19-1398; Rev 4; 5/07





General Description

The MAX3510 is a programmable power amplifier for use in CATV upstream applications. The device outputs up to 64dBmV (continuous wave) through a 2:1 (voltage ratio) transformer. It features variable gain controlled by a 3-wire digital serial bus. Gain control is available in 1dB steps. The device operates over a frequency range of 5MHz to 65MHz.

The MAX3510 offers a transmit-disable mode, which places the device in a high-isolation state for use between bursts in TDMA systems. In this mode the output stage is shut off, minimizing output noise. When entering and leaving transmit-disable mode, transients are kept to 7mV nominal at full gain. In addition, supply current is reduced to 25mA.

Two power-down modes are available. Software-shutdown mode permits power-down of all analog circuitry while maintaining the programmed gain setting. Shutdown mode disables all circuitry and reduces current consumption to less than 10μ A.

The MAX3510 is available in a 20-pin QSOP package for the extended-industrial temperature range (-40°C to $+85^{\circ}$ C).

Cable Modems CATV Set-Top Boxes **Applications**

Telephony-Over-Cable CATV Status Monitors

_Features

- Ultra-Low Power-Up/Down Transients, 7mV Typical at 59dBmV Output
- Single +5V Supply
- Output Level Ranges from <8dBmV to 64dBmV</p>
- Gain Programmable in 1dB Steps
- Low Transmit Output Noise Floor: -47dBmV (160kHz BW)
- Low Transmit-Disable Output Noise: -70dBmV
- Two Power-Down Modes

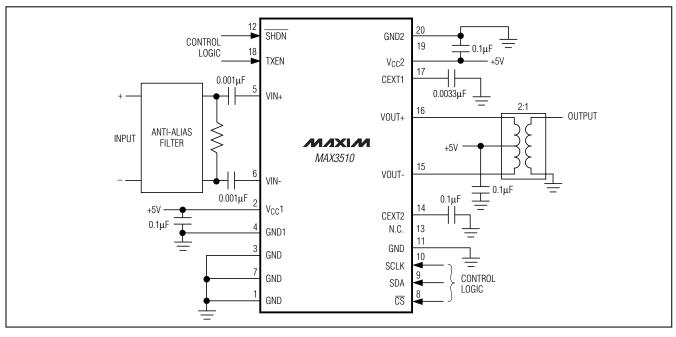
Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX3510EEP	-40°C to +85°C	20 QSOP
MAX3510EEP+	-40°C to +85°C	20 QSOP

+Denotes lead-free package.

Pin Configuration appears at end of data sheet.

Typical Operating Circuit



Maxim Integrated Products 1

For pricing, delivery, and ordering information, please contact Maxim/Dallas Direct! at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.

ABSOLUTE MAXIMUM RATINGS

V _{CC} (V _{CC} 1, V _{CC} 2), VOUT+, VOUT	0.5V to +10.0V
Input Voltage Levels (all inputs),	
CEXT1, CEXT2	0.3V to (V _{CC} + 0.3V)
Continuous Input Voltage (VIN+, VIN-)	2Vp-p
Continuous Current (VOUT+, VOUT-)	80mA

Continuous Power Dissipation (T_A = +70°C) 20-Pin QSOP (derate at 12.3mW/°C above +70°C)....1067mW Operating Temperature Range-40°C to +85°C Junction Temperature+150°C Storage Temperature Range-65°C to +165°C Lead Temperature (soldering, 10s)....+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC ELECTRICAL CHARACTERISTICS

 $(V_{CC} = +4.75V \text{ to } +5.25V, TXEN = \overline{SHDN} = \text{high}, D7 = 1, T_A = -40^{\circ}C \text{ to } +85^{\circ}C, \text{ unless otherwise noted}. No input signal applied. Typical parameters are at T_A = +25^{\circ}C.)$

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage	Vcc		4.75		5.25	V
Supply Current Transmit Mode	Icc			109	126	mA
Supply Current Transmit-Disable Mode	ICC	TXEN = low		26	30	mA
Supply Current Software- Shutdown Mode	ICC	TXEN = low, D7 = 0 (Note 3)		1.4		mA
Supply Current Shutdown Mode	ICC	SHDN = low, TXEN = low		1		μA
Input High Voltage	Vinh	$T_A = 25^{\circ}C$	2.0			V
Input Low Voltage	Vinl	$T_A = 25^{\circ}C$			0.8	V
Input High Current	IBIASH	(Note 3)			100	μA
Input Low Current	IBIASL	(Note 3)	-100			μA

AC ELECTRICAL CHARACTERISTICS

 $(V_{CC} = +4.75V \text{ to } +5.25V, TXEN = \overline{SHDN} = \text{high}, D7 = 1, V_{IN} = 34dBmV differential, output impedance = 75\Omega through a 2:1 transformer, T_A = -40°C to +85°C, unless otherwise noted. Typical parameters are at T_A = +25°C.)$

PARAMETER	SYMBOL	С	OND	ITIONS	MIN	TYP	MAX	UNITS
Voltage Gain				Gain-control word = 1, $T_A = -40^{\circ}C$ to $+85^{\circ}C$			-26	
		f _{IN} = 5MHz to 42MHz (Note 3)		n-control word = 63, : 0°C to +85°C	27			dB
	Av	(Gain-control word = 63, T _A = -40°C to 0°C		26			uв
		f _{IN} = 10MHz (Note 3)		n-control word = 50, -40°C to +85°C	16.7		20.4	
Bandwidth	f3dB	$V_{OUT} = 60 dBmV,$	-3dB	(Note 1)	84	100		MHz
Gain Rolloff (Notes 1, 2)		$V_{OUT} = 60 dBmV$, $f_{IN} = 42 MHz$			-0.9	-1	dB	
		$V_{OUT} = 60 dBmV$, $f_{IN} = 65 MHz$				-1.6	-1.8	
1dB Compression Point	P1dB	A _V = 26dB, 42M⊢	Hz (No	ote 1)	18.0	20.0		dBm
Output Stop Size		f _{IN} = 5MHz to 42MHz (Note 3)		$A_V = -26dB \text{ to } +27dB,$ $T_A = -0^{\circ}C \text{ to } +85^{\circ}C$	0.6	1	1.4	dB
Output Step Size				$A_V = -26dB$ to $+26dB$, $T_A = -40^{\circ}C$ to $0^{\circ}C$		1	1.4	ub



AC ELECTRICAL CHARACTERISTICS (continued)

 $(V_{CC} = +4.75V \text{ to } +5.25V, \text{TXEN} = \overline{\text{SHDN}} = \text{high}, \text{D7} = 1, V_{IN} = 34\text{dBmV}$ differential, output impedance = 75Ω through a 2:1 transformer, T_A = -40°C to +85°C, unless otherwise noted. Typical parameters are at T_A = +25°C.)

PARAMETER	SYMBOL	COND	MIN	ТҮР	MAX	UNITS		
T		BW = 160kHz, A _V = 26	6dB			-78	dBc	
Transmit Mode Noise (Note 1)		BW = 160kHz, A _V = -2	6dB		47	-46	dBmV	
Transmit-Disable Mode Noise Floor		$\begin{array}{l} TXEN = low, BW = 160\\ A_V = +26dB, f_{\mathsf{IN}} = 5MH \end{array}$			-70	dBmV		
Isolation in Transmit-Disable Mode		TXEN low, gain control fIN = 65MHz	36	45		dB		
TXEN Transient Duration		TXEN rise/fall time < 0.1	µs, T _A = +25°C (Note 1)		3.2	5	μs	
TXEN Transient Step Size		Gain = 26dB, T _A = +2	5°C		7	37		
(Note 1)		Gain = 2dB or lower, T	A = +25°C		0.7	3.7	- mV _{P-P}	
Input Impedance	Z _{IN}	$f_{IN} = 5MHz$ to 65MHz, $T_A = +25^{\circ}C$ (Note 1)	single-ended,	1.4	1.5		kΩ	
Output Impedance	Zout				75		Ω	
			$T_A = 0^{\circ}C$	8.0	13.5			
Output Return Loss in Transmit Mode	RL	f _{IN} = 5MHz to 65MHz (Note 1)	$T_A = +25^{\circ}C$	8.7	13.5		dB	
Mode			T _A = +85°C	8.9	13.9			
	RL	TXEN = low, $f_{IN} = 5MHz$ to $65MHz$	$T_A = 0^{\circ}C$	7.1	12.0		dB	
Output Return Loss in Transmit-Disable Mode			$T_A = +25^{\circ}C$	7.7	12.2			
		(Note 1)	$T_A = +85^{\circ}C$	9.7	12.7			
Two-Tone Third-Order Distortion	IM3	Input tones at 40MHz a V _{IN} = 28dBmV/tone, V ₀ T _A = +25°C			-56			
(Note 1)	1010	Input tones at 65MHz a V _{IN} = 28dBmV/tone, V ₀ T _A = +25°C		-54	-51	dBc		
		f _{IN} = 33MHz, (Note 3)	$V_{OUT} = +54 dBmV$		-59	-53		
2nd Harmonic Distortion	HD2	$T_A = -40^{\circ}C \text{ to } +85^{\circ}C$	$V_{OUT} = +59 dBmV$		-55	-50		
	HD2	$f_{IN} = 65MHz$, $V_{OUT} = 4T_A = +25^{\circ}C$ (Note 1)		-54	-50	dBc		
		f _{IN} = 22MHz,	Vout = +54dBmV		-58	-53		
2rd Harmonia Distortion	HD3	$T_{A} = -40^{\circ}C \text{ to } +85^{\circ}C$	$V_{OUT} = +59 dBmV$		-54	-50	,,,	
3rd Harmonic Distortion		$f_{IN} = 65MHz$, $V_{OUT} = 4T_A = +25^{\circ}C$ (Note 1)		-49	-44	- dBc		
AM to AM	AM/AM	A _V = 26dB, V _{IN} swept 38dBmV (Note 1)		0.1		dB		
AM to PM	AM/PM	A _V = 26dB, V _{IN} swept 38dBmV (Note 1)	from 34dBmV to		1		degree	

TIMING CHARACTERISTICS

(V_{CC} = +4.75V to +5.25V, TXEN = \overline{SHDN} = high, D7 = 1, T_A = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	COMMENT	MIN	TYP	MAX	UNITS
CS to SCK Rise Setup Time	tSENS		10			ns
CS to SCK Rise Hold Time	t SENH		20			ns
SDA to SCK Setup Time	tSDAS		10			ns
SDA to SCK Hold Time	t _{SDAH}		20			ns
SDA Pulse-Width High	t DATAH		50			ns
SDA Pulse-Width Low	t DATAL		50			ns
SCK Pulse-Width High	tsckh		50			ns
SCK Pulse-Width Low	t SCKL		50			ns

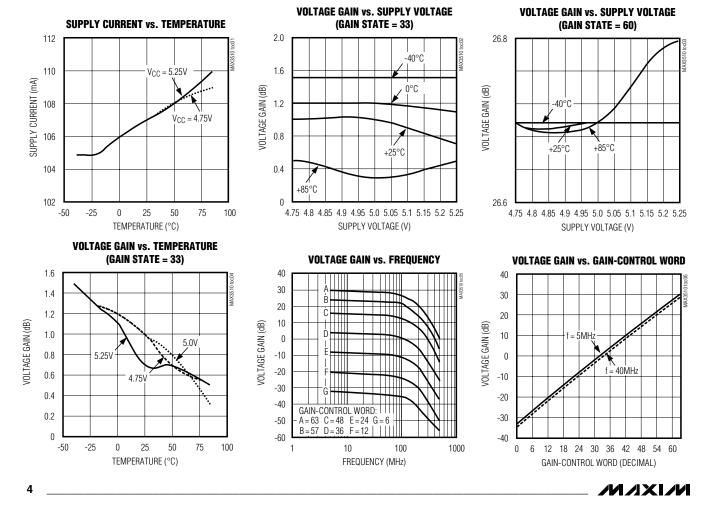
Note 1: Guaranteed by design and characterization.

Note 2: Reference to 5MHz.

Note 3: Parameters <25°C guaranteed by design and characterization ±3.

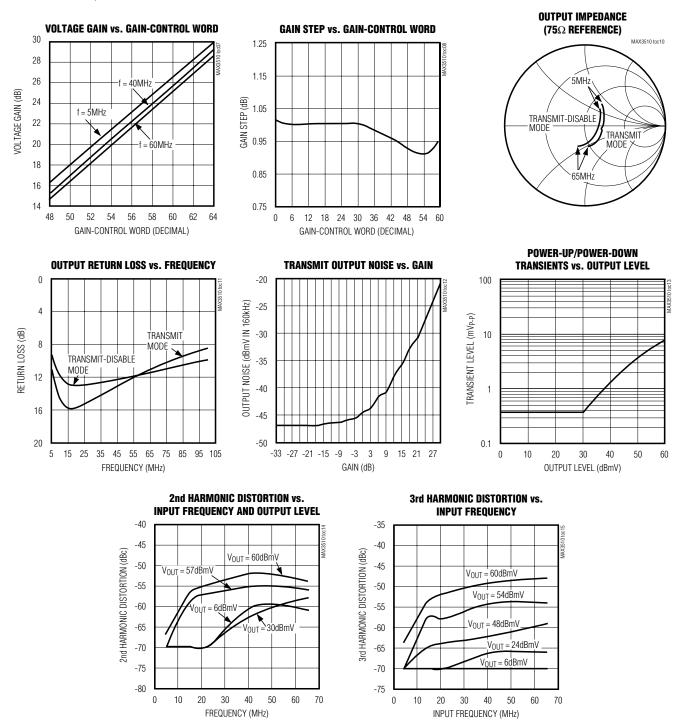
Typical Operating Characteristics

(V_{CC} = +5V, V_{IN} = +34dBmV, TXEN = \overline{SHDN} = high, f_{IN} = 20MHz, Z_{LOAD} = 75 Ω through a 2:1 transformer, T_A = +25°C, unless otherwise noted.)



Typical Operating Characteristics (continued)

 $(V_{CC} = +5V, V_{IN} = +34dBmV, TXEN = \overline{SHDN} = high, f_{IN} = 20MHz, Z_{LOAD} = 75\Omega$ through a 2:1 transformer, T_A = +25°C, unless otherwise noted.)



MXXIM

MAX3510

FREQUENCY	TRANSM	IIT MODE	TRANSM	IIT MODE	TRANSMIT DISABLE MODE		
MHz	REAL S11	IMAG S11	REAL S22	IMAG S22	REAL S22	IMAG S22	
1	0.937	-0.006	-0.494	0.625	-0.509	0.623	
2	0.937	-0.007	-0.054	0.550	-0.075	0.577	
5	0.936	-0.005	0.196	0.199	0.219	0.257	
10	0.932	-0.011	0.183	0.017	0.244	0.062	
20	0.932	-0.018	0.143	-0.081	0.219	-0.052	
30	0.932	-0.026	0.108	-0.149	0.194	-0.121	
40	0.927	-0.033	0.059	-0.199	0.158	-0.175	
60	0.922	-0.054	-0.060	-0.257	0.066	-0.252	
80	0.913	-0.075	-0.197	-0.252	-0.049	-0.284	
120	0.889	-0.145	-0.420	-0.070	-0.281	-0.207	
160	0.850	-0.249	-0.442	0.256	-0.409	0.037	
200	0.753	-0.408	-0.212	0.543	-0.327	0.345	

Table 1. Reflection Coefficients (75 Ω reference)

Pin Description

PIN	NAME	FUNCTION
1, 3, 7, 11	GND	Ground Pins
2	V _{CC} 1	Programmable-Gain Amplifier (PGA) +5V Supply. Bypass this pin to GND1 with a decoupling capacitor as close to the part as possible.
4	GND1	PGA RF Ground. As with all ground connections, maintain the shortest possible (low-inductance) length to the ground plane.
5	VIN+	Positive PGA Input. Along with VIN-, this port forms a high-impedance differential input to the PGA. Driving this port differentially will increase the rejection of second-order distortion at low output levels.
6	VIN-	Negative PGA Input. When not used, this port must be AC-coupled to ground. See VIN+.
8	CS	Serial-Interface Enable. TTL-compatible input. See the Serial Interface section.
9	SDA	Serial-Interface Data. TTL-compatible input. See the Serial Interface section.
10	SCLK	Serial-Interface Clock. TTL-compatible input. See the Serial Interface section.
12	SHDN	Shutdown. When this pin and TXEN (pin 18) are set low, all functions (including the serial interface) are dis- abled, leaving only leakage currents to flow.
13	N.C.	No Connection
14	CEXT2	RF Output Bypass. This pin must be bypassed to ground with a 0.1µF capacitor.
15	VOUT-	Negative Output. Along with VOUT+, this port forms a 300Ω impedance output. This port is matched to a 75Ω load using a 2:1 transformer.
16	VOUT+	Positive Output. See VOUT
17	CEXT1	Transmit-Disable (Enable) Timing Capacitor. See the Ramp Generator section.
18	TXEN	Power-Amplifier Enable. Setting this pin low shuts off the power amplifier.
19	V _{CC} 2	Power Amplifier Bias, +5V Supply. Bypass this pin to GND2 with a decoupling capacitor as close to the part as possible.
20	GND2	Power Amplifier Bias Ground. As with all ground connections, maintain the shortest possible (low induc- tance) length to the ground plane.



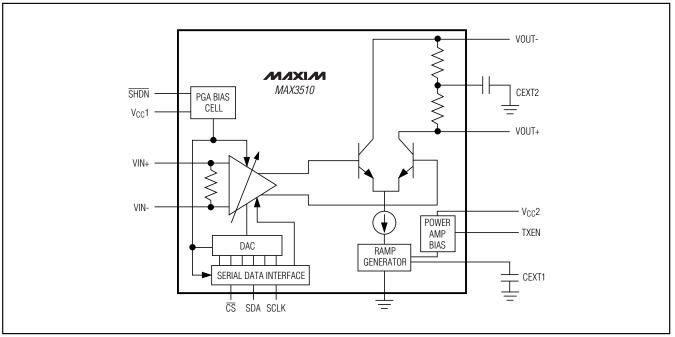


Figure 1. Functional Diagram

Detailed Description

The following sections describe the blocks shown in the functional diagram (Figure 1).

Programmable-Gain Amplifier

The programmable-gain amplifier (PGA) consists of the variable-gain amplifier (VGA) and the digital-to-analog converter (DAC), which provide better than 52dB of output level control in 1dB steps.

The PGA is implemented as a programmable Gilbertcell attenuator. It uses a differential architecture to achieve maximum linearity. The gain of the PGA is determined by a 6-bit word (D5–D0) programmed through the serial data interface (Tables 2 and 3).

Specified performance is achieved when the input is driven differentially. The device may be driven singleended; however, a slight increase in even-order distortion may result at low output levels. To drive the device in this manner, one of the input pins must be capacitively coupled to ground. Use a capacitor value large enough to allow for a low-impedance path to ground at the lowest frequency of operation. For operation down to 5MHz, a 0.001μ F capacitor is suggested.

Power Amplifier

The power amplifier is a Class A differential amplifier capable of driving +64dBmV differentially. This architecture provides superior even-order distortion performance but requires that a transformer be used to convert to a single-ended output. In transmit-disable mode, the power amplifier is shut off. An internal resistor is placed across the output, so that the output impedance remains matched when the amplifier is in transmit-disable mode. Disabling the output devices also allows the lowest standby noise.

To achieve the proper load line, the output impedance of the power amplifier is 300Ω differential. To match this output impedance to a 75Ω load, the transformer must have a turns ratio (voltage ratio) of 2:1 (4:1 impedance ratio).

The differential amplifier is biased directly from the +5V supply using the center tap of the output transformer. This provides a significant benefit when switching between transmit mode and transmit-disable mode. Stored energy due to bias currents will cancel within the transformer and prevent switching transients from reaching the load.

Ramp Generator

The ramp generator circuit is a simple RC charging circuit, which is used to control power-up and power-down of the output power amplifier. It is made up of CEXT1 and an internal $2k\Omega$ resistor. The choice of CEXT1 is governed by the period of the burst on/off cycle. CEXT1 must be small enough to fully charge/discharge within a burst. A typical value of CEXT1 is 0.0033µF.

Serial Interface

The serial interface has an active-low enable $\overline{(CS)}$ to bracket the data, with data clocked in MSB first on the rising edge of SCLK. Data is stored in the storage latch on the rising edge of \overline{CS} . The serial interface controls the state of the PGA. Tables 2 and 3 show the register format. Serial-interface timing is shown in Figure 2.

PGA Bias Cell

The PGA bias cell is accessed by the SHDN pin. When this pin is taken low, the programmable-gain amplifier and serial data interface are shut off. Note that any gain setting stored in the serial data interface latch will be lost. The power amplifier is unaffected by the PGA Bias cell, therefore TXEN must be held low to be in shutdown mode. This mode lowers supply current draw to less than 1µA typical.

Power Amp Bias Cell

The power amp bias cell is used to enable and disable bias to the output differential pair. This is controlled by the TXEN pin (18).

Functional Modes

The MAX3510 has four functional modes controlled through the serial interface or external pins (Table 3): transmit mode, transmit-disable mode, software-shut-down mode, and shutdown mode.

Transmit Mode

Transmit mode is the normal active mode of the MAX3510. The <u>TXEN</u> pin must be held high in this mode. Note that <u>SHDN</u> must also be held high.

Transmit-Disable Mode

When in transmit-disable mode, the power amplifier is completely shut off. This mode is activated by taking TXEN low while keeping SHDN high. This mode is typically used between bursts in TDMA systems. Transients are controlled by the action of the transformer balance.

Software-Shutdown Mode

Software-shutdown mode is enabled when D7 = 0 and TXEN is low. This mode minimizes current consumption while maintaining the programmed gain state stored in the latch of the serial-data interface. All analog func-

tions are disabled in this mode and current consumption is reduced to under 2mA.

Shutdown Mode

In normal operation the shutdown pin (\overline{SHDN}) is held high. When \overline{SHDN} and \overline{TXEN} are taken low, all circuits within the IC are disabled. Only leakage currents flow in this state. Data stored within the serial-data interface latches will be lost upon entering this mode. Current draw is reduced to 1µA (typ) in shutdown mode.

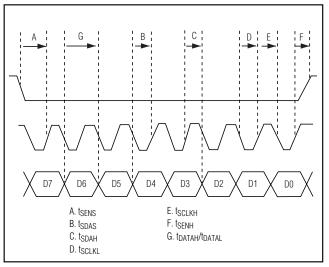


Figure 2. Serial-Interface Timing Diagram

Table 2. Serial-Interface Control Word

BIT	MNEMONIC	DESCRIPTION				
MSB 7	D7	Software Shutdown				
6	D6	Test Bit				
5	D5	Gain Control, Bit 5				
4	D4	Gain Control, Bit 4				
3	D3	Gain Control, Bit 3				
2	D2	Gain Control, Bit 2				
1	D1	Gain Control, Bit 1				
LSB 0	D0	Gain Control, Bit 0				



SHDN	TXEN	D7	D6	D5	D4	D3	D2	D1	D0	GAIN STATE (DECIMAL)	STATE
0	0	Х	Х	Х	Х	Х	Х	Х	Х	Х	Shutdown Mode
1	0	0	Х	Х	Х	Х	Х	Х	Х	Х	Software-Shutdown Mode
1	0	1	Х	Х	Х	Х	Х	Х	Х	Х	Transmit-Disable Mode
1	1	1	Х	Х	Х	Х	Х	Х	Х	Х	Transmit Mode
1	1	1	Х	0	0	0	0	0	0	0	$Gain = -32dB^*$
1	1	1	Х	0	0	0	0	0	1	1	Gain = -31dB*
1	1	1	Х						_		—
1	1	1	Х	1	0	0	0	0	0	32	Gain = 0dB*
1	1	1	Х	_	_	_	_	_	_		_
1	1	1	Х	1	1	1	1	1	0	62	Gain = 29dB*
1	1	1	Х	1	1	1	1	1	1	63	Gain = 30dB*

Table 3. Chip-State Control Bits

*Typical gain at +25°C and $V_{CC} = +5V$

Applications Information

Output Match

The MAX3510's output circuit is an open-collector differential amplifier. An on-chip resistor across the collectors provides a nominal output impedance of 300Ω in transmit mode and transmit disable mode.

Transformer

To match the output of the MAX3510 to a 75 Ω load, a 2:1 (voltage ratio) transformer is required. This transformer must have adequate bandwidth to cover the intended application. Note that most RF transformers specify bandwidth with a 50 Ω source on the primary and a matching resistance on the secondary winding. Operating in a 75 Ω system will tend to shift the low-frequency edge of the transformer bandwidth specification up by a factor of 1.5, due to primary inductance. Keep this in mind when specifying a transformer.

Bias to the output stage is provided through the center tap on the transformer primary. This greatly diminishes the on/off transients present at the output when switching between transmit and transmit-disable modes. Commercially available transformers typically have adequate balance between half-windings to achieve substantial transient cancellation.

Finally, keep in mind that transformer core inductance varies proportionally with temperature. If the application requires low temperature extremes (less than 0°C),

adequate primary inductance must be present to sustain low-frequency output capability as temperatures drop. In general this will not be a problem, as modern RF transformers have adequate bandwidth.

Input Circuit

To achieve rated performance, the input of the MAX3510 must be driven differentially with an appropriate input level. The differential input impedance is approximately $1.5k\Omega$. Most applications will require a differential lowpass filter preceding the device. The filter design will dictate terminating impedance of a specified value. Place this load impedance across the AC-coupled input pins (see *Typical Operating Circuit*).

The MAX3510 has sufficient gain to produce an output level of 60dBmV (CW through a 2:1 transformer) when driven with a 34dBmV input signal. Rated performance is achieved with this input level. When a lower input level is present, the maximum output level will be reduced proportionally and output linearity will increase. If an input level greater than 34dBmV is used, the 3rd-order distortion performance will degrade slightly.

If a single-ended source drives the MAX3510, one of the input terminals must be capacitively coupled to ground (VIN+ or VIN-). The value of this capacitor must be large enough to look like a short circuit at the lowest frequency of interest. For operation at 5MHz with a 75 Ω source impedance, a value of 0.1µF will suffice.



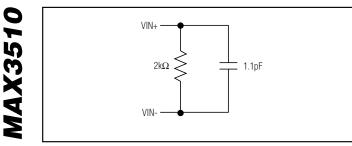


Figure 3. Equivalent Input Circuit

The model for the MAX3510 input impedance is shown in Figure 3.

Layout Issues

A well-designed printed circuit board is an essential part of an RF circuit. For best performance pay attention to power-supply layout issues as well the output circuit layout.

Output Circuit Layout

The differential implementation of the MAX3510's output has the benefit of significantly reducing even-order distortion, the most significant of which is 2nd-harmonic distortion. The degree of distortion cancellation depends on the amplitude and phase balance of the overall circuit. It is critical that the traces that lead from the output pins be exactly the same length.

Power-Supply Layout

For minimal coupling between different sections of the IC, the ideal power-supply layout is a star configuration. This configuration has a large-value decoupling capacitor at the central power-supply node. The power-supply traces branch out from this node, each going to a separate power-supply node in the MAX3510 circuit. At the end of each of these traces is a decoupling capacitor that provides a very low impedance at the frequency of interest. This arrangement provides local power-supply decoupling at each power-supply pin.

The power supply traces must be made as thick as practical to keep resistance well below 1 $\!\Omega.$

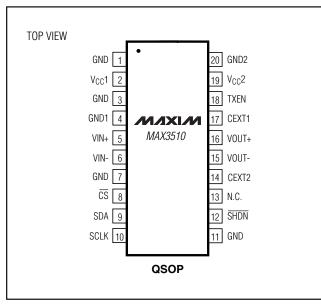
Ground inductance degrades distortion performance. Therefore, ground plane connections to GND1 and GND2 should be made with multiple vias if possible.

Chip Information

TRANSISTOR COUNT: 736

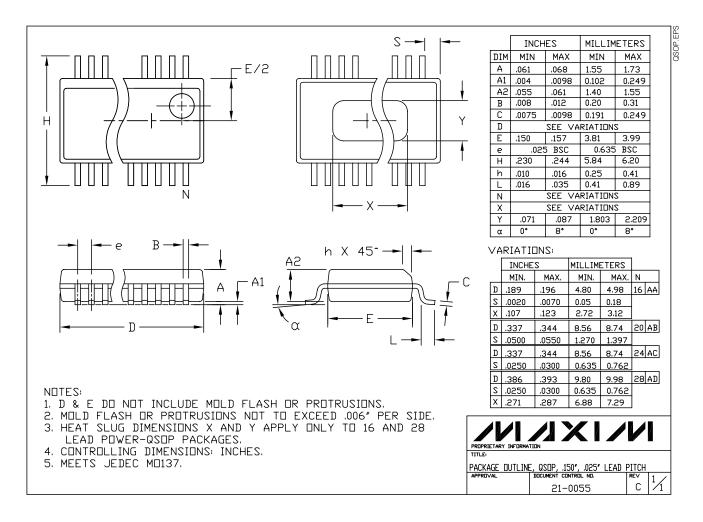


__Pin Configuration



Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)



Revision History

Pages changed at Rev 4: 1, 2, 12

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