

20MHz, Second-Order, Isolated Delta-Sigma Modulator for Current-Shunt Measurement

Check for Samples: AMC1204, AMC1204B

FEATURES

- ±250mV Input Voltage Range Optimized for Shunt Resistors
- Certified Digital Isolation:
 - CSA, IEC60747-5-5, and UL1577 Approved
 - Isolation Voltage: 4250V_{PEAK} (AMC1204B)
 - Working Voltage: 1200V_{PEAK}
 Transient Immunity: 15kV/µs
- Long Isolation Barrier Lifetime (see Application Report SLLA197)
- High Electromagnetic Field Immunity (see Application Note SLLA181A)
- Outstanding AC Performance:
 - SNR: 84dB (min)
 - THD: –80dB (max)
- Excellent DC Precision:
 - INL: ±8LSB (max)
 - Gain Error: ±2% (max)
- External Clock Input for Easier Synchronization
- Fully Specified Over the Extended Industrial Temperature Range

APPLICATIONS

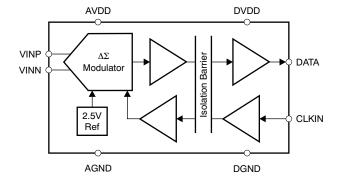
- Shunt Resistor Based Current Sensing in:
 - Motor Control
 - Green Energy
 - Inverter Applications
 - Uninterruptible Power Supplies

DESCRIPTION

The AMC1204 and AMC1204B are 1-bit digital output, isolated delta-sigma ($\Delta\Sigma$) modulators that can be clocked at up to 20MHz. The digital isolation of the modulator output is provided by a silicon dioxide (SiO₂) barrier that is highly resistant to magnetic interference. This barrier has been certified to provide basic galvanic isolation of up to 4000V_{PEAK} (AMC1204) and 4250V_{PEAK} (AMC1204B) according to UL1577, IEC60747-5-5, and CSA standards or specifications.

The AMC1204 and AMC1204B provide a single-chip solution for measuring the small signal of a shunt resistor across an isolated barrier. These types of resistors are typically used to sense currents in motor control inverters, green energy generation systems, and other industrial applications. The AMC1204 and AMC1204B differential inputs easily connect to the shunt resistor or other low-level signal sources. An internal reference eliminates the need for external components. When used with an appropriate external digital filter, an effective number of bits (ENOB) of 14 is achieved at a data rate of 78kSPS.

A 5V analog supply (AVDD) is used by the modulator while the isolated digital interface operates from a 3V, 3.3V, or 5V supply (DVDD). The AMC1204 and AMC1204B are available in SO-16 (DW) and SSO-8 (DWV) packages and are specified from -40°C to +105°C.



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This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE/ORDERING INFORMATION

For the most current package and ordering information see the Package Option Addendum at the end of this document, or visit the device product folder on www.ti.com.

FAMILY OVERVIEW

PART NUMBER	MODULATOR CLOCK (MHz)	DIGITAL SUPPLY	CLOCK SOURCE	INL (LSB)	GAIN ERROR (%)	THD (dB)
AMC1203	10	5V	Internal	±9	±2	-84.5
AMC1203B	10	5V	Internal	±6	±1	-88
AMC1204	20	3V, 3.3V, or 5V	External	±8	±2	-80
AMC1204B	20	3V, 3.3V, or 5V	External	±8	±2	-80

ABSOLUTE MAXIMUM RATINGS(1)

Over the operating ambient temperature range, unless otherwise noted.

		AMC1204,	AMC1204B	
	MIN	MAX	UNIT	
Supply voltage, AVDD to AGND of	or DVDD to DGND	-0.3	+6	V
Analog input voltage at VINP, VIN	IN	AGND - 0.5	AVDD + 0.5	V
Digital input voltage at CLKIN		DGND - 0.3	DVDD + 0.3	V
Input current to any pin except su	-10	+10	mA	
Maximum virtual junction tempera	iture, T _J		+150	°C
Operating ambient temperature ra	ange, T _{OA}	-40	+125	°C
	Human body model (HBM) JEDEC standard 22, test method A114-C.01	-3000	+3000	V
Electrostatic discharge (ESD), all pins	Charged device model (CDM) JEDEC standard 22, test method C101	-1500	+1500	V
	Machine model (MM) JEDEC standard 22, test method A115A	-200	+200	V

⁽¹⁾ 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 under the Electrical Characteristics is not implied. Exposure to absolute maximum rated conditions for extended periods may affect device reliability.

THERMAL INFORMATION

		AMC1204,	AMC1204, AMC1204B		
	THERMAL METRIC ⁽¹⁾	DW	DWV	UNITS	
		16 PINS	8 PINS		
θ_{JA}	Junction-to-ambient thermal resistance	78.5	106.5		
θ_{JCtop}	Junction-to-case (top) thermal resistance	41.3	53.6		
θ_{JB}	Junction-to-board thermal resistance	50.2	60.3	20/11/	
ΨЈТ	Junction-to-top characterization parameter	11.5	18.5	°C/W	
Ψ_{JB}	Junction-to-board characterization parameter	41.2	58.9		
θ_{JCbot}	Junction-to-case (bottom) thermal resistance	n/a	n/a		

(1) For more information about traditional and new thermal metrics, see the IC Package Thermal Metrics application report, SPRA953.

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REGULATORY INFORMATION

VDE/IEC	CSA	UL
Certified according to IEC60747-5-5	Approved under CSA component acceptance notice	Recognized under 1577 component recognition program
File number: 40016131	File number: 2350550	File number: E181974

IEC SAFETY LIMITING VALUES

Safety limiting intends to prevent potential damage to the isolation barrier upon failure of input or output (I/O) circuitry. A failure of the I/O circuitry can allow low resistance to ground or the supply and, without current limiting, dissipate sufficient power to overheat the die and damage the isolation barrier, potentially leading to secondary system failures. The safety-limiting constraint is the operating virtual junction temperature range specified in the Absolute Maximum Ratings table. The power dissipation and junction-to-air thermal impedance of the device installed in the application hardware determine the junction temperature. The assumed junction-to-air thermal resistance in the Thermal Information table is that of a device installed in the JESD51-3, Low Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages and is conservative. The power is the recommended maximum input voltage times the current. The junction temperature is then the ambient temperature plus the power times the junction-to-air thermal resistance.

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Is	Safety input, output, or supply current	$\theta_{JA} = +78.5^{\circ}\text{C/W}, \ V_{I} = 5.5\text{V}, \ T_{J} = +150^{\circ}\text{C}, \ T_{A} = +25^{\circ}\text{C}$			10	mA
T_C	Maximum case temperature				+150	°C

IEC 61000-4-5 RATINGS

PARAMETER		TEST CONDITIONS	VALUE	UNIT
V_{IOSM}	Surge immunity	1.2/50µs voltage surge and 8/20µs current surge	±6000	V

IEC 60664-1 RATINGS

PARAMETER	TEST CONDITIONS	SPECIFICATION
Basic isolation group	Material group	II
	Rated mains voltage ≤ 150V _{RMS}	I-IV
Installation algorification	Rated mains voltage < 300V _{RMS}	I-IV
Installation classification	Rated mains voltage < 400V _{RMS}	I-III
	Rated mains voltage < 600V _{RMS}	I-III

Product Folder Links: AMC1204 AMC1204B



ISOLATION CHARACTERISTICS

	PARAMETER	PARAMETER TEST CONDITIONS		AMC1204B	UNIT
V_{IORM}	Maximum working insulation voltage per IEC		1200	1200	V_{PEAK}
V _{PD(t)}	Partial discharge test voltage per IEC	t = 1s (100% production test), partial discharge < 5pC	2250	2250	V_{PEAK}
V	Transient even eltere	t = 60s (qualification test)	4000	4250	V_{PEAK}
V_{IOTM}	Transient overvoltage	t = 1s (100% production test)	4800	5100	V _{PEAK}
R _S	Isolation resistance	V _{IO} = 500V at T _S	> 10 ⁹	> 10 ⁹	Ω
PD	Pollution degree		2	2	Degrees

ISOLATOR CHARACTERISTICS(1)

PARAMETER		TEST CONDIT	TEST CONDITIONS		TYP	MAX	UNIT
1 (104)	Minimum pin non (alannana)	Shortest terminal to terminal	DWV package	8			mm
L(I01)	Minimum air gap (clearance)	distance through air	DW package	7.9			mm
	Minimum external tracking	Shortest terminal to terminal	DWV package	8			mm
L(102)	(creepage)	distance across the package surface	DW package	7.9			mm
СТІ	Tracking resistance (comparative tracking index)	DIN IEC 60112/VDE 0303 part 1		> 400			V
	Minimum internal gap (internal clearance)	Distance through the insulation		0.014			mm
R _{IO}	Input to output, V_{IO} = 500V, all pins on each side of the barrier tied together to create a two-terminal device, $T_A < +85^{\circ}C$				> 10 ¹²		Ω
		Input to output, $V_{IO} = 500V$, +100°C $\leq T_A < T_A \text{ max}$			> 10 ¹¹		Ω
C _{IO}	Barrier capacitance input to output	$V_I = 0.8V_{PP}$ at 1MHz			1.2		pF
Cı	Input capacitance to ground	$V_I = 0.8V_{PP}$ at 1MHz			3		pF

⁽¹⁾ Creepage and clearance requirements should be applied according to the specific equipment isolation standards of a specific application. Care should be taken to maintain the creepage and clearance distance of the board design to ensure that the mounting pads of the isolator on the printed circuit board (PCB) do not reduce this distance. Creepage and clearance on a PCB become equal according to the measurement techniques shown in the *Isolation Glossary* section. Techniques such as inserting grooves and/or ribs on the PCB are used to help increase these specifications.

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ELECTRICAL CHARACTERISTICS

All minimum/maximum specifications at $T_A = -40$ °C to +105°C, AVDD = 4.5V to 5.5V, DVDD = 2.7V to 5.5V, VINP = -250mV to +250mV, VINN = 0V, and sinc³ filter with OSR = 256, unless otherwise noted. Typical values are at $T_A = +25$ °C, AVDD = 5V, and DVDD = 3.3V.

			AMC1204, AMC1204B			
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
T _A	Specified ambient temperature range		-40		+105	°C
RESOLUT	ION				"	
	Resolution		16			Bits
DC ACCUI	RACY					
		$T_A = -40$ °C to +85°C	-8	±2	8	LSB
INL	Integral linearity error ⁽¹⁾	$T_A = -40^{\circ}\text{C to } +105^{\circ}\text{C}$	-16	±5	16	LSB
DNL	Differential nonlinearity		-1		1	LSB
V _{os}	Offset error ⁽²⁾		-1	±0.1	1	mV
TCV _{OS}	Offset error thermal drift		-3.5	±1	3.5	μV/°C
G _{ERR}	Gain error ⁽²⁾		-2	±0.5	2	%
TCG _{ERR}	Gain error thermal drift			±30		ppm/°C
PSRR	Power-supply rejection ratio			79		dB
ANALOG I						
FSR	Full-scale differential voltage input range	VINP – VINN		±320		mV
	Specified FSR		-250		250	mV
V _{CM}	Operating common-mode signal (3)		-160		AVDD	mV
C _I	Input capacitance to AGND	VINP or VINN	100	7	7,755	pF
C _{ID}	Differential input capacitance			3.5		pF
R _{ID}	Differential input resistance			12.5		kΩ
טויי	Differential input resistance	VINP – VINN = ±250mV	-10	12.0	10	μA
$I_{\rm IL}$	Input leakage current	VINP - VINN = ±320mV	-50		50	μΑ
CMTI	Common-mode transient immunity	VIIVI — VIIVIV — 1320IIIV	15		30	kV/μs
CIVITI	Common-mode transient immunity	V _{IN} from 0V to 5V at 0Hz	13	108		dΒ
CMRR	Common-mode rejection ratio	V _{IN} from 0V to 5V at 100kHz		114		dB
EXTERNA	I CLOCK	V _{IN} HOIH OV tO 5V at TOOKHZ		114		иь
			4E E	F O	200	no
t _{CLKIN}	Clock period		45.5 5	50	200	ns MU-
f _{CLKIN}	Input clock frequency	EMILE of COMULE		20		MHz
Duty _{CLKIN}	Duty cycle	5MHz ≤ f _{CLKIN} < 20MHz	40	50	60 55	%
AC ACCUI	DAOY	20MHz ≤ f _{CLKIN} ≤ 22MHz	45	50	55	70
AC ACCUI	RACT	(411 T 4000 ; 0500	70	07		
SINAD	Signal-to-noise + distortion	$f_{IN} = 1 \text{kHz}, T_A = -40^{\circ}\text{C to } +85^{\circ}\text{C}$	78	87		dB
		$f_{IN} = 1 \text{kHz}, T_A = -40^{\circ}\text{C to } +105^{\circ}\text{C}$	70	87		dB
SNR	Signal-to-noise ratio	$f_{IN} = 1 \text{kHz}, T_A = -40^{\circ}\text{C to } +85^{\circ}\text{C}$	84	88		dB
		$f_{IN} = 1 \text{kHz}, T_A = -40^{\circ}\text{C to } +105^{\circ}\text{C}$	83	88		dB
THD	Total harmonic distortion	$f_{IN} = 1kHz$, $T_A = -40^{\circ}C$ to $+85^{\circ}C$		-96	-80	dB
		$f_{IN} = 1 \text{kHz}, T_A = -40^{\circ}\text{C to } +105^{\circ}\text{C}$		-96	-70	dB
SFDR Spurious-free dynamic range		$f_{IN} = 1 \text{kHz}, T_A = -40^{\circ}\text{C to } +85^{\circ}\text{C}$	82	96		dB
		$f_{IN} = 1kHz, T_A = -40$ °C to +105°C	72	96		dB
DIGITAL IN		1				
I _{IN}	Input current	V _{IN} = DVDD to DGND	-10		10	μA
C _{IN}	Input capacitance			5		pF
CMOS log	ic family			th Schmitt-trigg	er	
V _{IH}	High-level input voltage	DVDD = 4.5V to 5.5V	0.7DVDD		OVDD + 0.3	V
V_{IL}	Low-level input voltage	DVDD = 4.5V to 5.5V	-0.3		0.3DVDD	V

⁽¹⁾ Integral nonlinearity is defined as the maximum deviation from a straight line passing through the end-points of the ideal ADC transfer function expressed as number of LSBs or as a percent of the specified 500mV input range.

⁽²⁾ Maximum values, including temperature drift, are ensured over the full specified temperature range.

⁽³⁾ Ensured by design.



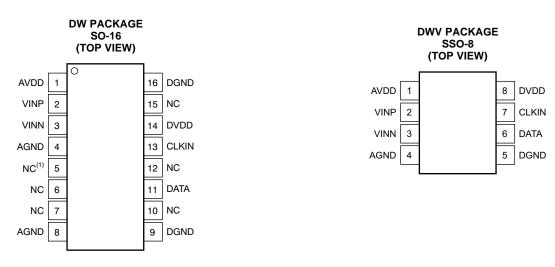
All minimum/maximum specifications at $T_A = -40^{\circ}\text{C}$ to $+105^{\circ}\text{C}$, AVDD = 4.5V to 5.5V, DVDD = 2.7V to 5.5V, VINP = -250mV to +250mV, VINN = 0V, and sinc³ filter with OSR = 256, unless otherwise noted. Typical values are at $T_A = +25^{\circ}\text{C}$, AVDD = 5V, and DVDD = 3.3V.

				04, AMC1204I	В	
	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
LVCMOS	S logic family		L	VCMOS		
V _{IH}	High-level input voltage	DVDD = 2.7V to 3.6V	2		DVDD + 0.3	V
V _{IL}	Low-level input voltage	DVDD = 2.7V to 3.6V	-0.3		0.8	V
DIGITAL	. OUTPUTS ⁽³⁾					
C _{OUT}	Output capacitance			5		pF
C _{LOAD}	Load capacitance				30	pF
CMOS Id	ogic family			CMOS		
V _{OH}	High-level output voltage	DVDD = 4.5V, $I_{OH} = -100\mu A$	4.4			V
V _{OL}	Low-level output voltage	DVDD = 4.5V, $I_{OL} = +100\mu A$			0.5	V
LVCMOS	S logic family		L	VCMOS		
		I _{OH} = 20μA	DVDD - 0.1			V
V _{OH}	High-level output voltage	$I_{OH} = -4mA,$ 2.7V \leq DVDD \leq 3.6V	DVDD - 0.4			V
		$I_{OH} = -4mA,$ $4.5V \le DVDD \le 5.5V$	DVDD - 0.8			V
.,		I _{OL} = 20μA			0.1	V
V _{OL}	Low-level output voltage	I _{OL} = 4mA			0.4	V
POWER	SUPPLY					
AVDD	High-side supply voltage		4.5	5	5.5	V
DVDD	Controller-side supply voltage		2.7	3.3	5.5	V
I _{AVDD}	High-side supply current	4.5V ≤ AVDD ≤ 5.5V		11	16	mA
	Cantrallar side sounds sounds	2.7V ≤ DVDD ≤ 3.6V		2	4	mA
I _{DVDD}	Controller-side supply current	4.5V ≤ DVDD ≤ 5.5V		2.8	5	mA
P_D	Power dissipation	AVDD = 5.5V, DVDD = 3.6V		61.6	102.4	mW

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PIN CONFIGURATIONS



(1) NC = no internal connection.

PIN DESCRIPTIONS

1						
PIN NAME	PIN#		FUNCTION			
PIN NAIVIE	DW	DWV	FUNCTION	DESCRIPTION		
AVDD	1	1	Power	High-side power supply		
VINP	2	2	Analog input	Noninverting analog input		
VINN	3	3	Analog input	Inverting analog input		
AGND	4, 8 ⁽¹⁾	4	Power	High-side ground		
DGND	9, 16	5	Power	Controller-side ground		
DATA	11	6	Digital output	Modulator data output		
CLKIN	13	7	Digital input	Modulator clock input		
DVDD	14	8	Power	Controller-side power supply		
NC	5-7, 10, 12, 15	_	_	No internal connection; can be tied to any potential or left unconnected		

(1) Both pins are connected internally via a low-impedance path; thus, only one of the pins must be tied to the ground plane.

TIMING INFORMATION

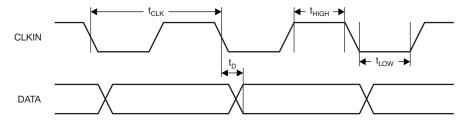


Figure 1. Modulator Output Timing

TIMING CHARACTERISTICS FOR Figure 1

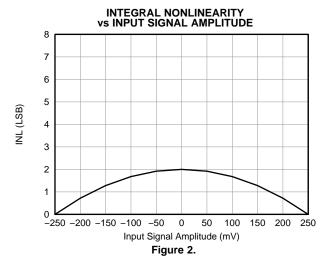
Over recommended ranges of supply voltage and operating free-air temperature, unless otherwise noted.

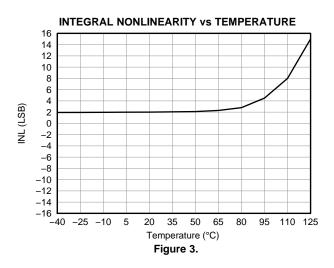
	PARAMETER	MIN	TYP	MAX	UNIT
t _{CLK}	CLKIN clock period	45.5	50	200	ns
t _{HIGH}	CLKIN clock high time	20	25	120	ns
t_{LOW}	CLKIN clock low time	20	25	120	ns
t_D	Delayed falling edge of CLKIN to DATA valid	2		15	ns

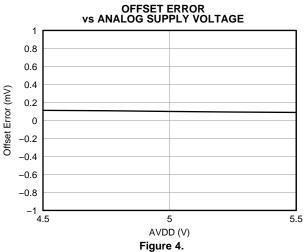
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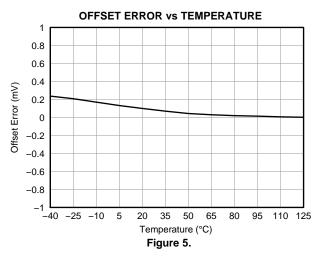


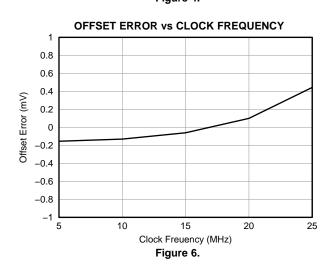
TYPICAL CHARACTERISTICS

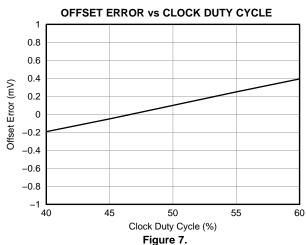




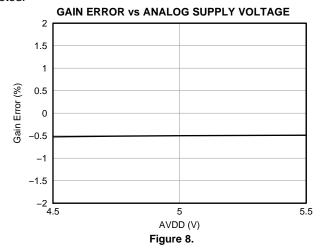


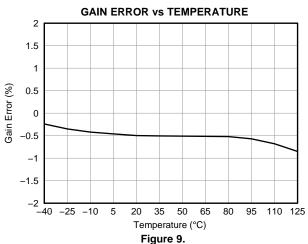


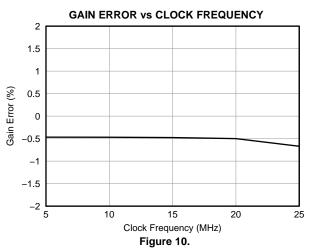


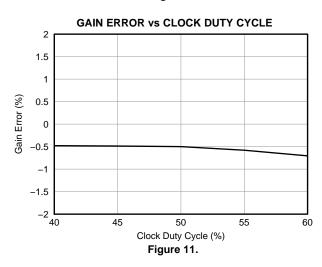


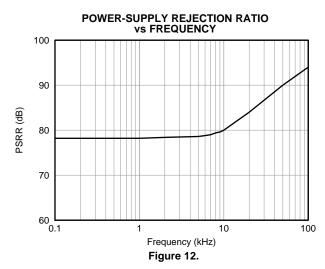


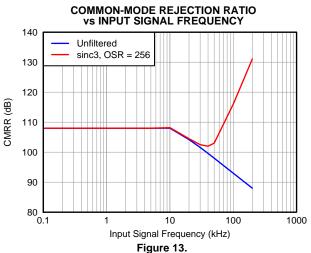






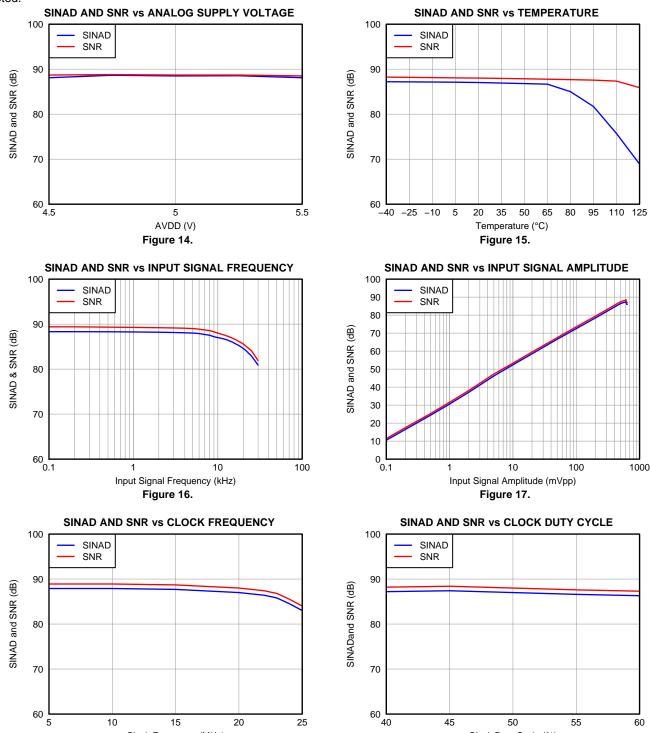








At AVDD = 5V, DVDD = 3.3V, VINP = -250mV to +250mV, VINN = 0V, and $sinc^3$ filter with OSR = 256, unless otherwise noted.



Clock Frequency (MHz)

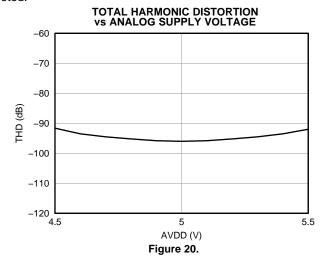
Figure 18.

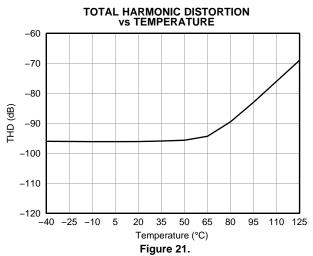
Clock Duty Cycle (%)

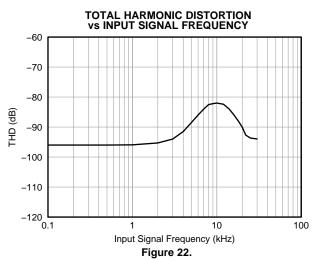
Figure 19.

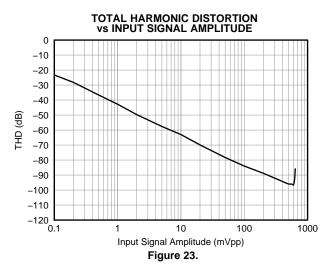


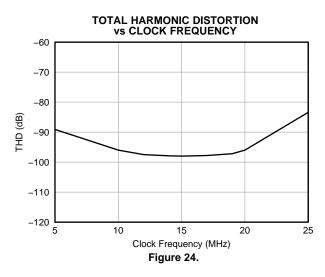
At AVDD = 5V, DVDD = 3.3V, VINP = -250mV to +250mV, VINN = 0V, and $sinc^3$ filter with OSR = 256, unless otherwise noted.

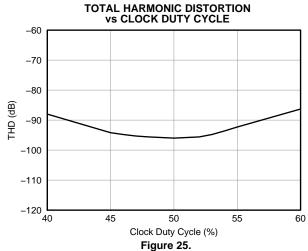






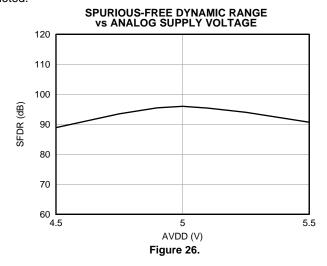


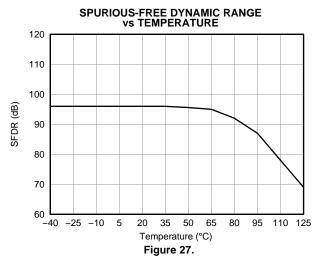


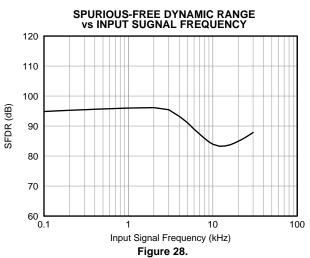


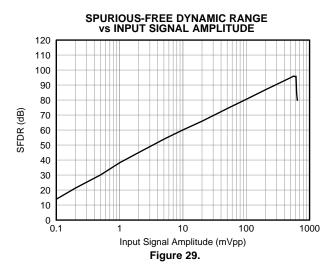
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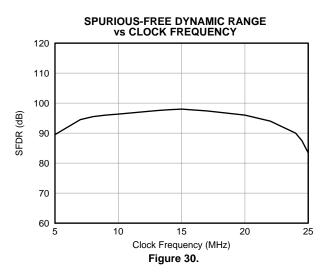


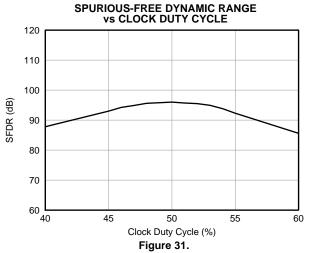




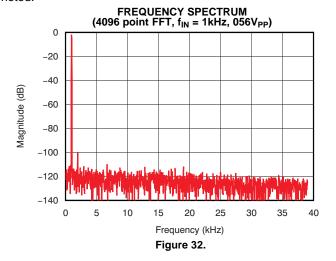


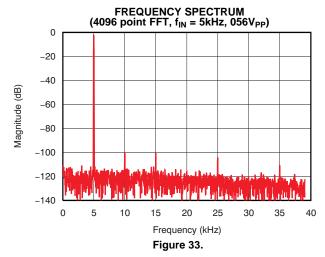


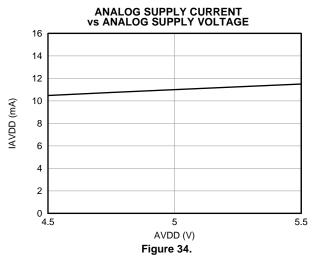


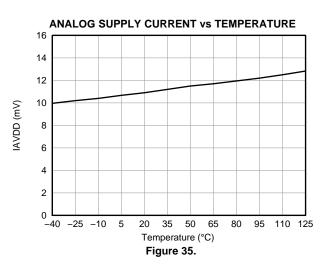


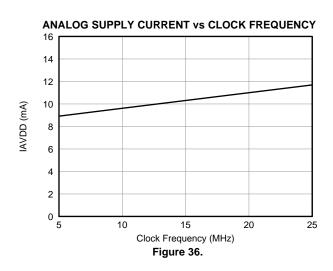


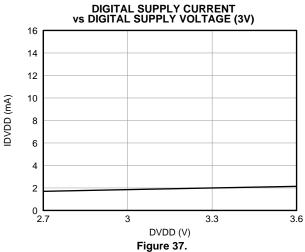




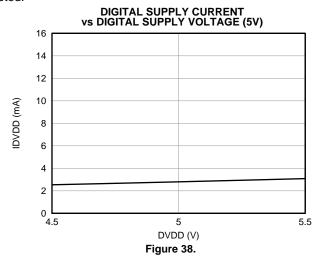


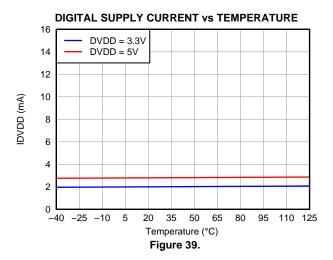


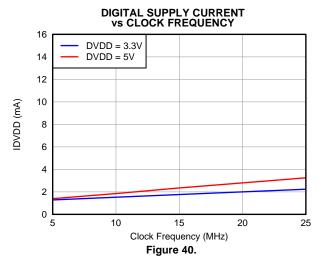














GENERAL DESCRIPTION

The AMC1204 and AMC1204B are single-channel, second-order, delta-sigma ($\Delta\Sigma$) modulators designed for medium- to high-resolution analog-to-digital conversions. The isolated output of the converter (DATA) provides a stream of digital ones and zeros. The time average of this serial output is proportional to the analog input voltage.

Figure 41 shows a detailed block diagram of the AMC1204 and AMC1204B. The analog input range is tailored to directly accommodate a voltage drop across a shunt resistor used for current sensing. The SiO₂-based capacitive isolation barrier supports a high level of magnetic field immunity as described in the application report ISO72x Digital Isolator Magnetic-Field Immunity (SLLA181A, available for download at www.ti.com). The external clock input simplifies the synchronization of multiple current sense channels on system level. The extended frequency range of up to 20MHz supports higher performance levels compared to the other solutions available on the market.

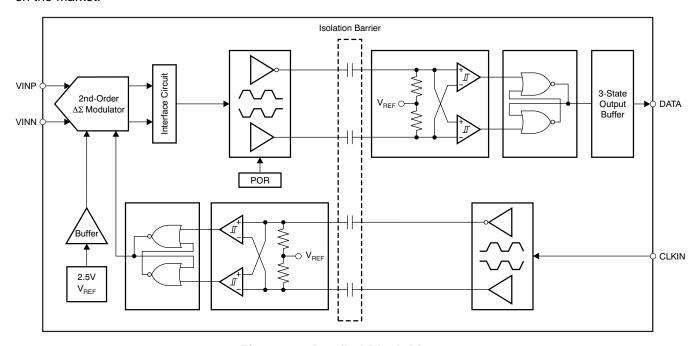


Figure 41. Detailed Block Diagram



THEORY OF OPERATION

The differential analog input of the AMC1204 and AMC1204B are implemented with a switched-capacitor circuit. This switched-capacitor circuit implements a second-order modulator stage that digitizes the input signal into a 1-bit output stream. The externally-provided clock source at the CLKIN pin is used by the capacitor circuit and the modulator and should be in the range of 5MHz to 22MHz. The analog input signal is continuously sampled by the modulator and compared to an internal voltage reference. A digital stream, accurately representing the analog input voltage over time, appears at the output of the converter at the DATA pin.

ANALOG INPUT

The AMC1204 and AMC1204B measure the differential input signal $V_{IN} = (VINP - VINN)$ against the internal reference of 2.5V using internal capacitors that are continuously charged and discharged. Figure 42 shows the simplified schematic of the ADC input circuitry; the right side of Figure 42 illustrates the input circuitry with the capacitors and switches replaced by an equivalent circuit.

In Figure 42, the S_1 switches close during the input sampling phase. With the S_1 switches closed, C_{DIFF} charges to the voltage difference across VINP and VINN. For the discharge phase, both S_1 switches open first and then both S_2 switches close. C_{DIFF} discharges approximately to AGND + 0.8V during this phase. This two-phase sample/discharge cycle repeats with a period of $t_{\text{CLKIN}} = 1/t_{\text{CLKIN}}$. t_{CLKIN} is the operating frequency of the modulator. The capacitors C_{IP} and C_{IN} are of parasitic nature and caused by bonding wires and the internal ESD protection structure.

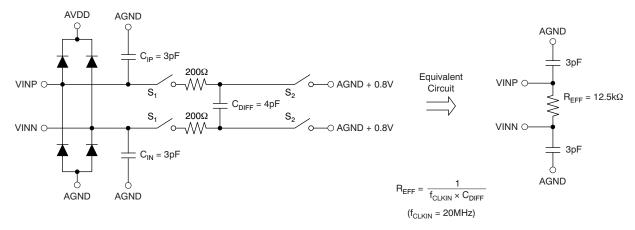


Figure 42. Equivalent Analog Input Circuit

The input impedance becomes a consideration in designs with high input signal source impedance. This high impedance may cause degradation in gain, linearity, and THD. The importance of this effect, however, depends on the desired system performance. This input stage provides the mechanism to achieve low system noise, high common-mode rejection (105dB), and excellent power-supply rejection.

There are two restrictions on the analog input signals VINP and VINN. First, if the input voltage exceeds the range AGND – 0.5V to AVDD + 0.3V, the input current must be limited to 10mA because the input protection diodes on the front end of the converter begin to turn on. In addition, the linearity and the noise performance of the device are ensured only when the differential analog input voltage remains within ±250mV.

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MODULATOR

The modulator topology of the AMC1204 and AMC1204B is fundamentally a second-order, switched-capacitor, $\Delta\Sigma$ modulator, such as the one conceptualized in Figure 43. The analog input voltage ($X_{(t)}$) and the output of the 1-bit digital-to-analog converter (DAC) are differentiated, providing an analog voltage (X_2) at the input of the first integrator or modulator stage. The output of the first integrator is further differentiated with the DAC output; the resulting voltage (X_3) feeds the input of the second integrator stage. When the value of the integrated signal (X_4) at the output of the second stage equals the comparator reference voltage, the output of the comparator switches from high to low, or vice versa, depending on its previous state. In this case, the 1-bit DAC responds on the next clock pulse by changing its analog output voltage (X_6), causing the integrators to progress in the opposite direction, while forcing the value of the integrator output to track the average of the input.

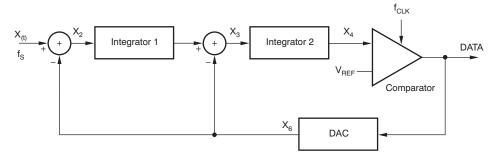


Figure 43. Block Diagram of a Second-Order Modulator

The modulator shifts the quantization noise to high frequencies, as shown in Figure 44; therefore, a low-pass digital filter should be used at the output of the device to increase the overall performance. This filter is also used to convert from the 1-bit data stream at a high sampling rate into a higher-bit data word at a lower rate (decimation). A digital signal processor (DSP), microcontroller (µC), or field programmable gate array (FPGA) can be used to implement the filter. Another option is to use a suitable application-specific device such as the AMC1210, a four-channel digital sinc-filter.

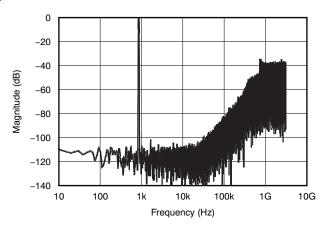


Figure 44. Quantization Noise Shaping



DIGITAL OUTPUT

A differential input signal of 0V ideally produces a stream of ones and zeros that are high 50% of the time and low 50% of the time. A differential input of +250mV produces a stream of ones and zeros that are high 89.06% of the time. A differential input of -250mV produces a stream of ones and zeros that are high 10.94% of the time. This is also the specified linear input range of the modulator with the performance as specified in this data sheet. The range between 250mV and 320mV (absolute values) is the non-linear range of the modulator. The output of the modulator clips with a stream of only zeros with an input less than or equal to -320mV or with a stream of only ones with an input greater than or equal to 320mV. The input voltage versus the output modulator signal is shown in Figure 45.

The system clock of the AMC1204 and AMC1204B is typically 20MHz and is provided externally at the CLKIN pin. The data are synchronously provided at 20MHz at the DATA output pin. The data are changing at the falling edge of CLKIN; for more details see the Timing Information section.

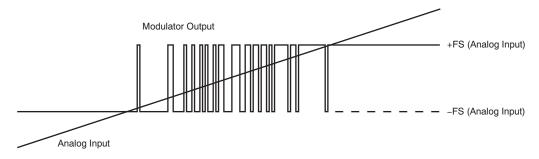


Figure 45. Analog Input versus AMC1204 Modulator Output

FILTER USAGE

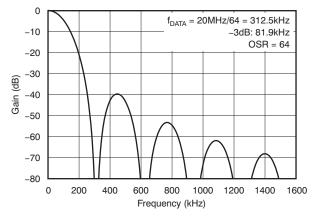
The modulator generates a bit stream that is processed by a digital filter to obtain a digital word similar to a conversion result of a conventional analog-to-digital converter (ADC). A very simple filter, built with minimal effort and hardware, is a sinc³-type filter, as shown in Equation 1:

$$H(z) = \left(\frac{1 - z^{-OSR}}{1 - z^{-1}}\right)^{S}$$
 (1)

This filter provides the best output performance at the lowest hardware size (count of digital gates). For an oversampling rate (OSR) in the range of 16 to 256, this filter is a good choice. All the characterization in this document is also done with a sinc³ filter with OSR = 256 and an output word width of 16 bits.



In a sinc³ filter response (shown in Figure 46 and Figure 47), the location of the first notch occurs at the frequency of output data rate $f_{DATA} = f_{CLK}/OSR$. The –3dB point is located at half the Nyquist frequency or $f_{DATA}/4$. For some applications, it may be necessary to use another filter type with different frequency response. Performance can be improved, for example, by using a cascaded filter structure. The first decimation stage could be built of a sinc³ filter with a low OSR and the second stage using a high-order filter.



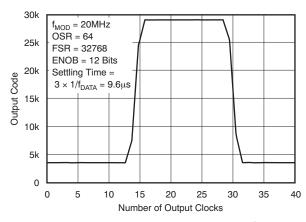


Figure 46. Frequency Response of the Sinc³ Filter

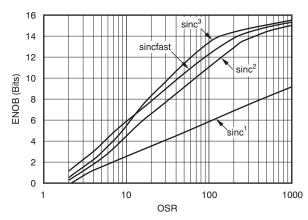
Figure 47. Pole Response of the Sinc³ Filter

The effective number of bits (ENOB) is often used to compare the performance of ADCs and $\Delta\Sigma$ modulators. Figure 48 illustrates the ENOB of the AMC1204 and AMC1204B with different oversampling ratios. In this data sheet, this number is calculated from SNR using Equation 2:

$$SNR = 1.76dB + 6.02dB \times ENOB$$
 (2)

In motor control applications, a very fast response time for overcurrent detection is required. The time for fully settling the filter depends on its order; that is, a $sinc^3$ filter requires three data clocks for full settling (with $f_{DATA} = f_{CLK}/OSR$). Therefore, for overcurrent protection, filter types other than $sinc^3$ might be a better choice; an alternative is the $sinc^2$ filter. Figure 49 compares the settling times of different filter orders with sincfast being a modified $sinc^2$ filter with behavior as shown in Equation 3.

$$H(z) = \left(\frac{1 - z^{-OSR}}{1 - z^{-1}}\right) (1 + z^{-2OSR})$$
(3)





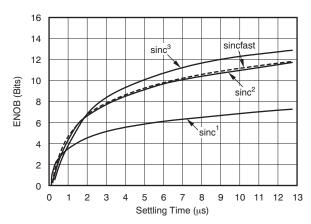


Figure 49. Measured Effective Number of Bits versus Settling Time



An example code for an implementation of a sinc³ filter in an FPGA follows. For more information, see the application note *Combining ADS1202 with FPGA Digital Filter for Current Measurement in Motor Control Applications (SBAA094)*, available for download at www.ti.com.

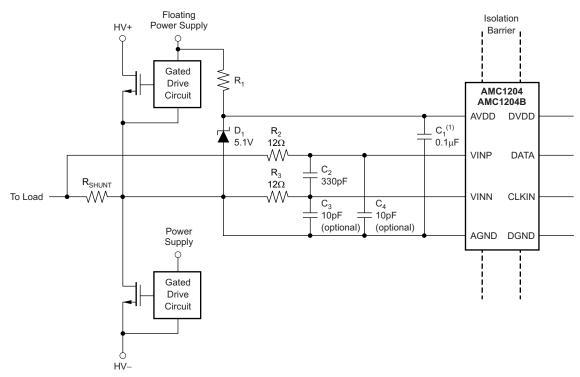
```
library IEEE;
use IEEE.std_logic_1164.all;
use IEEE.std_logic_unsigned.all;
entity FLT is
 port(RESN, MOUT, MCLK, CNR : in std_logic;
      CN5 : out std_logic_vector(23 downto 0));
architecture RTL of FLT is
  signal DNO, DN1, DN3, DN5 : std_logic_vector(23 downto 0);
  signal CN1, CN2, CN3, CN4 : std_logic_vector(23 downto 0);
  signal DELTA1 : std_logic_vector(23 downto 0);
process(MCLK, RESn)
 begin
    if RESn = '0' then
     DELTA1 <= (others => '0');
    elsif MCLK'event and MCLK = '1' then
     if MOUT = '1' then
       DELTA1 <= DELTA1 + 1;
      end if;
    end if;
  end process;
process(RESN, MCLK)
    if RESN = '0' then
      CN1 <= (others => '0');
     CN2 <= (others => '0');
    elsif MCLK'event and MCLK = '1' then
      CN1 <= CN1 + DELTA1;
     CN2 <= CN2 + CN1;
    end if;
  end process;
process(RESN, CNR)
 begin
    if RESN = '0' then
     DN0 <= (others => '0');
     DN1 <= (others => '0');
      DN3 <= (others => '0');
     DN5 <= (others => '0');
    elsif CNR'event and CNR = '1' then
      DN0 <= CN2;
      DN1 <= DN0;
     DN3 <= CN3;
     DN5 <= CN4;
    end if;
  end process;
CN3 <= DN0 - DN1;
CN4 <= CN3 - DN3;
CN5 <= CN4 - DN5;
end RTL;
```



APPLICATION INFORMATION

A typical operation of the AMC1204 and AMC1204B in a motor control application is shown in Figure 50. Measurement of the motor phase current is done via the shunt resistor R_{SHUNT} (in this case, a two-terminal shunt). For better performance, the differential signal is filtered using RC filters (components R_2 , R_3 , and C_2). Optionally, C_3 and C_4 can be used to reduce charge dumping from the inputs. In this case, care should be taken when choosing the quality of these capacitors—mismatch in values of these capacitors leads to a common-mode error at the input of the modulator.

The high-side power supply (AVDD) for the AMC1204 and AMC1204B is derived from the power supply of the upper gate driver. For lowest cost, a zener diode can be used to limit the voltage to $5V \pm 10\%$. A decoupling capacitor of $0.1\mu\text{F}$ is recommended for filtering this power-supply path. This capacitor (C_1 in Figure 50) should be placed as close as possible to the AVDD pin for best performance. If better filtering is required, an additional $1\mu\text{F}$ to $10\mu\text{F}$ capacitor can be used. The floating ground reference AGND is derived from the end of the shunt resistor, which is connected to the negative input (VINN) of the AMC1204 and AMC1204B. If a four-terminal shunt is used, the inputs of AMC1204 and AMC1204B are connected to the inner leads, while AGND is connected to one of the outer leads of the shunt. Both digital signals, CLKIN and DATA, can be directly connected to a digital filter (for example, the AMC1210); see Figure 51.



(1) Place C₁ close to the AMC1204 and AMC1204B.

Figure 50. Typical Application Diagram



Figure 51 shows an example of two AMC1204 and AMC1204B devices and one ADS1209 (a dual-channel, 10MHz, non-isolated modulator) connected to an AMC1210, building the entire analog front-end of a resolver-based motor control application.

For detailed information on the ADS1209 and AMC1210, visit the respective device product folders at www.ti.com.

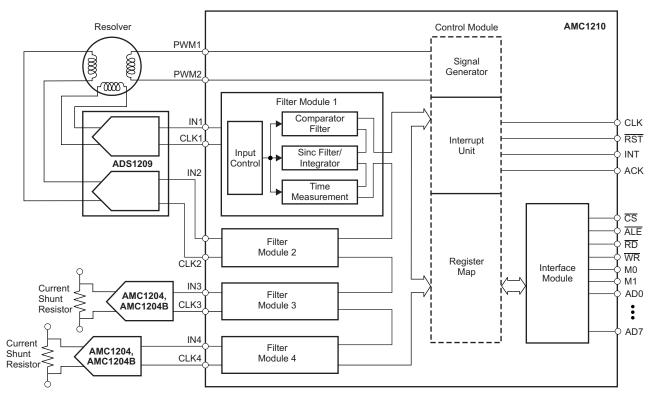


Figure 51. Example of a Resolver-Based Motor Control Analog Front-End



A layout recommendation showing the critical placement of the decoupling capacitor on the high-side and placement of the other components required by the AMC1204 and AMC1204B is presented in Figure 52.

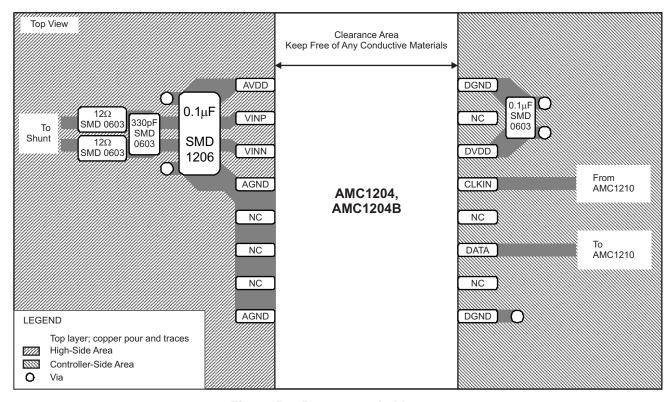
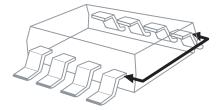


Figure 52. Recommended Layout

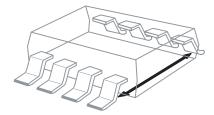


ISOLATION GLOSSARY

Creepage Distance: The shortest path between two conductive input to output leads measured along the surface of the insulation. The shortest distance path is found around the end of the package body.



Clearance: The shortest distance between two conductive input to output leads measured through air (line of sight).



Input-to-Output Barrier Capacitance: The total capacitance between all input terminals connected together, and all output terminals connected together.

Input-to-Output Barrier Resistance: The total resistance between all input terminals connected together, and all output terminals connected together.

Primary Circuit: An internal circuit directly connected to an external supply mains or other equivalent source that supplies the primary circuit electric power.

Secondary Circuit: A circuit with no direct connection to primary power that derives its power from a separate isolated source.

Comparative Tracking Index (CTI): CTI is an index used for electrical insulating materials. It is defined as the numerical value of the voltage that causes failure by tracking during standard testing. Tracking is the process that produces a partially conducting path of localized deterioration on or through the surface of an insulating material as a result of the action of electric discharges on or close to an insulation surface. The higher CTI value of the insulating material, the smaller the minimum creepage distance.

Generally, insulation breakdown occurs either through the material, over its surface, or both. Surface failure may arise from flashover or from the progressive degradation of the insulation surface by small localized sparks. Such sparks are the result of the breaking of a surface film of conducting contaminant on the insulation. The resulting break in the leakage current produces an overvoltage at the site of the discontinuity, and an electric spark is generated. These sparks often cause carbonization on insulation material and lead to a carbon track between points of different potential. This process is known as tracking.

Insulation:

Operational insulation—Insulation needed for the correct operation of the equipment.

Basic insulation—Insulation to provide basic protection against electric shock.

Supplementary insulation—Independent insulation applied in addition to basic insulation in order to ensure protection against electric shock in the event of a failure of the basic insulation.

Double insulation—Insulation comprising both basic and supplementary insulation.

Reinforced insulation—A single insulation system that provides a degree of protection against electric shock equivalent to double insulation.

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Pollution Degree:

Pollution Degree 1—No pollution, or only dry, nonconductive pollution occurs. The pollution has no influence on device performance.

Pollution Degree 2—Normally, only nonconductive pollution occurs. However, a temporary conductivity caused by condensation is to be expected.

Pollution Degree 3—Conductive pollution, or dry nonconductive pollution that becomes conductive because of condensation, occurs. Condensation is to be expected.

Pollution Degree 4—Continuous conductivity occurs as a result of conductive dust, rain, or other wet conditions.

Installation Category:

Overvoltage Category—This section is directed at insulation coordination by identifying the transient overvoltages that may occur, and by assigning four different levels as indicated in IEC 60664.

- 1. Signal Level: Special equipment or parts of equipment.
- 2. Local Level: Portable equipment, etc.
- 3. Distribution Level: Fixed installation.
- 4. Primary Supply Level: Overhead lines, cable systems.

Each category should be subject to smaller transients than the previous category.



REVISION HISTORY

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision C (August 2012) to Revision D	Page
Deleted chip photo	1
Added DWV (SSO-8) package to document	1
 Changed first sub-bullet of Certified Digital Isolation Feature bullet: changed IEC60747-5-2 to IEC6074 	7-5-5 1
Changed IEC60747-5-2 to IEC60747-5-5 in first paragraph of Description section	1
Changed last paragraph of Description section	1
Added DWV package to Thermal Information table	2
Changed IEC60747-5-2 to IEC60747-5-5 in first row of Regulatory Information table	3
 Added DWV package row to L(I01) and L(I02) parameters in Isolator Characteristics table 	4
Added DWV pin out drawing	7
Added DWV information to Pin Descriptions table	7
 Changed first paragraph of Digital Output section: changed 78.1% to 89.06% and 21.9% to 10.94% 	18
Changes from Revision B (August 2011) to Revision C	Page
Added AMC1204B to document	1
Changed Certified digital isolation, isolation voltage Feature bullet	1
Changed Description section to include AMC1204B	1
Added AMC1204B row to Family Overview table	2
Added AMC1204B values to Isolation Characteristics table	4
Changed AMC1204 V _{IOTM} t = 1s value in Isolation Characteristics table	4
Changed CTI minimum specification in Isolator Characteristics table	4
Changed footnote 1 in Electrical Characteristics table	5
• Changed Analog Inputs, V_{CM} parameter minimum specification and unit in Electrical Characteristics take	ole 5
• Changed Digital Output, C_{OUT} and C_{LOAD} parameters unit specifications in Electrical Characteristics tab	le 6
Changed package name from TSSOP to SO	7
Updated Figure 50	21
Updated Figure 51	<u>22</u>
Updated Figure 52	23
Changes from Revision A (April 2011) to Revision B	Page
Changed value of V _{IOSM} parameter in IEC 61000-4-5 Ratings table	3

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5-Feb-2014

PACKAGING INFORMATION

Orderable Device	Status	Package Type	_	Pins	_	Eco Plan	Lead/Ball Finish	MSL Peak Temp	Op Temp (°C)	Device Marking	Samples
	(1)		Drawing		Qty	(2)	(6)	(3)		(4/5)	
AMC1204BDW	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 125	1204B	Samples
AMC1204BDWR	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 125	1204B	Samples
AMC1204BDWV	ACTIVE	SOIC	DWV	8	64	Green (RoHS & no Sb/Br)	CU SN	Level-3-260C-168 HR	-40 to 125	AMC1204B	Samples
AMC1204BDWVR	ACTIVE	SOIC	DWV	8	1000	Green (RoHS & no Sb/Br)	CU SN	Level-3-260C-168 HR	-40 to 125	AMC1204B	Samples
AMC1204DW	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 125	AMC1204	Samples
AMC1204DWR	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 125	AMC1204	Samples

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes. **Pb-Free** (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between

the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.



PACKAGE OPTION ADDENDUM

5-Feb-2014

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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OTHER QUALIFIED VERSIONS OF AMC1204:

Automotive: AMC1204-Q1

NOTE: Qualified Version Definitions:

Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

PACKAGE MATERIALS INFORMATION

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TAPE AND REEL INFORMATION





Α0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device Device	Package Type	Package Drawing		SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
AMC1204BDWR	SOIC	DW	16	2000	330.0	16.4	10.75	10.7	2.7	12.0	16.0	Q1
AMC1204BDWVR	SOIC	DWV	8	1000	330.0	16.4	12.05	6.15	3.3	16.0	16.0	Q1
AMC1204DWR	SOIC	DW	16	2000	330.0	16.4	10.75	10.7	2.7	12.0	16.0	Q1

www.ti.com 20-Dec-2013



*All dimensions are nominal

7 till difficilities die Frentinia							
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
AMC1204BDWR	SOIC	DW	16	2000	367.0	367.0	38.0
AMC1204BDWVR	SOIC	DWV	8	1000	367.0	367.0	38.0
AMC1204DWR	SOIC	DW	16	2000	367.0	367.0	38.0



SOIC



NOTES:

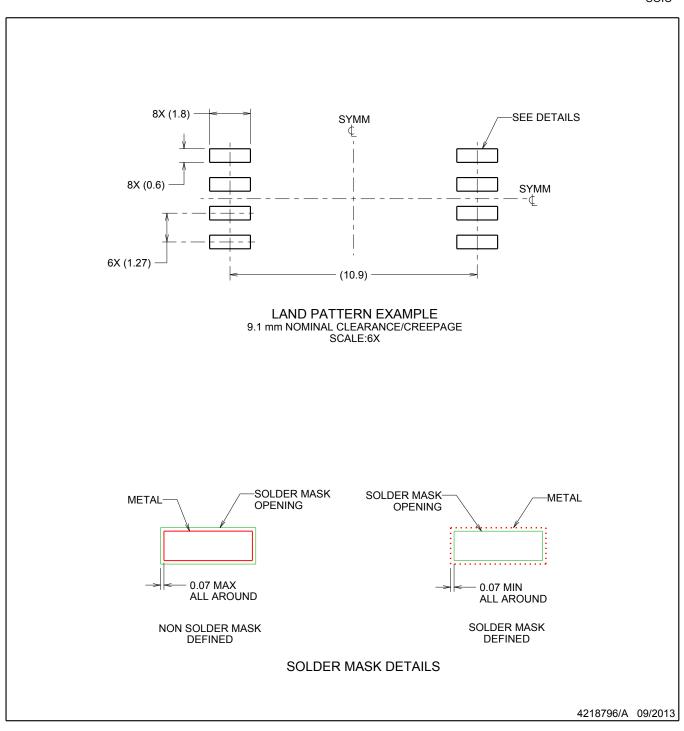
- 1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing
- per ASME Y14.5M.

 2. This drawing is subject to change without notice.

 3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm, per side.
- 4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm, per side.



SOIC

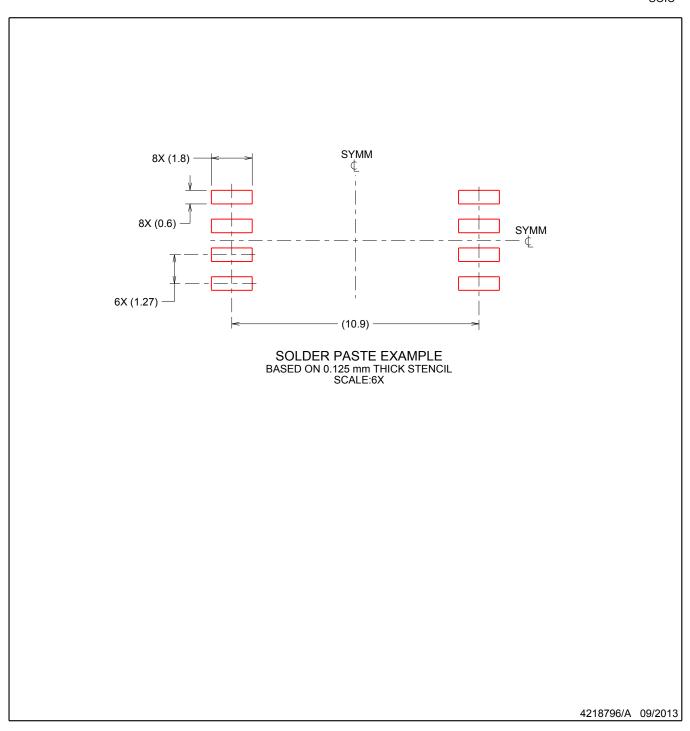


NOTES: (continued)

- 5. Publication IPC-7351 may have alternate designs.
- 6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOIC



NOTES: (continued)

- 7. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
- 8. Board assembly site may have different recommendations for stencil design.



DW (R-PDSO-G16)

PLASTIC SMALL OUTLINE



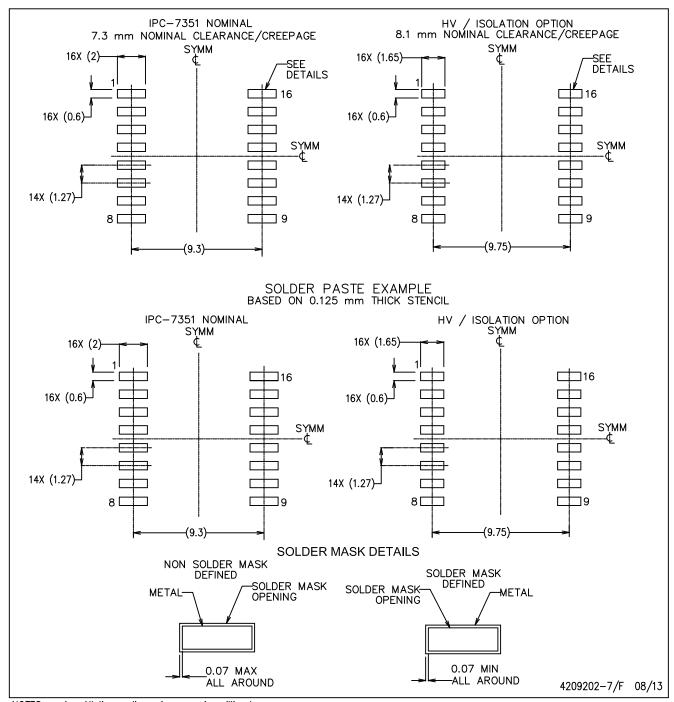
NOTES: A. All linear dimensions are in inches (millimeters). Dimensioning and tolerancing per ASME Y14.5M-1994.

- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
- D. Falls within JEDEC MS-013 variation AA.



DW (R-PDSO-G16)

PLASTIC SMALL OUTLINE



NOTES: A. All linear dimensions are in millimeters.

- B. This drawing is subject to change without notice.
- C. Refer to IPC7351 for alternate board design.
- D. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
- E. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
- F. Board assembly site may have different recommendations for stencil design.



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