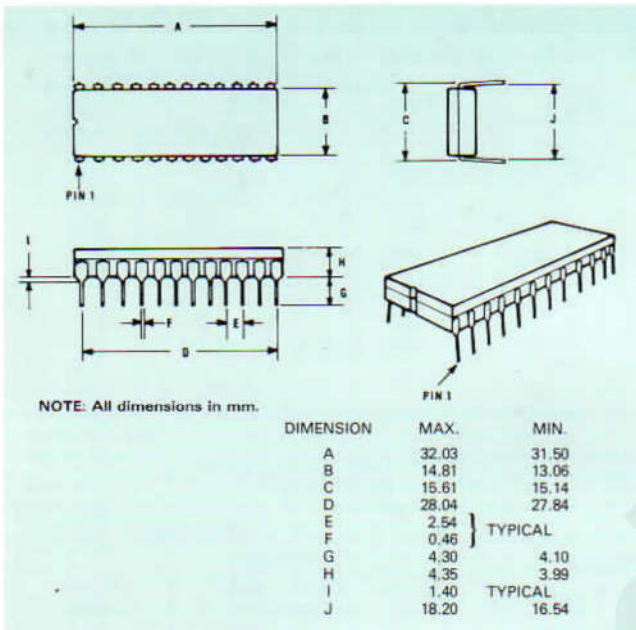
- Notes:**
1. Characteristics specified at 5V V_{DD} .
 2. Bandpass limits at -1dB of mean passband level.
 3. Measured at the Rx audio output in Private with Rx audio input A.C short circuit.
 4. Talk off:—for 30mV pilot tone (273Hz), 5kHz white noise at -3dB on tone, 1 drop out per minute is expected. Typically 5ms/drop out.
Falsing:—for 380mVrms (not clipping) 5kHz white noise 25 falses per minute are expected. 10ms/false. Measured without integration components.
 5. All bandpass filters display similar performances. See figure 5.
 6. Tested with composite signal of 300 mVrms 1kHz tone, Pilot tone 30mVrms in white noise of 5kHz at 75mVrms.
 7. In Tx only.
 8. See figure 3 with respect to signal to noise ratio.
 9. For -3dB, 1kHz input.

Package Outlines

The FX004J, the cerdip package, is illustrated in *Figure 6*. The 'LG' version is shown in *Figure 7*, and the 'LH' version in *Figure 8*. Both 'LG' and 'LH' packages are supplied in conductive trays for handling convenience.

To allow complete identification, the FX004LG and LH packages have an indent spot adjacent to pin 1 and a chamfered corner between pins 3 and 4 for LG packages, between pins 4 and 5 for LH package. Pins number anti-clockwise when viewed from the top (indent side).

Fig. 6 FX004J DIL Package



Handling Precautions

The FX004J/LG/LH is a CMOS LSI circuit which includes input protection. However, precautions should be taken to prevent static discharges which may cause damage.

Fig. 7 FX004LG Package

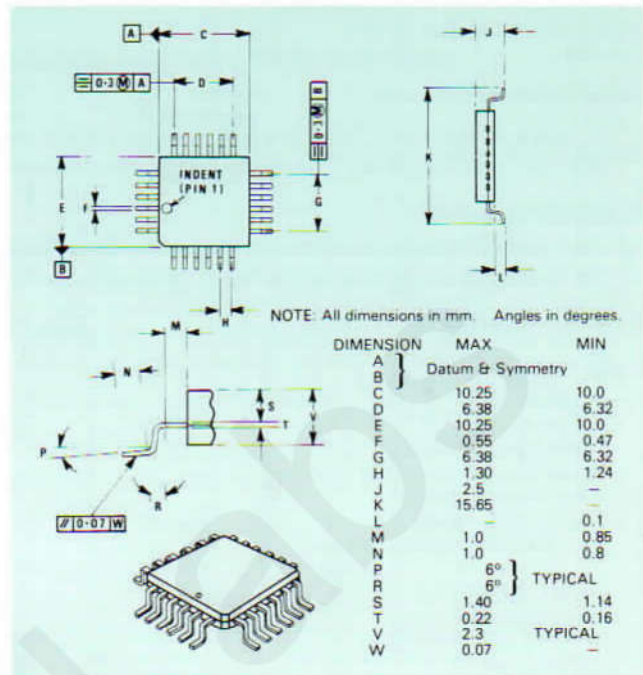
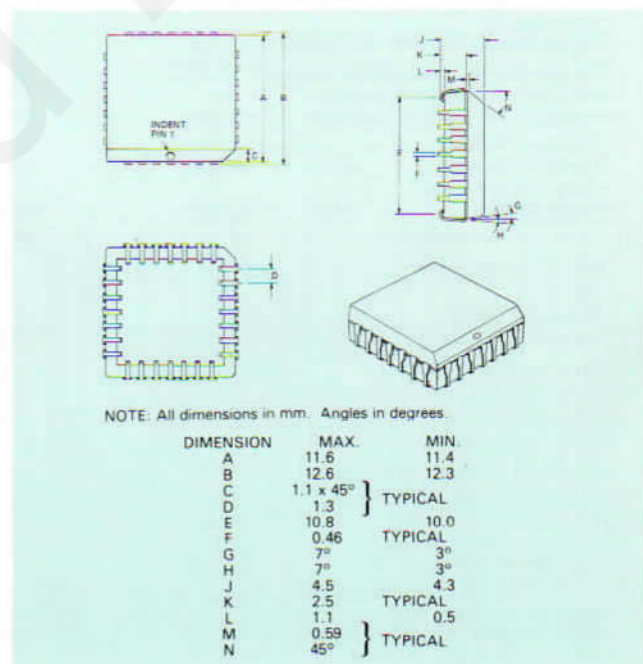


Fig. 8 FX004LH Package



Ordering Information

- FX004J** 24-pin cerdip DIL
- FX004LG** 24-pin quad plastic encapsulated, bent and cropped.
- FX004LH** 28-lead Plastic leaded chip carrier.

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