DTMF Tone Generator With Binary Input

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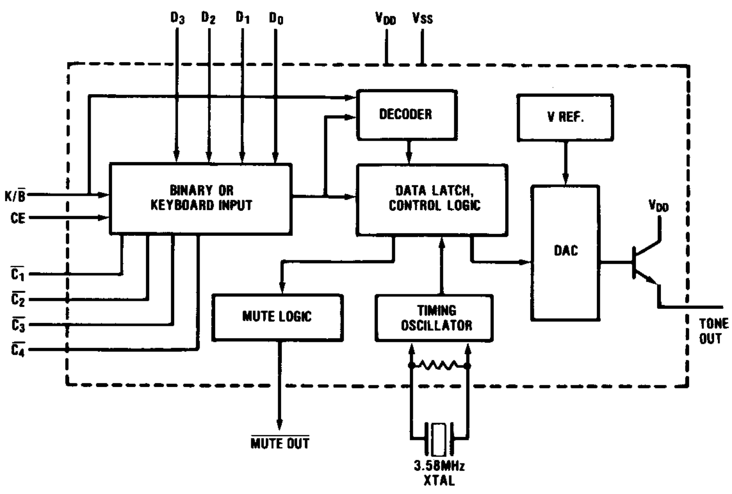
Features

- Available in 16 pin Small Outline IC Package for Space Savings
- Wide Operating Supply Voltage Range 3.0 to 10.0 Volts
- Direct Interface to TTL 4-Bit Logic for Binary Inputs or Standard X-Y Keyboard with Common Terminal
- Uses Low Cost 3.58MHz TV Crystal to Derive 16 Standard Dual Tone Frequencies
- Reference Voltage Generated On-Chip Eliminates External Circuitry
- Dual Tone and Single Tone Capabilities
- Low Power CMOS Circuitry Allows Telephone Line Power Operation

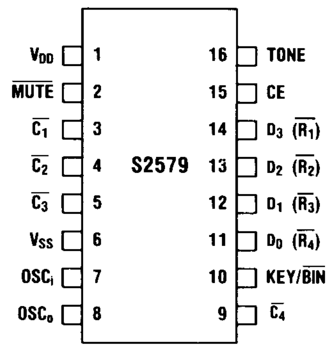
General Description

The S2579 binary input DTMF generator is a CMOS integrated circuit specially designed to accept external logic or microprocessor inputs. The S2579 can also be programmed to interface to 3x4 or 4x4 keyboard with common. The 16 standard dual tone frequencies are derived from a 3.58MHz crystal providing high accuracy and stability. A voltage reference is generated on the chip which is stable over the operating voltage and temperature range and regulates the signal levels of the dual tones to meet the recommended telephone industry specification. Other applications for the S2579 include radio and mobile telephones, remote control, point-of-sale, and credit card verification terminals and process control.

Block Diagram



Pin Configuration



ALSO AVAILABLE IN 16 PIN SOIC

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Absolute Maximum Ratings

DC Supply Voltage ($V_{DD} - V_{SS}$)	+10.5V
Operating Temperature	0°C to +70°C
Storage Temperature	−55°C to +125°C
Power Dissipation at 25°C	500mW
Input Voltage	$V_{SS} - 0.6 \leq V_{IN} \leq V_{DD} + 0.6$
Input/Output Current (except tone output)	15mA
Tone Output Current	50mA

Electrical Characteristics

Specifications apply over the operating temperature range of 0°C to +70°C unless otherwise noted. Absolute values of measured parameters are specified.

Symbol	Parameter/Conditions	(V_{DD}-V_{SS}) Volts	Min.	Typ.	Max.	Units
	Supply Voltage					
V_{DD}	Tone Output Mode (With Valid Data)		3.0	5.0	10.0	V
	Supply Current					
I_{DD}	Standby (No Key Selected, No Data, Tone and $\overline{\text{Mute}}$ Unloaded)	5.0 10.0		1.6 2.8	2.0 3.2	mA mA
	Operating (Tone and $\overline{\text{Mute}}$, Unloaded)	5.0 10.0		4.0 9.0	5.0 18.0	mA mA
R_p	Pullup Resistor (Column, Row and CE Inputs)	5.0 10.0	13 13	25 25		KΩ KΩ
	Key/$\overline{\text{BIN}}$ Select Unloaded)	5.0 10.0	13 13	25 25		KΩ KΩ
OSC	Operating Frequency	5.0- 10.0		3.58		MHz
	Tone Output					
V_{OR}	Low Band Alone $R_L = 150\Omega$	5.0	393	481	598	mVrms
dB_{CR}	Ratio of Column to Row Tone	5.0 10.0	1.0	2.0	3.0	dB
%DIS	Distortion*	5.0- 10.0		7	10	%
I_{OL}	Output Sink Current (Pin_2, $\overline{\text{MUTE}}$)	5.0	1.6	4.8		mA
D_{ST}	Data Setup Time	5.0	100			ns
D_{HT}	Data Hold Time	5.0	50			ns
	Logic Inputs					
V_{IL}	Input Voltage, Low	5.0			0.8	V
V_{IH}	Input Voltage, High	5.0	2.0			V

*Distortion measured in accordance with the specifications described in Ref. 1 as the "ratio of the total power of all extraneous frequencies in the voice-band above 500Hz accompanying the signal to the total power of the frequency pair".

S2579

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Pin/Function Descriptions

Pin #	Name	Function
1	V_{DD}	The positive supply voltage pin.
2	$\overline{MUTE}$	This is an open drain output that turns on, to mute the microphone and speaker when a key is pressed.
3 4 5 9	$\overline{C1}$ $\overline{C2}$ $\overline{C3}$ $\overline{C4}$	When pin 10 is high these are the 4 column inputs and must be pulled low true. When pin 10 is low, a low on $\overline{C1}$ provides a single low group tone when CE is valid. If $\overline{C2}$ is low a single high group tone will be generated. Pull-up resistors are present on each pin in the 30KΩ range. These are not latching inputs like the row inputs. These pins ($\overline{C_1}$ $\overline{C_2}$) must be held low for the duration of the single tone.
6	V_{SS}	The negative supply voltage pin.
7 8	OSC_i OSC_0	A standard 3.58 MHz TV crystal is connected across these pins. There is an internal resistor.
10	KEY/$\overline{BIN}$	Keyboard/$\overline{Binary}$: This pin selects whether the S2579 will be interfaced with a X-Y keyboard or 4 bit data bus from a microprocessor.
11 12 13 14	D_0 ($\overline{R_4}$) D_1 ($\overline{R_3}$) D_2 ($\overline{R_2}$) D_3 ($\overline{R_1}$)	When pin 10 is high these are the 4 row inputs and must be pulled low true. When pin 10 is low these are the binary data inputs for the 16 DTMF tones (See table 1). Pull-up resistors are on each pin in the 30KΩ range. The data is latched into the S2579 on the rising edge of CE.
15	CE	CHIP ENABLE: When this pin is low, all outputs are disabled. When CE and KEY/$\overline{BIN}$ are high, any single key depression will output a valid DTMF tone. If KEY/$\overline{BIN}$ is low, each time CE is brought high a tone will be output, the value will depend on the levels present at the D_0, D_1, D_2, D_3, $\overline{C_1}$, and $\overline{C_2}$ input pins during the positive transition of CE. The tone will continue until CE is brought low. (In the case of single tones $\overline{C_1}$ or $\overline{C_2}$ must be kept low for the duration of the tone).
16	TONE	TONE OUT. This output is an emitter follower DC coupled for impedance transformation. Typically drives a 100Ω or 150Ω resistor.

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Functional Description

Basic Chip Operation

The dual tone multifrequency (DTMF) signal consists of linear addition of two voice frequency signals. One of four signals is selected from a group of frequencies called "low group" and the other is selected from a group of frequencies called "high group". The low group consists of four frequencies; 697, 770, 852 and 941Hz. The high group consists of four frequencies; 1209, 1336, 1477 and 1633Hz.

Tone Generation

When a valid address is detected, the S2579 programs the high and low group dividers with appropriate divider ratios so that the output of these dividers cycle at 16 times the desired high group and low group frequencies. The outputs of the programmable dividers drive two 8-stage Johnson counters. The symmetry of the clock input to the two divide by 16 Johnson counters allows 32 equal time segments to be generated within each output cycle. The 32 segments are used to digitally synthesize a stair-step waveform to approximate the sinewave function (see Figure 2). This is done by connecting a weighted resistor ladder network between the outputs of the Johnson counter, V_{DD} and V_{REF}. V_{REF} closely tracks V_{DD} over the operating voltage and temperature range and therefore the peak-to-peak amplitude V_P ($V_{DD} - V_{REF}$) of the stair-step function is fairly constant. V_{REF} is so chosen that V_P falls within the allowed range of the high group and low group tones (see Table 3).

The individual tones generated by the sinewave synthesizer are then linearly added and drive an emitter follower to allow proper impedance transformation while preserving signal level.

Logic Interface

The S2579 will directly interface with TTL and CMOS logic outputs. When programmed for logic inputs, the S2579 requires active "high" logic levels. Pull-up resistors are present on the row and column inputs in the 30KΩ range.

Keyboard Interface

The S2579 can interface with either the standard telephone pushbutton keyboard (see Figure 1) or an X-Y keyboard with common. The common of the keyboard must be connected to V_{SS}.

When programmed for keyboard interface, the S2579 requires active "low inputs".

Single Tone Mode

Single tones in either the low group frequencies or the high group frequencies can be generated using the S2579. With pin 10 low, (Binary input) and valid data on the row inputs, a low input on the $\overline{C_1}$ or $\overline{C_2}$ pin will generate the appropriate single row or column frequency tone (Table 3). When pin 10 is high, a low group tone can be generated by depressing two digit keys in the appropriate column, i.e., selecting the appropriate column input and two row inputs in that column.

Key/$\overline{\text{BIN}}$

This input is used for programming the S2579 to accept either logic or keyboard inputs. If the Key/$\overline{\text{BIN}}$ pin is tied "low", the S2579 will be programmed to accept logic or binary input levels. Left floating or tied "high" the S2579 will accept keyboard inputs.

$\overline{\text{MUTE}}$ Output

The S2579 has a N-Channel transistor for the $\overline{\text{MUTE}}$ output. With no keys depressed, the $\overline{\text{MUTE}}$ output is open. When a valid address is enabled, the $\overline{\text{MUTE}}$ output goes low.

Oscillator

The device contains an oscillator circuit with the required parasitic capacitances and feedback resistance on chip so that it is only necessary to connect a standard 3.58MHzz TV crystal across the OSC_i and OSC_O terminals to implement the oscillator function.

Figure 1. Standard Telephone Push Button Keyboard

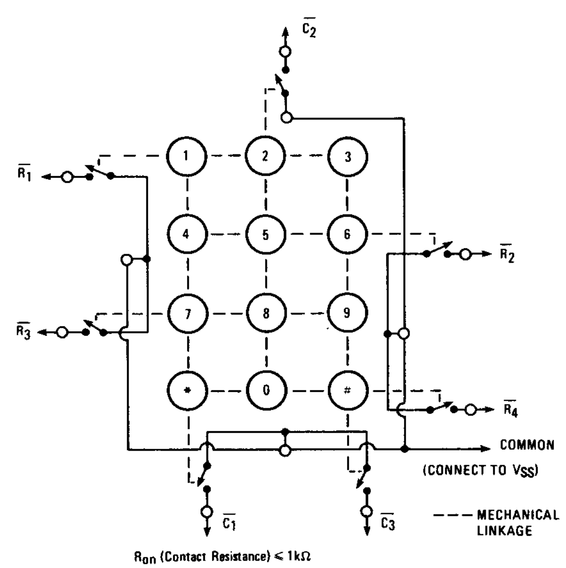

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Table 1. Functional Truth Table for Logic Interface

Keyboard Inputs	$\overline{C1}$	$\overline{C2}$	Binary Inputs D3	D2	D1	D0	Frequencies Generated F_L	F_H
1	*	*	0	0	0	1	697	1209
2	*	*	0	0	1	0	697	1336
3	*	*	0	0	1	1	697	1477
4	*	*	0	1	0	0	770	1209
5	*	*	0	1	0	1	770	1336
6	*	*	0	1	1	0	770	1477
7	*	*	0	1	1	1	852	1209
8	*	*	1	0	0	0	852	1336
9	*	*	1	0	0	1	852	1477
0	*	*	1	0	1	0	941	1336
*	*	*	1	0	1	1	941	1209
#	*	*	1	1	0	0	941	1477
A	*	*	1	1	0	1	697	1633
B	*	*	1	1	1	0	770	1633
C	*	*	1	1	1	1	852	1633
D	*	*	0	0	0	0	941	1633
SINGLE TONE	0	*	VALID DATA					F_H
SINGLE TONE	*	0	VALID DATA				F_L	

* Indicates Normally Open, Internal Pullups Make This a "1" State.

Table 2. Functional Truth Table for Keyboard Interface

Inputs: Keys Depressed	Number of Columns Low	Number of Rows Low	Chip Enable	Tone	Output: $\overline{MUTE}$
X	X	X	0	0	1(OPEN)
None	0	0	1	0	1(OPEN)
One	1	1	1	$F_L + F_H$	0
Two or more keys in column	1	2 or 3 or 4	1	F_H	0
Two or more keys in row	2 or 3 or 4	1	1	F_L	0

Table 3. Comparisons of Specified Vs. Actual Tone Frequencies Generated by S2579

ACTIVE INPUT	OUTPUT FREQUENCY Hz SPECIFIED	ACTUAL	%ERROR SEE NOTE
R1	697	699.1	+0.30
R2	770	766.2	−0.49
R3	852	847.4	−0.54
R4	941	948.0	+0.74
C1	1209	1215.9	+0.57
C2	1336	1331.7	−0.32
C3	1477	1471.9	−0.35
C4	1633	1645.0	+0.73

NOTE: %ERROR DOES NOT INCLUDE OSCILLATOR DRIFT

The oscillator functions whenever a row input is activated. The reference frequency is divided by 2 and then drives two sets of programmable dividers, the high group and the low group.

Chip Enable

The S2579 has a chip enable input at pin 15. The chip enable for the S2579 is active "High". When the chip enable is "Low", the tone output goes to V_{SS}, the oscillator is inhibited and the $\overline{MUTE}$ output goes open.

Quartz Crystal Specification (25° C ± 2°C)

Operating Temperature Range: 0°C to +70°C
Frequency 3.579545MHz
Frequency Calibration Tolerance . . . . . 02 ± %
Load Capacitance 18pF
Effective Series Resistance . . . . . 180 Ohms, max.
Drive Level-Correlation/Operating 2mW
Shunt Capacitance. . . . . 7pF, max.
Oscillation Mode . . . . . Fundamental

Figure 2. Stairstep Waveform of the Digitally Synthesized Sinewave

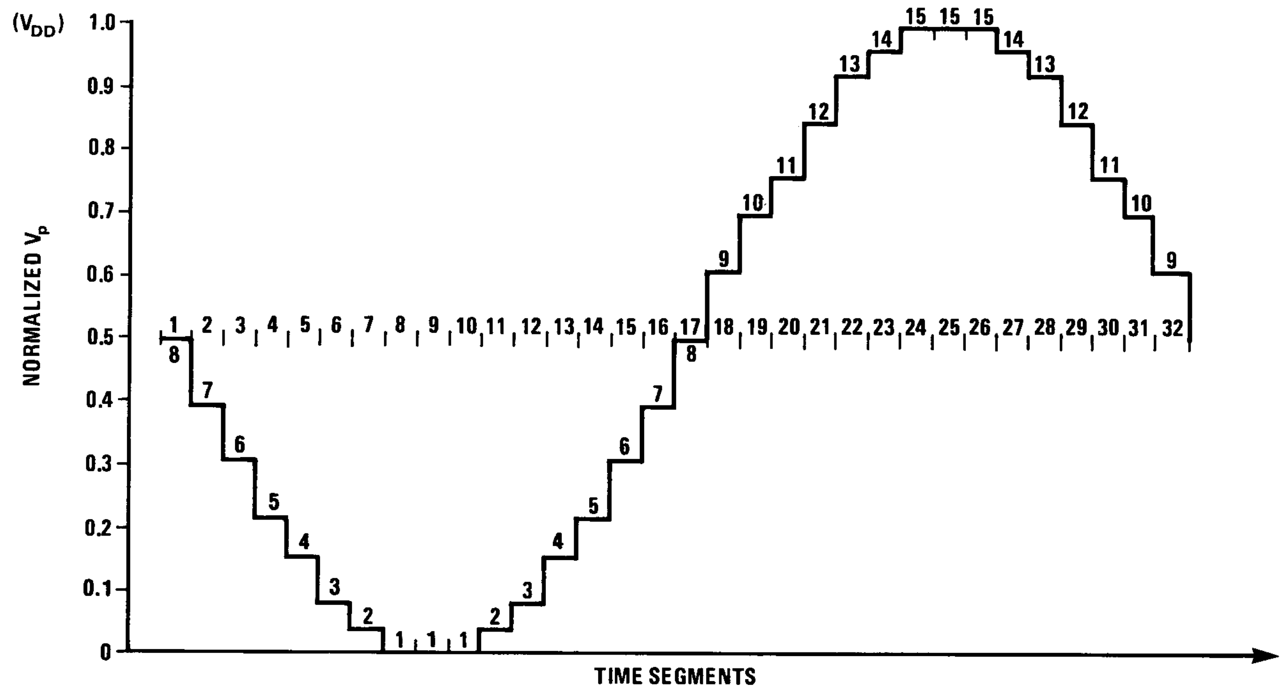

FIGURE 6. STAIRSTEP WAVEFORM OF THE DIGITALLY SYNTHESIZED SINEWAVE

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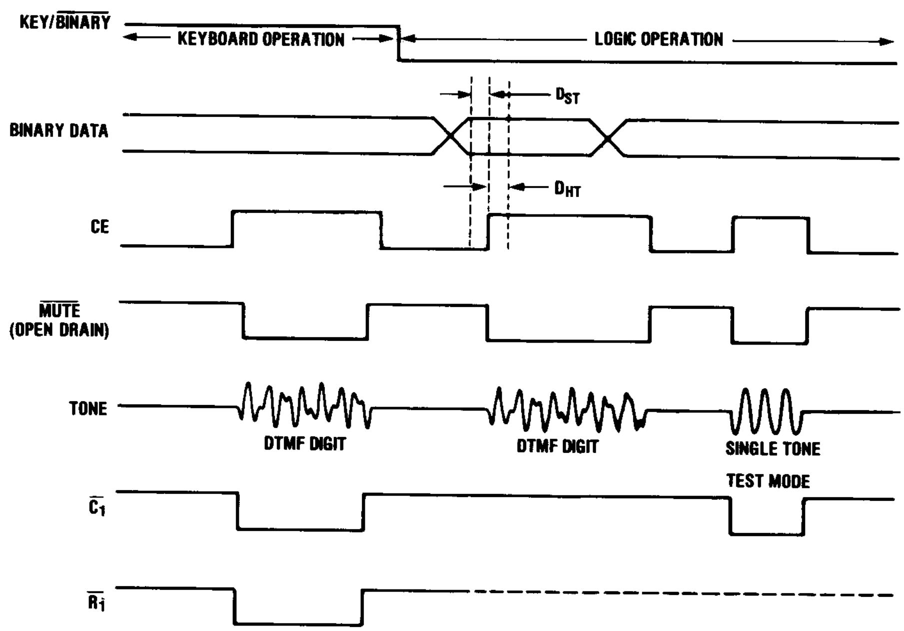
Figure 3. S2579 Timing Diagram



Amplitude/Distortion Measurements

Amplitude and distortion are two important parameters in all applications of the digital tone generator. Amplitude depends upon the operating supply voltage as well as the load resistance connected on the tone output pin. The on-chip reference circuit is fully operational when the supply voltage equals or exceeds 4 volts and as a consequence the tone amplitude is regulated in the supply voltage range above 4 volts. The load resistor value also controls the amplitude. If R_L is low, the reflected impedance into the base of the output transistor is low and the tone output amplitude is lower. For R_L greater than 1KΩ the reflected impedance is sufficiently large and highest amplitude is produced. Individual tone amplitudes can be measured by applying the dual tone signal to a wave analyzer (H-P type 3580A) and amplitudes at the selected frequencies can be noted. This measurement also permits verification of the pre-emphasis between the individual frequency tones.

Distortion is defined as "the ratio of the total power of all extraneous frequencies in the voiceband above 500Hz accompanying the signal to the power of the frequency pair". This ratio must be less than 10% or when expressed in dB must be lower than −20dB. (Ref. 1.) Voiceband is conventionally the frequency band of 300Hz to 3400Hz. Mathematically distortion can be expressed as:

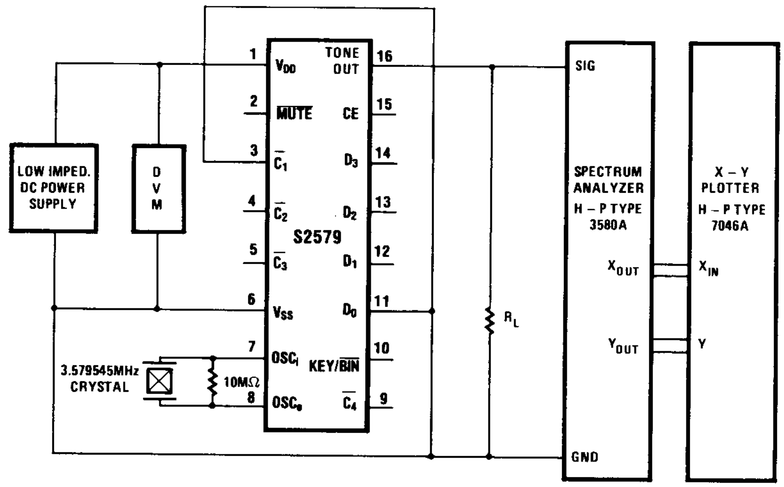
$$\text{Dist.} = \frac{\sqrt{(V_1)^2 + (V_2)^2 + \ldots + (V_N)^2}}{\sqrt{(V_L)^2 + (V_H)^2}}$$

where $(V_1) \ldots (V_N)$ are extraneous frequency (i.e., intermodulation and harmonic) components in the 500 Hz to 3400Hz band and V_L and V_H are the individual frequency components of the DTMF signal. The expression can be expressed in dB as:

$$\text{DIST}_{dB} = 20 \log \frac{\sqrt{(V_1)^2 + (V_2)^2 + \ldots + (V_N)^2}}{\sqrt{(V_L)^2 + (V_H)^2}}$$

$$= 10\{\log[(V_1{}^2 + \ldots (V_N)^2] - \log[(V_L)^2 + (V_H)^2]\} \ldots (1)$$

Figure 4. Test Circuit for Distortion Measurement



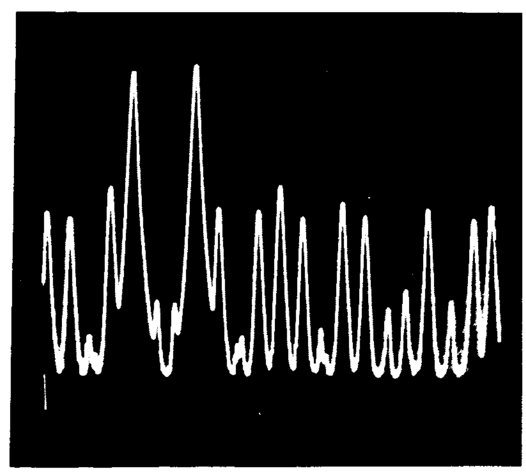
An accurate way of measuring distortion is to plot a spectrum of the signal by using a spectrum analyzer (H-P type 3580A) and an X-Y plotter (H-P type 7046A). Individual extraneous and signal frequency components are then noted and distortion is calculated by using the expression (1) above. Figure 5 shows a spectrum plot of a typical signal obtained from S2579 device operating from a fixed supply of $5V_{DC}$ and $R_L = 390\Omega$ in the test circuit of Figure 4. Mathematical analysis of the spectrum shows distortion to be −30dB (3.2%). For quick estimate of distortion, a rule of thumb as outlined below can be used.

"As a first approximation distortion in dB equals the difference between the amplitude (dB) of the extraneous component that has the highest amplitude and the amplitude (dB) of the low frequency signal." This rule of thumb would give an estimate of −28dB as distortion for the spectrum plot of Figure 5 which is close to the computed result of −30dB.

In a telephone application amplitude and distortion are affected by several factors that are interdependent. For detailed discussion of the telephone application and other applications of the S2579 Tone Generator, refer to the applications note "Applications of Digital Tone Generator."

Ref. 1: Bell System Communications Technical Reference, PUB 47001, **"Electrical Characteristics of Bell System Network Facilities at the Interface with Voiceband Ancillary and Data Equipment,"** August 1976.

Figure 5. A Typical Spectrum Plot



DEVICE: S2579 $R_L = 390\Omega$
TEMP: ROOM TEST CKT: FIGURE 4
$(V_{DD} - V_{SS})$: 5V DC FIXED DUAL TONE: R_4, C_1
HORIZONTAL SCALE = 0.5KHz/DIV
VERTICAL SCALE = 10dB/DIV