FAIRCHILD
SEMICONDUCTOR®

SPT5510

16-BIT, 200 MWPS ECL D/A CONVERTER

FEATURES

- 16-Bit, 200 MWPS digital-to-analog converter
- Differential linearity of ±0.6 LSB (typical)
- Integral linearity of ±0.75 LSB (typical)
- Fast settling time: 35 ns to 0.0008%; 25 ns to 0.01%
- Low glitch energy
- On-chip voltage reference
- ECL compatibility

APPLICATIONS

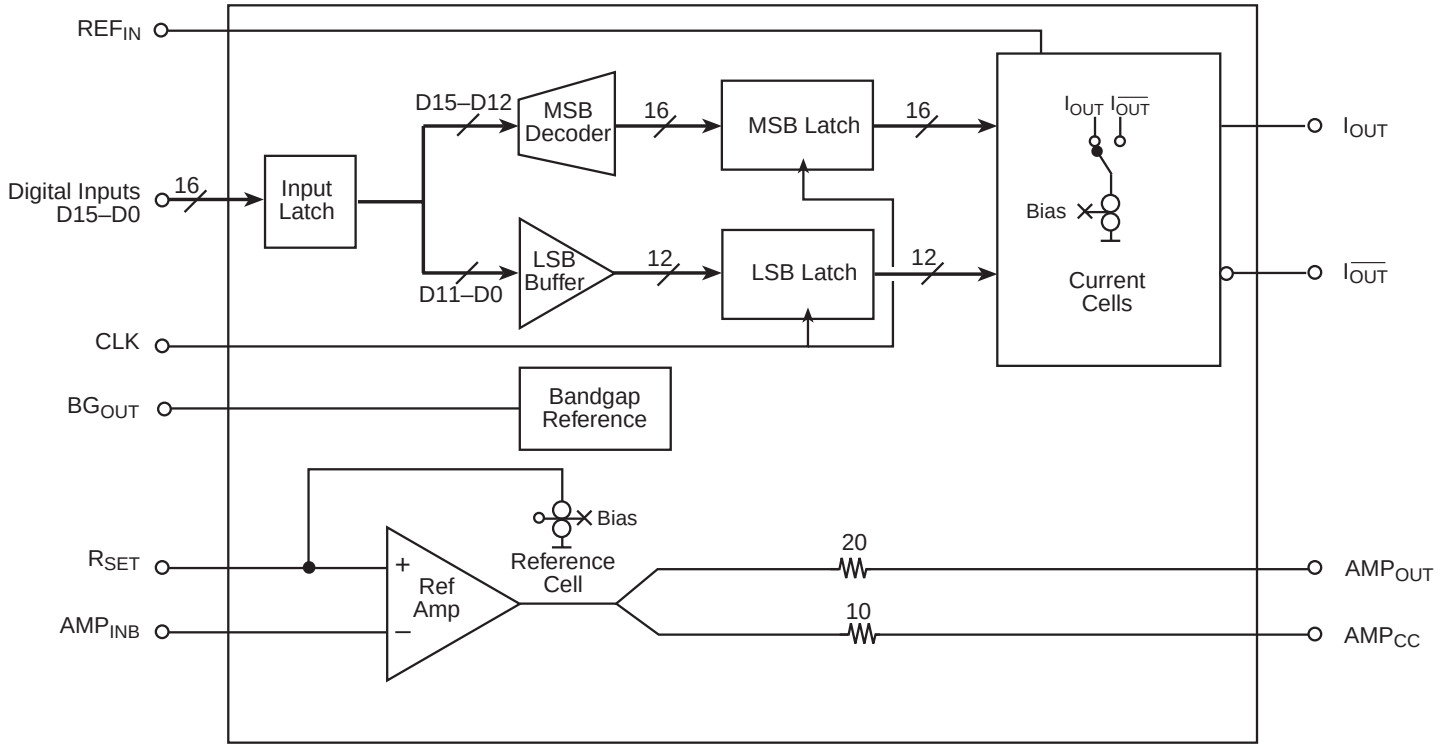
- High-precision arbitrary waveform generation
- Test and measurement instrumentation
- Digital waveform synthesis
- Microwave and satellite modems
- Disk drive test equipment
- Industrial process control
- Military applications

GENERAL DESCRIPTION

The SPT5510 is a 16-bit, 200 MWPS digital-to-analog converter designed for high-resolution waveform synthesis for test and measurement instrumentation applications. It features true 16-bit linearity, with differential non-linearity of typically ±0.6 LSB and integral non-linearity of ±0.75 LSB. It has a very high-speed update rate of up to 200 MHz and is ECL compatible. It has an ultrafast settling time of 25 ns to 0.01% and 35 ns to 0.0008%.

The SPT5510 operates over an industrial temperature range of –40 °C to +85 °C and is available in a 10 x 10 mm, 44-lead metric quad flat pack (MQFP) plastic package.

BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS (Beyond which damage may occur)[1]

Supply Voltages

Negative supply voltage (V_{EE}) ..... –7 V
A/D ground voltage differential ..... 0.5 V

Input Voltages

Digital input voltage (D15–D0, Clock)... ..... –2.5 to 0 V
Ref amp input voltage range ..... –2.5 to 0 V
Reference input voltage range (Ref In) ..... V_{EE} to –2.5 V

Output Currents

Bandgap reference output current ..... ±500 µA
Ref amplifier output current ..... ±2.5 mA

Temperature

Operating temperature ..... –40 to +85 °C
Junction temperature ..... +150 °C
Lead, soldering (10 seconds) ..... +250 °C
Storage ..... –65 to +150 °C

Note: 1. Operation at any Absolute Maximum Rating is not implied. See Electrical Specifications for nominal operating conditions.

ELECTRICAL SPECIFICATIONS

T_A= 25 °C, V_{EE}=–5.2 V ±5%, 50% duty cycle clock, unless otherwise specified.

PARAMETERS	TEST CONDITIONS	TEST LEVEL	SPT5510 MIN	SPT5510 TYP	SPT5510 MAX	UNITS
DC Performance[1]						
Resolution				16		Bits
Differential Linearity		VI	–1.95	±0.6	1.95	LSB
Differential Linearity	T_{MIN}–T_{MAX}	IV	–4.0	±1.0	4.0	LSB
Integral Linearity		VI	–1.95	±0.75	1.95	LSB
Integral Linearity	T_{MIN}–T_{MAX}	IV	–4.0	±1.5	4.0	LSB
Integral Linearity Drift		IV	–0.2		0.2	LSB/°C
Offset Drift	T_{MIN}–T_{MAX}	IV	–2.5		2.5	ppm FS/°C
Monotonicity		V	15			Bits
Output Capacitance		V		10		pF
Gain Error		I	–2	0.4	2	% FS
Gain Error Tempco	With Ext Reference	V		50		ppm FS/°C
Gain Error Tempco	With Internal Bandgap Ref	V		50		ppm FS/°C
Offset Error		I	–4		4	µA
Compliance Voltage		IV	–1.2		2	V
Output Resistance		IV	0.88	1.1	1.32	kΩ
Dynamic Performance						
Conversion Rate		IV	200			MHz
Settling Time t_{ST}[2]						
	Settling to ±0.01%	V		25		ns
	Settling to ±0.0008%	V		35		ns
Delay Time t_D		V		2		ns
Glitch Energy		V		30		pV-s
Full Scale Output Current	With On-Chip References	V		19		mA
Rise Time/Fall Time	R_L = 50 Ω	V		2		ns
Spurious Free Dynamic Range						
f_{OUT}=5 MHz; f_{CLOCK}=30 MHz	10 MHz Span	V		84		dB
f_{OUT}=10 MHz; f_{CLOCK}=100 MHz	10 MHz Span	V		76		dB

[1]Measured at 0 V output using I-V.

[2]Measured as voltage settling for mid-scale transition; R_L = 50 Ω.

ELECTRICAL SPECIFICATIONS

T_A= 25 °C, V_{EE}=–5.2 V ±5%, 50% duty cycle clock, unless otherwise specified.

PARAMETERS	TEST CONDITIONS	TEST LEVEL	SPT5510 MIN	SPT5510 TYP	SPT5510 MAX	UNITS
Power Supply Requirements						
Negative Supply Current (–5.2 V)	T_{MIN} –T_{MAX}	VI		115	150	mA
Nominal Power Dissipation		V		600	800	mW
Power Supply Rejection Ratio	ΔV Supply = ±5 %	I	–0.6	±0.002	0.6	% FS
Voltage Input and Control						
Bandgap Reference Voltage		V		–1.2		V
Bandgap Output Current	T_A=25 °C ±10 °C	IV	–110	16	220	µA
Ref Amp Bandwidth[3]		V		40		MHz
Ref Amp Input Current		V		16		µA
Ref Amp Output Current		V		200		µA
Ref In Operating Voltage		V		–3.4		V
Digital Inputs						
Logic 1 Voltage	T_{MIN} –T_{MAX}	VI	–1.0	–0.8		V
Logic 0 Voltage	T_{MIN} –T_{MAX}	VI		–1.7	–1.5	V
Logic 1 Current	–0.8 V	V		2.5		µA
Logic 0 Current	–1.8 V	V		0		µA
Input Capacitance		V		3		pF
Input Setup Time (t_S)		IV	3.0			ns
Input Hold Time (t_H)		IV	0.5			ns
Clock Pulse Width (t_{PWH})		IV	1.5			ns

[3]Ref Amp Bandwidth is limited by its compensation network

TEST LEVEL CODES

All electrical characteristics are subject to the following conditions:

All parameters having min/max specifications are guaranteed. The Test Level column indicates the specific device testing actually performed during production and Quality Assurance inspection. Any blank section in the data column indicates that the specification is not tested at the specified condition.

TEST LEVEL	TEST PROCEDURE
I	100% production tested at the specified temperature.
II	100% production tested at T_A = +25 °C, and sample tested at the specified temperatures.
III	QA sample tested only at the specified temperatures.
IV	Parameter is guaranteed (but not tested) by design and characterization data.
V	Parameter is a typical value for information purposes only.
VI	100% production tested at T_A = +25 °C. Parameter is guaranteed over specified temperature range.

THEORY OF OPERATION

The SPT5510 is a segmented 16-bit current-output DAC. The four MSBs, D15–D12, are decoded to fifteen unit cells (current sinks). The remaining bits (D11–D0) are binary; bits D9–D0 are derived from an R-2R ladder. All cells are laser trimmed for maximum accuracy. The block diagram shows the basic architecture.

All output cells are always on, with the data determining whether a given cell's current is routed from I_{OUT} or $I_{\overline{OUT}}$. This provides nearly constant power dissipation independent of data and clock rate. It also reduces noise transients on power and ground lines.

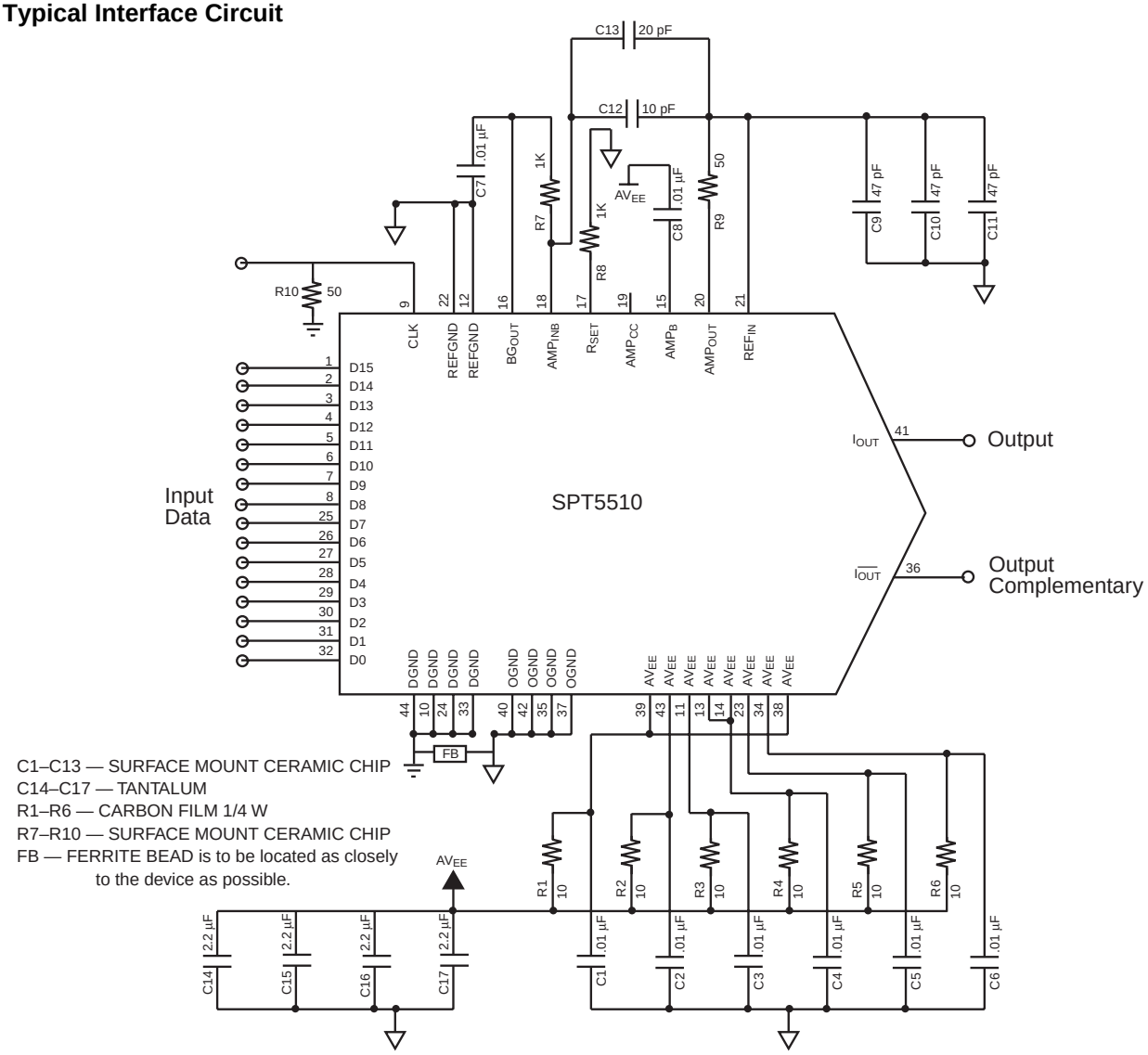
The reference loop utilizes an MSB-weighted cell and provides a gain of about 16 to the output. The on-chip reference amplifier has very high open-loop gain and is offset trimmed to provide a very low temperature drift (typically <10 ppm/°C gain drift).

POWER SUPPLY AND GROUNDING

The SPT5510 requires a single –5.2V power supply. All supply pins attach to a common on-chip power bus and should be treated as analog supplies. For best settling performance, each supply pin should be decoupled as shown in figure 1 – typical interface circuit.

There are three separate on-chip ground busses. DGND pins should be tied together and connected to system ground through a ferrite bead. REFGND and OGND pins should be tied directly to the SPT5510's ground plane and connected to system ground through a ferrite bead. It is critical that REFGND and OGND are very tightly coupled, as any differential signal (dc offset, noise, etc.) will be transmitted to the output. Two of the OGND pins can be disconnected from the ground plane and used as sense lines for a current-to-voltage converter, as shown in the OUTPUTS section.

Figure 1 – Typical Interface Circuit



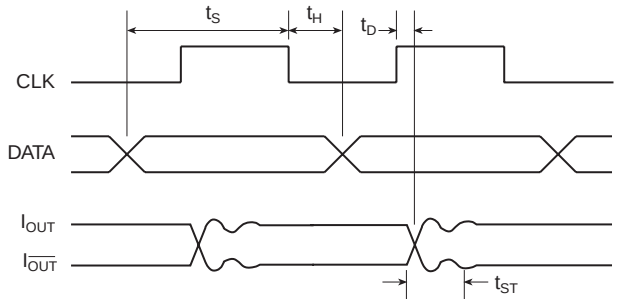
Wideband decoupling is required for optimum settling performance. This may require several capacitors in parallel, and series resistors when appropriate, to reduce resonance effects. Some applications may need only a single capacitor; however, decoupling influences both long- and short-term settling, so caution is urged. Your application may require some research to determine the optimum power supply decoupling network.

DIGITAL INPUTS AND TIMING

Each digital input is buffered, decoded, and then latched into D flip-flops which drive the output switches. Master-slave flip-flops are not used; thus, there is only a 1/2 clock period delay (max) from data change to output change. In this architecture, clock and data edge speeds (i.e., rise/fall times) may affect data feedthrough. Using a data edge of approximately 0.8 ns will cause data feedthrough of about 10 pV-s, while a 5 ns data edge will reduce the feedthrough to about 4 pV-s. Data lines may include series resistors or RC filters for edge control if desired.

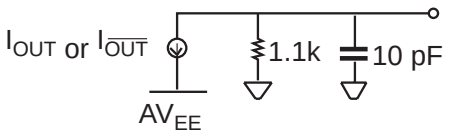
The clock signal controls when the data is latched into the flip-flops. When the CLK is high, the DAC is in track mode. A negative going CLK latches the data. If CLK is held low, the DAC is in hold mode. See figure 2.

Figure 2 – Timing Diagram



t_H = hold time
t_D = time to output valid
t_S = setup time
t_{ST} = settling time

Figure 3 – Equivalent Output Circuit



OUTPUTS

The output is comprised of current sinks, R-2R ladder, and associated parasitics. See figure 3 for an equivalent output circuit.

The DAC's full-scale output current when using the internal reference amplifier is determined by the voltage at pin AMP_{INB} and the R_{SET} resistance. It can be found (to within an LSB) by using the following formula:

$$I_{OUT}\ FS = (AMP_{INB}/R_{SET}) \times 16$$

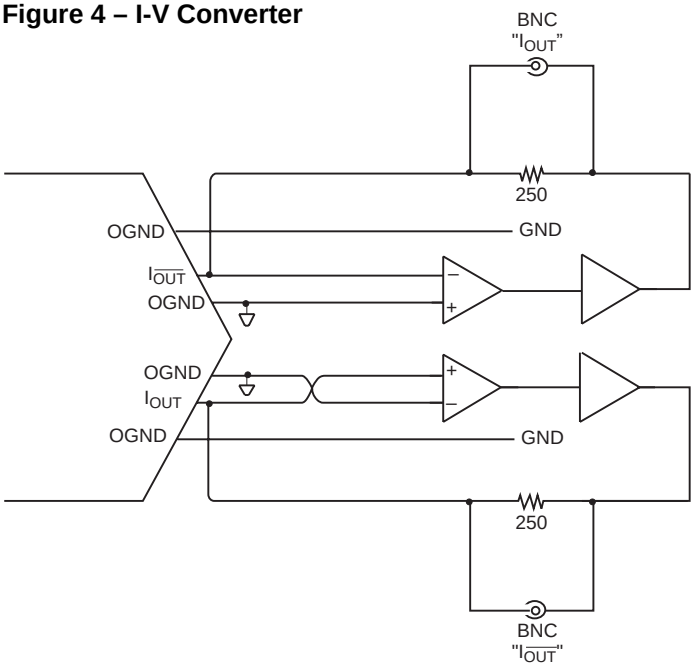
The inputs determine whether the current from each sink comes from I_{OUT} or $I_{\overline{OUT}}$ as follows:

Code (D15 is MSB)	I_{OUT}	$I_{\overline{OUT}}$
0 (zero scale)	No current	All current
32768 (mid-scale)	$I_{OUT} = I_{\overline{OUT}}$	$I_{OUT} = I_{\overline{OUT}}$
65535 (full-scale)	All current	No current

Differential outputs facilitate maximum noise rejection and signal swing. The DAC is trimmed using a current to voltage (I-V) converter which provides a virtual ground at the outputs and includes sense lines to mitigate the impact of bus drops. Operating into a load other than a virtual ground will introduce a slight bow at the output. This bow is related to the current sinks' finite output impedance and ladder impedance.

An example circuit using an I-V converter is shown in figure 4. Note that resistor and op-amp self heating over the DAC's full-scale range will introduce additional temperature dependence. The op-amp and feedback resistor must both have very low tempcos if the DAC's intrinsic gain drift is to be maintained. A sense line helps reduce wire effects – both IR loss and temperature drift.

Figure 4 – I-V Converter

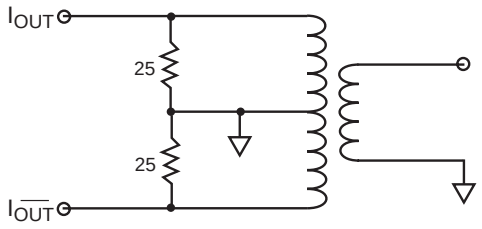


The feedback resistor should be matched to R_{SET} to reduce gain drift. Also, the op amp's ground reference should be the same as R_{SET}'s to reduce gain and offset errors. A composite amplifier may be required to obtain optimal dc performance. A differential circuit may be used; a common heat sink covering both sides (op amps and resistors) will help reduce temperature effects.

Achieving good settling performance requires careful board layout with multiple decoupling circuits and very clean power and ground routing. It is important that digital switching currents do not flow across analog input (REF_{IN}) and output signals. Terminations must be broadband and near the device. Measuring settling performance is quite challenging and requires several test systems to ensure settling errors from the instruments are not included.

Dynamic performance characteristics (e.g., settling, rise and fall times, etc.) were measured with the outputs terminated to ground through 50 Ω resistors. SFDR was determined using a transformer to convert the output from differential to single-ended as shown in figure 5. The SPT5510 is designed primarily for step and settle or narrowband RF applications. The second harmonic generally dominates wideband SFDR measurements, although close-in spurs are very small.

Figure 5 – Transformer Output Circuit



BANDGAP VOLTAGE REFERENCE

The on-chip bandgap voltage reference is designed to bias the non-inverting input of the reference amplifier (AMP_{INB}) through a resistor equal to R_{SET} to help compensate the reference amplifier (see the following section). If the bandgap voltage is required by another DAC, or elsewhere in the system, it must be buffered with a precision op amp configured as a high impedance (e.g., unity gain follower) buffer. A resistor, or RC filter, plus a ferrite bead will help isolate the output from the reference amplifier's compensation and high-frequency charge pulses produced during operation. The output should always be very carefully checked for oscillations using a sensitive, wideband oscilloscope and spectrum analyzer.

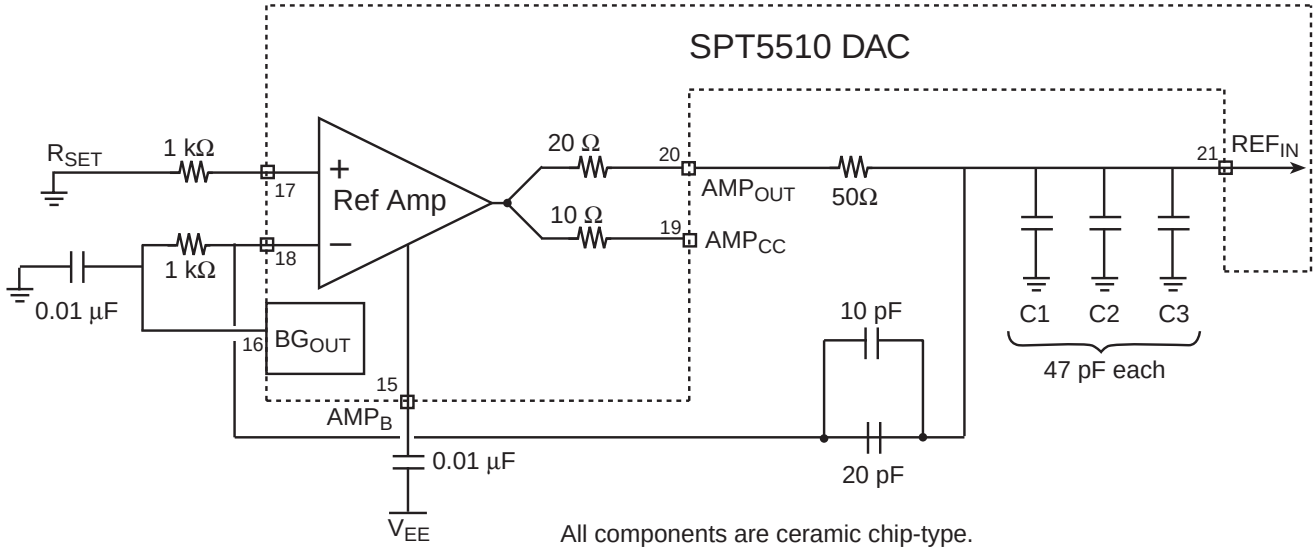
REFERENCE AMPLIFIER

The reference amplifier is a highly temperature-stable driver to bias the precision current sinks. The reference amplifier should only be used to drive REF_{IN}. Additional loads will change the amplifier's compensation, which can lead to instability and other settling issues.

There are two reference amplifier outputs: AMP_{OUT} and AMP_{CC}. AMP_{OUT} has a 20 ohm series resistor between the output of the reference amplifier and the AMP_{OUT} pin; AMP_{CC} has a 10 ohm resistor. These parallel outputs aide compensation and decoupling. The open-loop output impedance is approximately 1200 ohms.

Reference amplifier compensation is key to achieving high performance. Without proper compensation, oscillations that affect accuracy and settling time will occur. Figure 6 shows a typical reference amplifier compensation circuit. Note that several small value capacitors are used from REF_{IN} to ground. This is to provide suitably low impedance

Figure 6 – Reference Amplifier Circuit



All components are ceramic chip-type.

around 300 MHz, the amplifier's phase crossover point. The unity-gain bandwidth is roughly 700 MHz. Larger value capacitors exhibit lower self-resonance frequency and thus may not adequately compensate the reference amplifier. Large capacitors may also introduce low frequency tails which increase settling time. The DAC itself exhibits very broadband switching spikes (charge kickback) at the R_{SET} node, which can contribute to amplifier instability if not suppressed. Note that the AMP_{INB} input must not be directly bypassed, as this will short all feedback to ground, leading to severe oscillation.

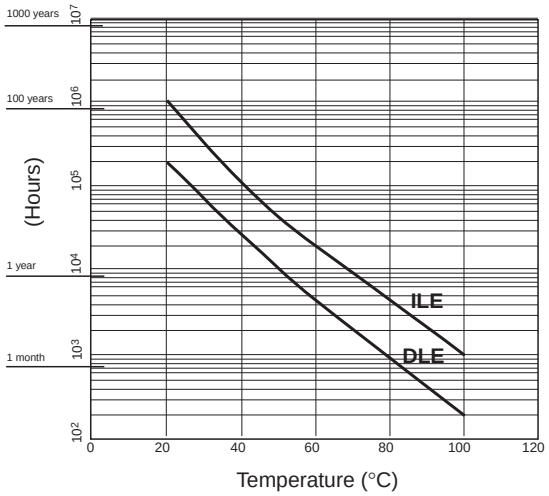
Compensation must be optimized for each application. As with any high-speed, high-resolution design, attention must be paid to grounding, decoupling, and parasitic elements that may cause instability. It may be wise to use a guard ring, and/or clear the board ground, around the reference amplifier's inputs. All traces must be short, and capacitors with high self-resonance must be used.

Compensation is perhaps the most challenging aspect of setting up the SPT5510. By slowly switching a full-scale data input (generating a low-frequency square wave), with appropriate clock timing, the DAC's output can be observed using a suitable oscilloscope and spectrum analyzer to observe and suppress any oscillations caused by board and decoupling parasitics. Consult Fairchild Applications for further assistance if required.

LONG-TERM STABILITY VERSUS TEMPERATURE

As with all high-speed, high-resolution digital-to-analog converters, the initial accuracy of the device will degrade with both time and temperature. The graph shown in figure 7 can be used to determine the expected change in linearity performance over time when the device is operated at various ambient temperatures. This graph shows how long it will take for the SPT5510 linearity to change by 8 ppm (or 1/2 LSB) at any operating temperature. The top curve shown represents integral nonlinearity (ILE) changes; the bottom curve shows differential nonlinearity (DLE) changes.

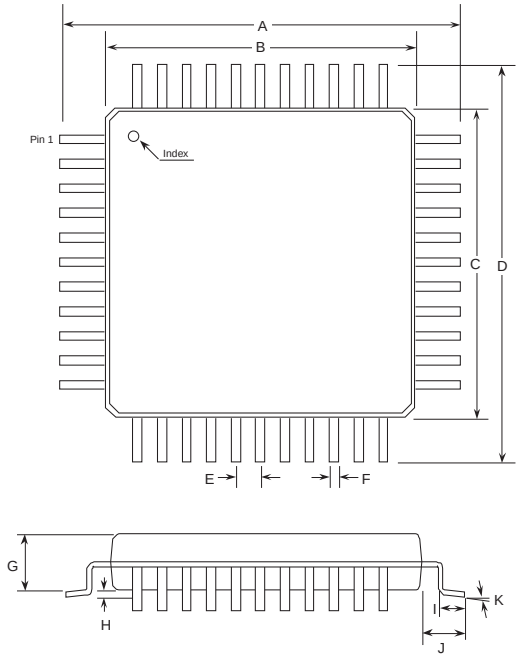
Figure 7 – Linearity Performance over Time



Expected time required to produce an 8 ppm (1/2 LSB) linearity (ILE or DLE) shift as a function of temperature.

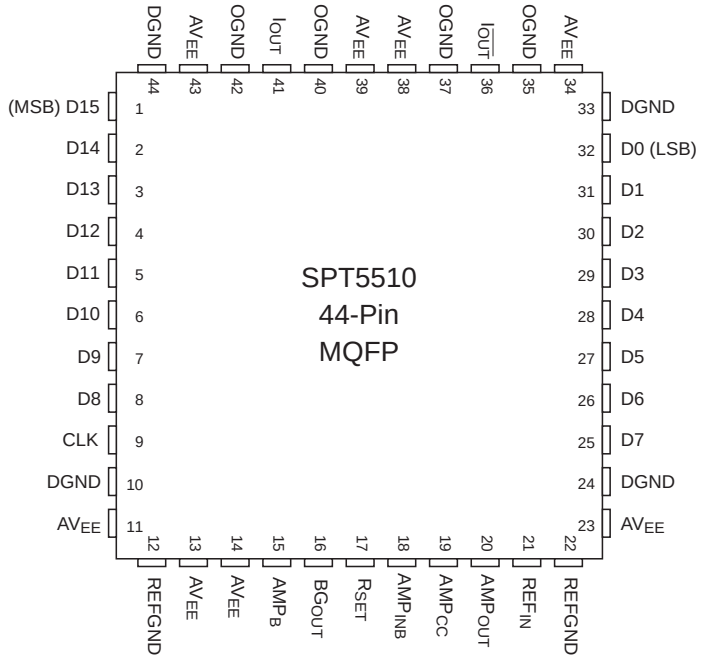
PACKAGE OUTLINE

44-Lead MQFP



SYMBOL	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.5098	0.5295	12.95	13.45
B	0.3917	0.3957	9.95	10.05
C	0.3917	0.3957	9.95	10.05
D	0.5098	0.5295	12.95	13.45
E	0.0311	0.0319	0.79	0.81
F	0.0118	0.0177	0.30	0.45
G	0.0768	0.0827	1.95	2.10
H	0.0039	0.0098	0.10	0.25
I	0.0287	0.0406	0.73	1.03
J	0.0630 REF		1.60 REF	
K	0°	7°	0°	7°

PIN ASSIGNMENTS



PIN FUNCTIONS

NAME	FUNCTION
D15–D0	Digital Input Bits – all inputs high sends all current to I_{OUT}, none to $I_{\overline{OUT}}$
CLK	Clock – latches D flip-flops
I_{OUT}	Analog Current Output
$I_{\overline{OUT}}$	Complementary Analog Current Output
BG_{OUT}	Bandgap Voltage Reference
AMP_{INB}	Ref Amp's Inverting Input
R_{SET}	Ref Amp's Non-Inverting Input – connection for reference-current-setting resistor, nominally 1kΩ to ground
AMP_{OUT}	Bias Voltage for Output Current Switches – drives REF_{IN} (on-chip 20 Ω resistor for compensation)
REF_{IN}	Bias Voltage Node for Output Current Switches – driven by AMP_{OUT}
AMP_B	Used to Decouple Ref Amp's Circuits to AV_{EE}
AMP_{CC}	AMP_{OUT} plus on-chip 10 Ω series resistor for compensation
AV_{EE}	Negative Supply – –5.2 V
DGND	Digital Ground Return
OGND	Output Ground Return
REFGND	Reference Amplifier Ground Return

ORDERING INFORMATION

PART NUMBER	TEMPERATURE RANGE	PACKAGE
SPT5510SIM	–40 to +85 °C	44L MQFP

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.