

National Semiconductor is now part of  
Texas Instruments.

Search <http://www.ti.com/> for the latest technical  
information and details on our current products and services.

# LMH0387

## 3 Gbps HD/SD SDI Configurable I/O Adaptive Cable Equalizer / Cable Driver

### General Description

The LMH0387 3 Gbps HD/SD SDI Configurable I/O Adaptive Cable Equalizer / Cable Driver provides a single chip interface to a BNC. The device can be configured either in the input mode as an equalizer to receive data over coaxial cable or in the output mode as a cable driver to transmit data over coaxial cable. The same I/O pin is used both for the input and the output functions of the device, allowing the system designer the flexibility to use a BNC attached to the device as either an input or an output.

The LMH0387 offers designers flexibility in system design and quicker time to market. The device operates over a wide range of data rates from 125 Mbps to 2.97 Gbps (DC to 2.97 Gbps when driving cable) and supports SMPTE 424M, SMPTE 292M, SMPTE 344M, and SMPTE 259M. The return loss network is integrated within the device so no external components are required to meet the SMPTE return loss specification.

In the input mode, the LMH0387 features include a power-saving sleep mode, programmable output common mode voltage and swing, cable length indication, launch amplitude optimization, input signal detection, and an SPI interface. In the output mode, the LMH0387 features include two selectable slew rates for SMPTE 424M / 292M and SMPTE 259M compliance, and output driver power down control.

The device is available in a 7 x 7 mm 48-pin laminate Thin Chip Scale Package (TCSP).

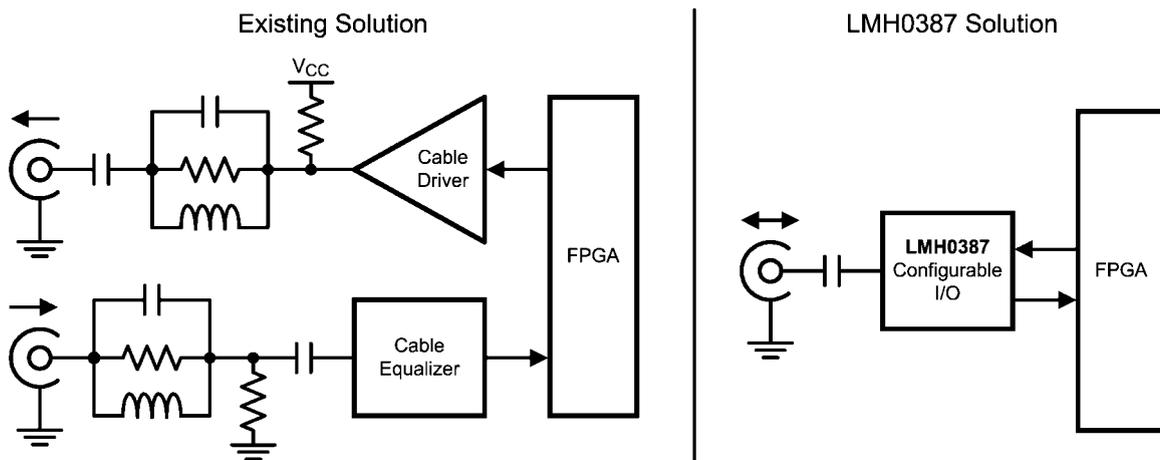
### Features

- SMPTE 424M, SMPTE 292M, SMPTE 344M, and SMPTE 259M compliant
- Supports DVB-ASI at 270 Mbps
- Data rates: 125 Mbps to 2.97 Gbps when receiving (DC to 2.97 Gbps when driving cable)
- Equalizes up to 120 meters of Belden 1694A at 2.97 Gbps, up to 200 meters of Belden 1694A at 1.485 Gbps, or up to 400 meters of Belden 1694A at 270 Mbps
- Integrated return loss network (no external components required)
- Power saving modes
- Cable driver selectable slew rate
- Internally terminated 100Ω LVDS receiver outputs with programmable common mode voltage and swing
- Programmable launch amplitude optimization for receiver
- Cable length indication
- Single 3.3V supply operation
- 48-pin laminate TCSP package
- Industrial temperature range: -40°C to +85°C

### Applications

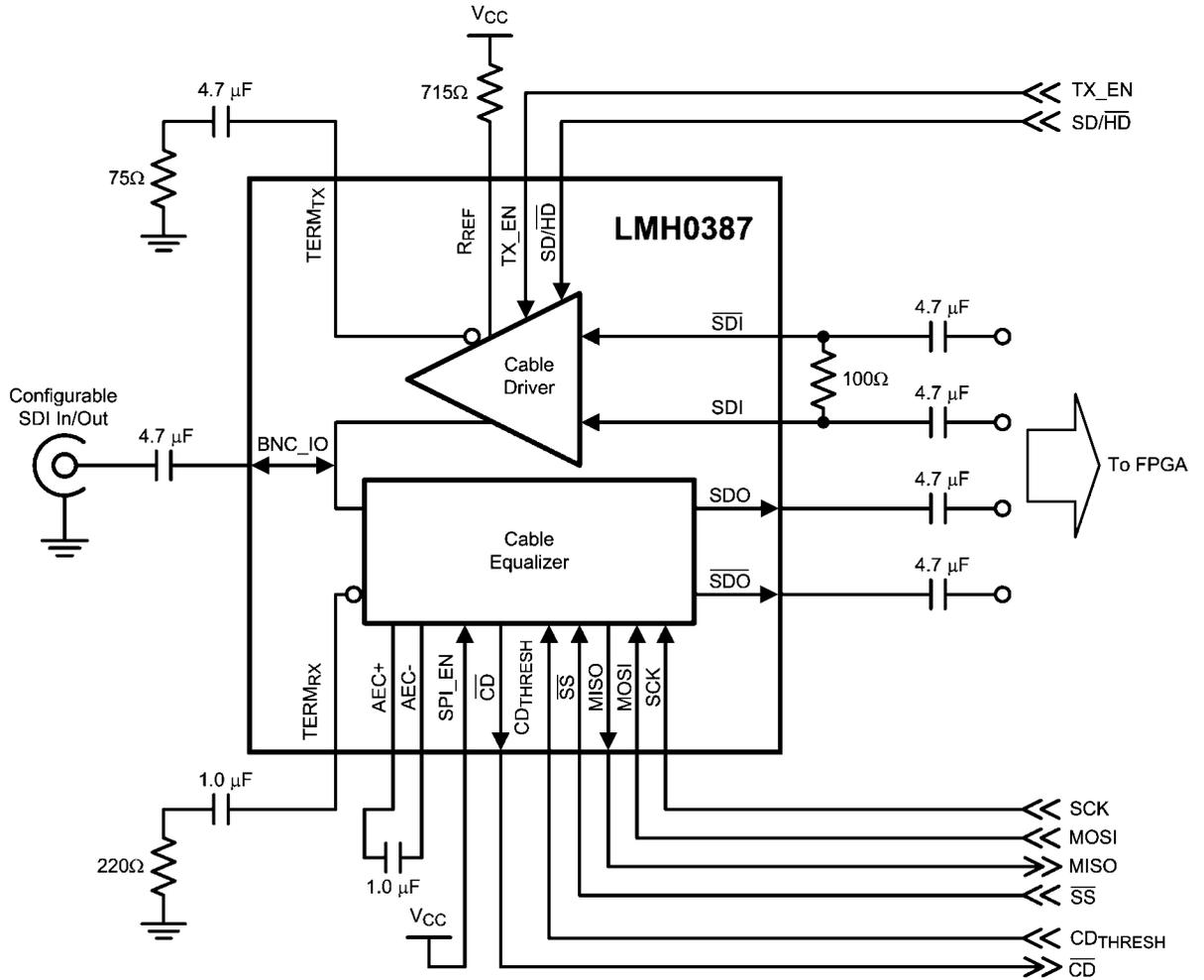
- SMPTE 424M, SMPTE 292M, and SMPTE 259M serial digital interfaces
- Digital video servers and modular equipment
- Video encoders and decoders
- Distribution amplifiers

### Typical Application



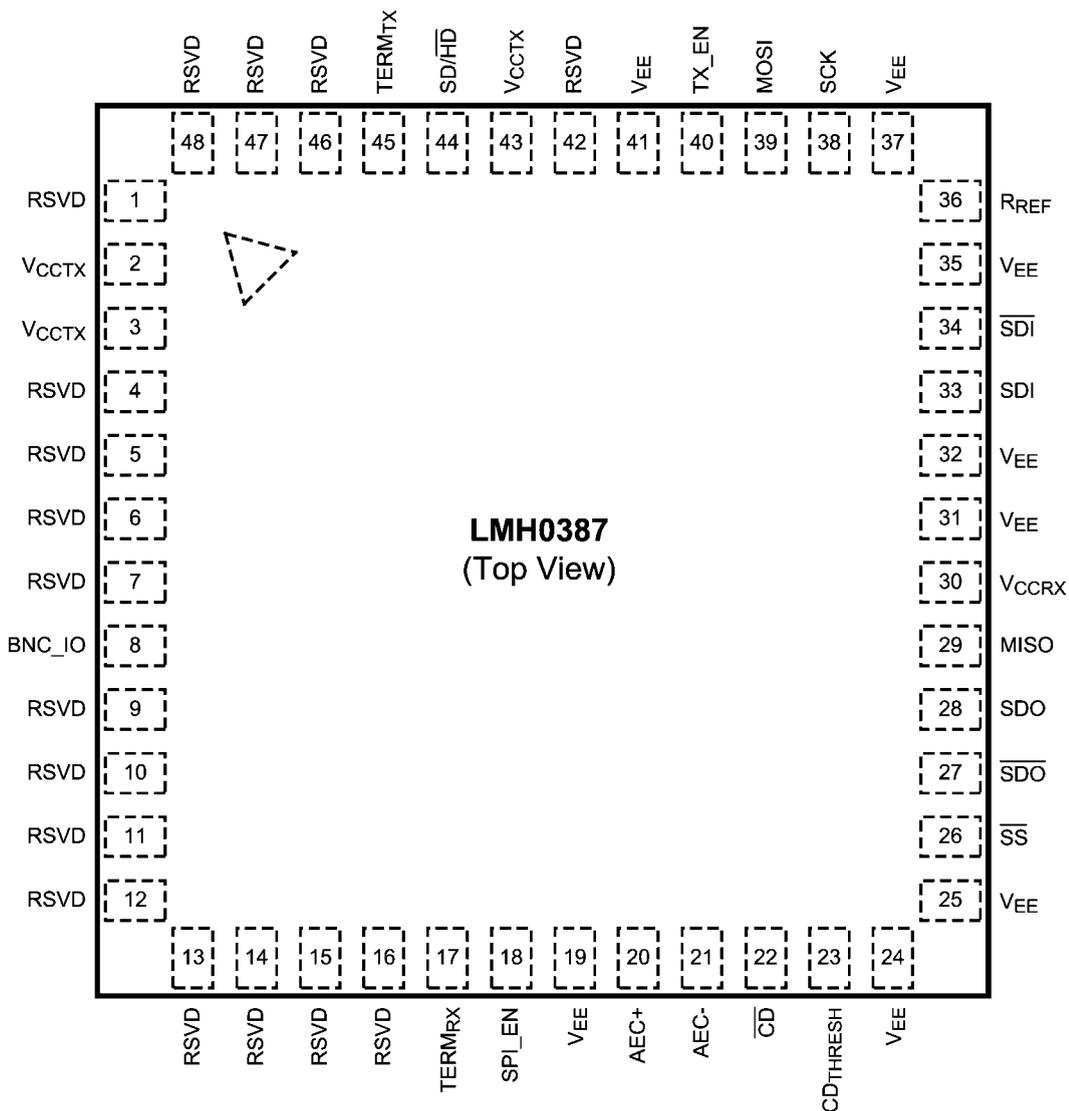
30104423

# Typical Application Circuit



30104401

## Connection Diagram



30104403

**48-Pin Laminate TCSP**  
**Order Number LMH0387SL**  
**NS Package Number SLD48A**

## Ordering Information

Part Number	Package	Quantity
LMH0387SL	48-Pin Laminate TCSP, 7.0 x 7.0 x 0.8 mm, 0.5 mm pitch	Reel of 1000
LMH0387SLE	48-Pin Laminate TCSP, 7.0 x 7.0 x 0.8 mm, 0.5 mm pitch	Reel of 250
LMH0387SLX	48-Pin Laminate TCSP, 7.0 x 7.0 x 0.8 mm, 0.5 mm pitch	Reel of 2500

## Pin Descriptions

Pin	Name	I/O, Type	Description
1, 4-7, 9-16, 42, 46-48	RSVD	N/A	Do not connect.
2, 3, 43	V <sub>CCTX</sub>	Power	Positive power supply for transmitter (+3.3V).
8	BNC_IO	I/O, SDI	Serial digital interface input or output for connection to a BNC. Connect this pin to the BNC via an AC coupling capacitor (nominally 4.7µF).
17	TERM <sub>RX</sub>	I, SDI	Termination for unused receiver (equalizer) input. This network should consist of a 1.0 µF capacitor followed by a 220Ω resistor to ground.
18	SPI_EN	I, LVCMOS	SPI register access enable (equalizer). This pin should always be high; it must be pulled high while operating in the input mode and may optionally be pulled high while operating in the output mode. This pin has an internal pulldown.
19, 24, 25, 31, 32, 35, 37, 41	V <sub>EE</sub>	Power	Negative power supply (ground).
20, 21	AEC+, AEC-	I/O, Analog	AEC loop filter external capacitor for equalizer (1.0 µF connected between AEC+ and AEC-).
22	CD	O, LVCMOS	Carrier detect for BNC_IO pin. H = No input signal detected on BNC_IO pin. L = Input signal detected on BNC_IO pin.
23	CD <sub>THRESH</sub>	I, Analog	Carrier detect threshold input. Sets the threshold for $\overline{\text{CD}}$ . CD <sub>THRESH</sub> may be either unconnected or connected to ground for normal $\overline{\text{CD}}$ operation.
26	$\overline{\text{SS}}$ (SPI)	I, LVCMOS	SPI slave select. This pin has an internal pullup.
27, 28	SDO, SDO	O, LVDS	Serial data differential output from receiver (equalizer).
29	MISO (SPI)	O, LVCMOS	SPI Master Input / Slave Output. LMH0387 control data transmit.
30	V <sub>CCR<sub>X</sub></sub>	Power	Positive power supply for receiver (+3.3V).
33, 34	SDI, $\overline{\text{SDI}}$	I, SDI	Serial data differential input for transmitter (cable driver).
36	R <sub>REF</sub>	I, Analog	BNC_IO output driver level control. Connect a resistor (nominally 715Ω) to V <sub>CC</sub> to set the output voltage swing for the BNC_IO pin.
38	SCK (SPI)	I, LVCMOS	SPI serial clock input.
39	MOSI (SPI)	I, LVCMOS	SPI Master Output / Slave Input. LMH0387 control data receive.
40	TX_EN	I, LVCMOS	Transmitter output driver enable. TX_EN has an internal pullup. H = BNC_IO output driver is enabled. L = BNC_IO output driver is powered off. To configure the LMH0387 as a receiver, the BNC_IO output driver must be disabled by tying TX_EN low. To configure the LMH0387 as a transmitter, the output driver must be enabled by tying TX_EN high and the receiver may be powered down using the sleep mode setting via the SPI.
44	SD/ $\overline{\text{HD}}$	I, LVCMOS	BNC_IO output slew rate control. SD/ $\overline{\text{HD}}$ has an internal pulldown. H = BNC_IO output rise/fall time complies with SMPTE 259M (SD). L = BNC_IO output rise/fall time complies with SMPTE 424M / 292M (3G/HD).
45	TERM <sub>TX</sub>	O, SDI	Termination for unused transmitter (cable driver) output. This network should consist of a 4.7 µF capacitor followed by a 75Ω resistor to ground.

## Absolute Maximum Ratings *(Note 1)*

Supply Voltage	4.0V
Input Voltage (all inputs)	-0.3V to $V_{CC}+0.3V$
Storage Temperature Range	-65°C to +150°C
Junction Temperature	+125°C
Package Thermal Resistance	
$\theta_{JA}$ 48-pin TCSP	65°C/W
$\theta_{JC}$ 48-pin TCSP	36°C/W
ESD Rating (HBM)	$\geq \pm 6$ kV
ESD Rating (MM)	$\geq \pm 300V$
ESD Rating (CDM)	$\geq \pm 2.5$ kV

## Recommended Operating Conditions

Supply Voltage ( $V_{CC} - V_{EE}$ )	3.3V $\pm 5\%$
BNC_IO Input / Output Coupling Capacitance	4.7 $\mu F$
AEC Capacitor (Connected between AEC+ and AEC-)	1.0 $\mu F$
Operating Free Air Temperature ( $T_A$ )	-40°C to +85°C

## Control Pin Electrical Characteristics

Over Supply Voltage and Operating Temperature ranges, unless otherwise specified *(Note 2, Note 3)*.

Symbol	Parameter	Conditions	Reference	Min	Typ	Max	Units
$V_{IH}$	Input Voltage High Level		Logic Inputs	2.0		$V_{CC}$	V
$V_{IL}$	Input Voltage Low Level			$V_{EE}$		0.8	V
$V_{OH}$	Output Voltage High Level	$I_{OH} = -2$ mA	Logic Outputs	2.4			V
$V_{OL}$	Output Voltage Low Level	$I_{OL} = +2$ mA				0.4	V

## Input Mode (Equalizer) DC Electrical Characteristics

Over Supply Voltage and Operating Temperature ranges, unless otherwise specified *(Note 2, Note 3)*.

Symbol	Parameter	Conditions	Reference	Min	Typ	Max	Units	
$V_{IN}$	Input Voltage Swing	0m cable length, <i>(Note 5)</i>	BNC_IO	720	800	950	mV <sub>P-P</sub>	
$V_{SSP-P}$	Differential Output Voltage, P-P	100 $\Omega$ load, default register settings <i>(Note 6, Figure 1)</i>	SDO, $\overline{SDO}$	500	700	900	mV <sub>P-P</sub>	
$V_{OD}$	Differential Output Voltage			250	350	450	mV	
$\Delta V_{OD}$	Change in Magnitude of $V_{OD}$ for Complimentary Output States						50	mV
$V_{OS}$	Offset Voltage				1.125	1.25	1.375	V
$\Delta V_{OS}$	Change in Magnitude of $V_{OS}$ for Complimentary Output States						50	mV
$I_{OS}$	Output Short Circuit Current							30
	$CD_{THRESH}$ DC Voltage (floating)		$CD_{THRESH}$		1.3		V	
	$CD_{THRESH}$ Range				0.8		V	
$I_{CC}$	Supply Current	Equalizing cable > 120m (Belden 1694A), TX_EN = 0			91	113	mA	
		Equalizing cable $\leq$ 120m (Belden 1694A), TX_EN = 0, <i>(Note 7)</i>			71		mA	
		Power save mode (equalizer in sleep mode, TX_EN = 0)			11		mA	

## Output Mode (Cable Driver) DC Electrical Characteristics

Over Supply Voltage and Operating Temperature ranges, unless otherwise specified (*Note 2, Note 3*).

Symbol	Parameter	Conditions	Reference	Min	Typ	Max	Units
$V_{CMOUT}$	Output Common Mode Voltage		BNC_IO		$V_{CC} - V_{OUT}$		V
$V_{OUT}$	Output Voltage Swing	$R_{REF} = 715\Omega$ 1%		720	800	880	mV <sub>P-P</sub>
$V_{CMIN}$	Input Common Mode Voltage		SDI, $\overline{SDI}$	$0.9 + V_{ID}/2$		$V_{CC} - V_{ID}/2$	V
$V_{ID}$	Input Voltage Swing	Differential		100		2200	mV <sub>P-P</sub>
$I_{CC}$	Supply Current	SD/HD = 0, equalizer in sleep mode			57	71	mA
		SD/HD = 1, equalizer in sleep mode			50		mA
		Power save mode (TX_EN = 0, equalizer in sleep mode)			11		mA
		Loopback mode (Tx and Rx both enabled), SD/HD = 0			117		mA

## Input Mode (Equalizer) AC Electrical Characteristics

Over Supply Voltage and Operating Temperature ranges, unless otherwise specified (*Note 3*).

Symbol	Parameter	Conditions	Reference	Min	Typ	Max	Units
$DR_{MIN}$	Minimum Input Data Rate		BNC_IO		125		Mbps
$DR_{MAX}$	Maximum Input Data Rate					2970	Mbps
$t_{jit}$	Equalizer Jitter for Various Cable Lengths	270 Mbps, Belden 1694A, 0-350 meters, ( <i>Note 8, Note 9</i> )	SDO, $\overline{SDO}$			0.2	UI
		270 Mbps, Belden 1694A, 350-400 meters, ( <i>Note 9</i> )			0.2	UI	
		1.485 Gbps, Belden 1694A, 0-170 meters, ( <i>Note 8, Note 9</i> )				0.25	UI
		1.485 Gbps, Belden 1694A, 170-200 meters, ( <i>Note 9</i> )			0.3	UI	
		2.97 Gbps, Belden 1694A, 0-100 meters, ( <i>Note 8, Note 9</i> )				0.3	UI
		2.97 Gbps, Belden 1694A, 100-120 meters, ( <i>Note 9</i> )			0.35	UI	
$t_r, t_f$	Output Rise Time, Fall Time	20% – 80%, 100 $\Omega$ load, ( <i>Note 4, Figure 1</i> )			80	130	ps
$\Delta t_r, \Delta t_f$	Mismatch in Rise/Fall Time	( <i>Note 4</i> )			2	15	ps
$t_{OS}$	Output Overshoot	( <i>Note 4</i> )			1	5	%
$RL_{IN}$	Input Return Loss	5 MHz - 1.5 GHz, ( <i>Note 4, Note 10</i> )	BNC_IO	15			dB
		1.5 GHz - 3.0 GHz, ( <i>Note 4, Note 10</i> )		10			dB

## Output Mode (Cable Driver) AC Electrical Characteristics

Over Supply Voltage and Operating Temperature ranges, unless otherwise specified (*Note 3*).

Symbol	Parameter	Conditions	Reference	Min	Typ	Max	Units
$DR_{MAX}$	Maximum Input Data Rate		SDI, $\overline{SDI}$			2970	Mbps
$t_{jit}$	Additive Jitter	2.97 Gbps, ( <i>Note 11</i> )	BNC_IO		20		$\mu\text{s}_{P-P}$
		1.485 Gbps, ( <i>Note 11</i> )			18		$\mu\text{s}_{P-P}$
		270 Mbps, ( <i>Note 11</i> )			15		$\mu\text{s}_{P-P}$
$t_r, t_f$	Output Rise Time, Fall Time	$SD/\overline{HD} = 0, 20\% - 80\%$			65	130	ps
		$SD/\overline{HD} = 1, 20\% - 80\%$		400		800	ps
$\Delta t_r, \Delta t_f$	Mismatch in Rise/Fall Time	$SD/\overline{HD} = 0$				30	ps
		$SD/\overline{HD} = 1$				50	ps
	Duty Cycle Distortion	$SD/\overline{HD} = 0, (\text{Note } 4)$				30	ps
		$SD/\overline{HD} = 1, (\text{Note } 4)$				100	ps
$t_{OS}$	Output Overshoot	$SD/\overline{HD} = 0, (\text{Note } 4)$				10	%
		$SD/\overline{HD} = 1, (\text{Note } 4)$				8	%
$RL_{OUT}$	Output Return Loss	5 MHz - 1.5 GHz, ( <i>Note 4, Note 10</i> )		15			dB
		1.5 GHz - 3.0 GHz, ( <i>Note 4, Note 10</i> )		10			dB

## Input Mode (Equalizer) SPI Interface AC Electrical Characteristics

Over Supply Voltage and Operating Temperature ranges, unless otherwise specified (*Note 3*).

Symbol	Parameter	Conditions	Reference	Min	Typ	Max	Units
<b>Recommended Input Timing Requirements</b>							
$f_{SCK}$	SCK Frequency		SCK			20	MHz
$t_{PH}$	SCK Pulse Width High	<i>Figure 2, Figure 3</i>		40			% SCK period
$t_{PL}$	SCK Pulse Width Low			40			% SCK period
$t_{SU}$	MOSI Setup Time	<i>Figure 2, Figure 3</i>	MOSI	4			ns
$t_H$	MOSI Hold Time			4			ns
$t_{SSSU}$	$\overline{SS}$ Setup Time	<i>Figure 2, Figure 3</i>	$\overline{SS}$	4			ns
$t_{SSH}$	$\overline{SS}$ Hold Time			4			ns
$t_{SSOF}$	$\overline{SS}$ Off Time			10			ns
<b>Switching Characteristics</b>							
$t_{ODZ}$	MISO Driven-to-Tristate Time	<i>Figure 3</i>	MISO			15	ns
$t_{OZD}$	MISO Tristate-to-Driven Time					15	ns
$t_{OD}$	MISO Output Delay Time					15	ns

**Note 1:** "Absolute Maximum Ratings" are those parameter values beyond which the life and operation of the device cannot be guaranteed. The stating herein of these maximums shall not be construed to imply that the device can or should be operated at or beyond these values. The table of "Electrical Characteristics" specifies acceptable device operating conditions.

**Note 2:** Current flow into device pins is defined as positive. Current flow out of device pins is defined as negative. All voltages are stated referenced to  $V_{EE} = 0$  Volts.

**Note 3:** Typical values are stated for  $V_{CC} = +3.3V$  and  $T_A = +25^\circ C$ .

**Note 4:** Specification is guaranteed by characterization.

**Note 5:** The LMH0387 equalizer can be optimized for different launch amplitudes via the SPI.

**Note 6:** The differential output voltage and offset voltage are adjustable via the SPI.

**Note 7:** The equalizer automatically shifts equalization stages at cable lengths less than or equal to 120m (Beiden 1694A) to reduce power consumption. This power savings is also achieved by setting Extended 3G Reach Mode = 1 via the SPI. (Note: Forcing the Extended 3G Reach Mode in this way increases the cable reach for 3G data rates but also limits the achievable cable lengths at HD and SD data rates).

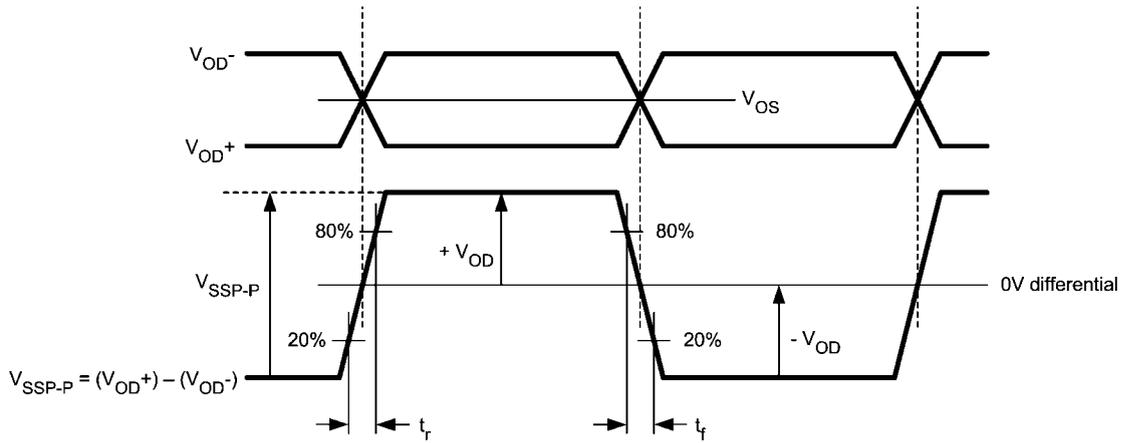
**Note 8:** Based on design and characterization data over the full range of recommended operating conditions of the device. Jitter is measured in accordance with SMPTE RP 184, SMPTE RP 192, and the applicable serial data transmission standard: SMPTE 424M, SMPTE 292M, or SMPTE 259M.

**Note 9:** LMH0387 equalizer launch amplitude fine tuning set to nominal via the SPI by writing 30h ("00110000 binary") to SPI register 02h.

**Note 10:** Return loss is dependent on board design. The LMH0387 exceeds this specification on the SD387 evaluation board.

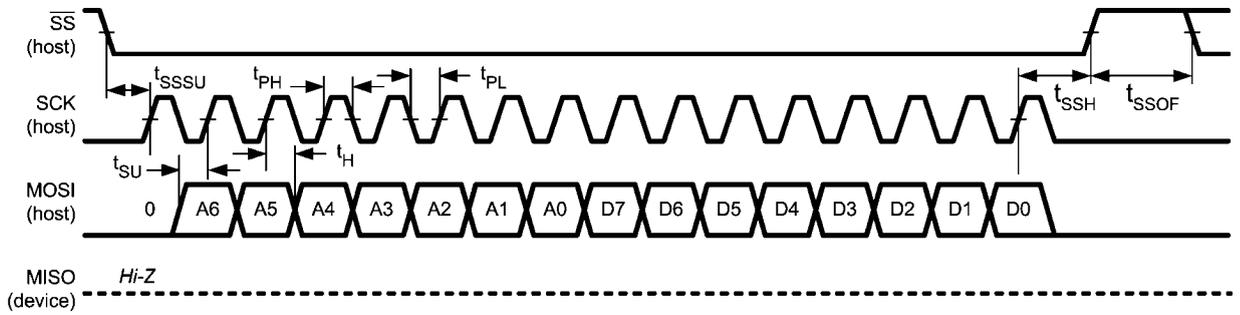
**Note 11:** Cable driver additive jitter is measured with the input AC coupled.

## Timing Diagrams



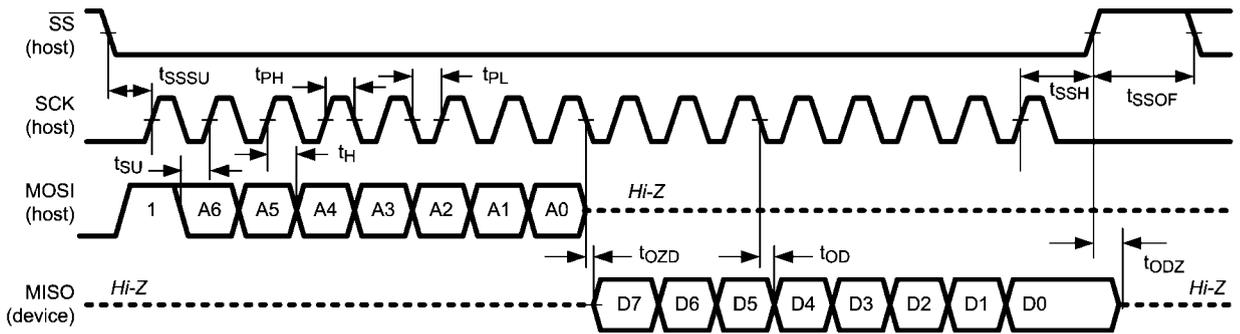
30104408

**FIGURE 1. LVDS Output Voltage, Offset, and Timing Parameters**



30104409

**FIGURE 2. SPI Write**



30104410

**FIGURE 3. SPI Read**

## Device Description

The LMH0387 3 Gbps HD/SD SDI Configurable I/O Adaptive Cable Equalizer / Cable Driver is used at the input or output port of digital video equipment. It is designed to allow the sharing of a single BNC connector for either input or output.

### CONFIGURING THE INPUT (EQUALIZER) OR OUTPUT (CABLE DRIVER) MODE

The LMH0387 must be configured in either the input mode as an equalizer, or the output mode as a cable driver.

#### Input Mode (Equalizer)

To configure the LMH0387 in the input mode, the equalizer must be enabled and the cable driver must be disabled as described in the following steps:

1. Disable the cable driver by pulling the TX\_EN pin low.
2. Enable the equalizer by setting the sleep mode via the SPI to either auto sleep or disabled (never sleep). To do this, write either "01" (auto sleep – default) or "00" (never sleep) to bits [4:3] of SPI register 00h.
3. Set the equalizer launch amplitude fine tuning to the nominal setting via the SPI. To do this, write 30h ("00110000" binary) to SPI register 02h.

#### Output Mode (Cable Driver)

To configure the LMH0387 in the output mode, the cable driver must be enabled. The equalizer may either be disabled for power savings or enabled to provide a loopback path for the data being transmitted. For the normal output mode (equalizer disabled for power savings) follow these steps:

1. Disable the equalizer by forcing it to sleep via the SPI. To do this, write "10" (force sleep) to bits [4:3] of SPI register 00h.
2. Enable the cable driver by pulling the TX\_EN pin high.

To configure the LMH0387 for the output mode with the loopback path, the equalizer can be enabled in output mode by writing either "01" (auto sleep – default) or "00" (never sleep) to bits [4:3] of SPI register 00h. In this case, the LMH0387 input/output mode may be configured simply by toggling the TX\_EN pin since the equalizer remains active in either mode (TX\_EN set low for input mode and high for output mode).

## Input Mode (Equalizer) Description

SPI register access is required while operating the LMH0387 in the input mode. The equalizer launch amplitude fine tuning must be set to nominal via the SPI for correct equalizer operation. To do this, write 30h ("00110000" binary) to SPI register 02h. The SPI registers provide access to many other useful LMH0387 features while in the input mode. Refer to the [Input Mode \(Equalizer\) SPI Register Access](#) section for details.

### INPUT INTERFACING

The LMH0387 accepts single-ended input at the BNC\_IO pin. The input must be AC coupled. The [Typical Application Circuit](#) diagram shows the typical configuration. The TERM<sub>RX</sub> input must be properly terminated with a 1.0  $\mu$ F capacitor followed by a 220 $\Omega$  resistor to ground as shown.

The LMH0387 BNC\_IO input can be optimized for different launch amplitudes via the SPI (see [LAUNCH AMPLITUDE OPTIMIZATION \(REGISTER 02h\)](#) in the [Input Mode \(Equalizer\) SPI Register Access](#) section).

The LMH0387 correctly handles equalizer pathological signals for standard definition and high definition serial digital

video, as described in SMPTE RP 178 and RP 198, respectively.

### OUTPUT INTERFACING

The LMH0387 equalizer outputs, SDO and  $\overline{\text{SDO}}$ , are internally terminated 100 $\Omega$  LVDS outputs. These outputs can be DC coupled to most common differential receivers.

The default output common mode voltage ( $V_{\text{OC}}$ ) is 1.25V. The output common mode voltage may be adjusted via the SPI in 200 mV increments, from 1.05V to 1.85V (see [OUTPUT DRIVER ADJUSTMENTS \(REGISTER 01h\)](#) in the [Input Mode \(Equalizer\) SPI Register Access](#) section). This adjustable output common mode voltage offers flexibility for interfacing to many types of receivers.

The default differential output swing ( $V_{\text{SSP-P}}$ ) is 700 mV<sub>P-P</sub>. The differential output swing may be adjusted via the SPI in 100 mV increments from 400 mV<sub>P-P</sub> to 800 mV<sub>P-P</sub> (see [OUTPUT DRIVER ADJUSTMENTS \(REGISTER 01h\)](#) in the [Input Mode \(Equalizer\) SPI Register Access](#) section).

The LMH0387 equalizer output should be DC coupled to the input of the receiving device as long as the common mode ranges of both devices are compatible. 100 $\Omega$  differential transmission lines should be used to connect between the LMH0387 outputs and the input of the receiving device where possible.

The LMH0387 allows flexibility when interfacing to low voltage crosspoint switches (i.e. 1.8V) and other devices with limited input ranges. The LMH0387 equalizer outputs can be DC coupled to these devices in most cases, avoiding the need to AC couple.

The LMH0387 may be AC coupled to the receiving device when necessary. For example, the LMH0387 equalizer outputs are not strictly compatible with 3.3V CML and thus should not be connected via 50 $\Omega$  resistors to 3.3V. If the input common mode range of the receiving device is not compatible with the output common mode range of the LMH0387, then AC coupling is required. Following the AC coupling capacitors, the signal may have to be biased at the input of the receiving device.

### CARRIER DETECT ( $\overline{\text{CD}}$ )

Carrier detect  $\overline{\text{CD}}$  indicates if a valid signal is present at the LMH0387 BNC\_IO pin. If CD<sub>THRESH</sub> is used, the carrier detect threshold will be altered accordingly.  $\overline{\text{CD}}$  provides a high voltage when no signal is present at the LMH0387 BNC\_IO pin.  $\overline{\text{CD}}$  is low when a valid input signal is detected.

### CARRIER DETECT THRESHOLD (CD<sub>THRESH</sub>)

The CD<sub>THRESH</sub> pin sets the threshold for the carrier detect. The carrier detect threshold is set by applying a voltage inversely proportional to the length of cable to equalize before loss of carrier is triggered. The applied voltage must be greater than the CD<sub>THRESH</sub> floating voltage (typically 1.3V) in order to change the CD threshold. As the applied CD<sub>THRESH</sub> voltage is increased, the amount of cable that will be equalized before carrier detect is de-asserted is decreased. CD<sub>THRESH</sub> may be left unconnected or connected to ground for normal  $\overline{\text{CD}}$  operation.

[Figure 4](#) shows the minimum CD<sub>THRESH</sub> input voltage required to force carrier detect to inactive vs. Belden 1694A cable length. The results shown are valid for Belden 1694A cable lengths of 0-120m at 2.97 Gbps, 0-200m at 1.485 Gbps, and 0-400m at 270 Mbps.

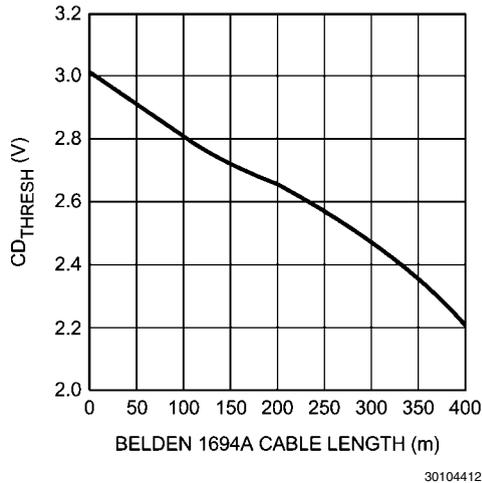


FIGURE 4.  $CD_{THRESH}$  vs. Belden 1694A Cable Length

### AUTO SLEEP

The LMH0387 equalizer is set for auto sleep operation by default. The equalizer portion of the LMH0387 powers down when no input signal is detected on the BNC\_IO pin. The equalizer powers on again once an input signal is detected. The auto sleep functionality can be changed to force sleep or turned off completely via the SPI registers.

In auto sleep mode, the time to power down the equalizer when the input signal is removed is less than 200  $\mu$ s and should not have any impact on the system timing requirements. The equalizer will wake up automatically once an input signal is detected, and the delay between signal detection and full functionality of the equalizer is negligible. The overall system will be limited only by the settling time constant of the equalizer adaptation loop.

## Input Mode (Equalizer) SPI Register Access

SPI register access is required for correct input mode (equalizer) operation. The SPI registers provide access to all of the equalizer features along with a cable length indicator, programmable output common mode voltage and swing, and launch amplitude optimization. There are four supported 8-bit registers in the device (see [Table 1](#)).

Note: The SPI\_EN pin must always be pulled high while using the LMH0387 in the input mode (equalizer), and may optionally be pulled high while using the LMH0387 in the output mode (cable driver) as well.

### SPI Write

The SPI write is shown in [Figure 2](#). The MOSI payload consists of a “0” (write command), seven address bits, and eight data bits. The  $\overline{SS}$  signal is driven low, and the 16 bits are sent to the LMH0387’s MOSI input. Data is latched on the rising edge of SCK. The MISO output is normally tri-stated during this operation. After the SPI write,  $\overline{SS}$  must return high.

### SPI Read

The SPI read is shown in [Figure 3](#). The MOSI payload consists of a “1” (read command) and seven address bits. The  $\overline{SS}$  signal is driven low, and the eight bits are sent to the LMH0387’s MOSI input. The addressed location is accessed immediately after the rising edge of the 8<sup>th</sup> clock and the eight data bits are shifted out on MISO starting with the falling edge of the 8<sup>th</sup> clock. MOSI must be tri-stated immediately after the

rising edge of the 8<sup>th</sup> clock. After the SPI read,  $\overline{SS}$  must return high.

### GENERAL CONTROL (REGISTER 00h)

SPI Register 00h, General Control, provides access to many basic features of the equalizer, including the carrier detect status and the mute, sleep mode, and extended 3G reach mode controls.

#### Carrier Detect

This bit shows the status of the carrier detect for the BNC\_IO pin.

#### Mute

The mute control can be used to manually mute or enable SDO and  $\overline{SDO}$ . Setting this bit to “1” will mute the equalizer outputs by forcing them to logic zero. Setting the mute bit to “0” will force the equalizer outputs to be active.

#### Sleep Mode

The sleep mode is used to automatically or selectively power down the equalizer for power savings when it is not needed. The auto sleep mode allows the equalizer to power down when no input signal is detected, and is activated by default or by writing “01” to bits [4:3] of SPI register 00h. If the auto sleep mode is active, the equalizer goes into a deep power save mode when no input signal is detected on the BNC\_IO pin. The device powers on again once an input signal is detected. The sleep functionality can be turned off completely (equalizer will never sleep) by writing “00” to bits [4:3] of SPI register 00h. Additionally, the equalizer can be forced to power down regardless of whether there is an input signal or not by writing “10” to bits [4:3] of SPI register 00h. The sleep mode has precedence over the mute mode.

#### Extended 3G Reach Mode

The LMH0387 equalizer provides a mode to extend the 3G cable reach in systems which have margin in the jitter budget. This allows for additional cable reach at 2.97 Gbps at the expense of slightly higher output jitter. The extended 3G reach mode provides 10m of additional Belden 1694A cable reach, with an increase of output jitter at this longer cable length of 0.05 to 0.1 UI. (Note: In Extended 3G Reach Mode, the maximum equalizable cable lengths for HD and SD data rates will be limited to less than what can be achieved in normal mode).

### OUTPUT DRIVER ADJUSTMENTS (REGISTER 01h)

The equalizer output driver swing (amplitude) and offset voltage (common mode voltage) are adjustable via SPI register 01h.

#### Output Swing

The output swing is adjustable via bits [7:5] of SPI register 01h. The default value for these register bits is “011” for a peak to peak differential output voltage of 700 mV<sub>P-P</sub>. The output swing can be adjusted in 100 mV increments from 400 mV<sub>P-P</sub> to 800 mV<sub>P-P</sub>.

#### Offset Voltage

The offset voltage is adjustable via bits [4:2] of SPI register 01h. The default value for these register bits is “001” for an output offset of 1.25V. The output common mode voltage may be adjusted in 200 mV increments, from 1.05V to 1.85V. It can also be set to “101” for the maximum offset voltage. At this maximum offset voltage setting, the outputs are referenced to the positive supply and the offset voltage is around 2.1V.

### LAUNCH AMPLITUDE OPTIMIZATION (REGISTER 02h)

The LMH0387 can compensate for attenuation of the input signal prior to the equalizer. This compensation is useful for applications with a passive splitter at the equalizer input or a

non-ideal input termination network, and is controlled by SPI register 02h.

**For correct equalizer operation with the default SMPTE 800 mV<sub>P-P</sub> launch amplitude and no external attenuation, the equalizer launch amplitude fine tuning must be set to the “nominal” setting via the SPI. To do this, write 30h (“00110000” binary) to SPI register 02h.**

#### Coarse Control

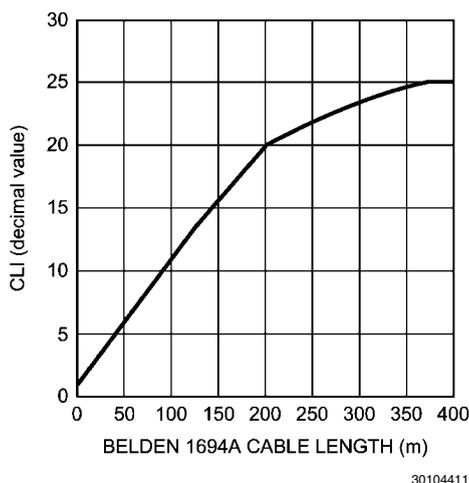
Bit 7 of SPI register 02h is used for coarse control of the launch amplitude setting. At the default setting of “0”, the equalizer operates normally and expects a launch amplitude of 800 mV<sub>P-P</sub>. Bit 7 may be set to “1” to optimize the equalizer for input signals with 6 dB of attenuation (400 mV<sub>P-P</sub>).

#### Fine Control

Once the coarse control is set, the equalizer input compensation may be further fine tuned by bits [6:3] of SPI register 02h. These bits may be used to tweak the input gain stage -2% to +60% around the coarse control setting. For typical equalizer operation, bits [6:3] of SPI register 02h should be changed from the default setting of “0000” to the nominal setting of “0110”.

#### CABLE LENGTH INDICATOR (CLI) (REGISTER 03h)

The Cable Length Indicator (CLI) provides an indication of the length of cable attached to the equalizer input. CLI is accessible via bits [7:3] of SPI register 03h. The 5-bit CLI ranges in decimal value from 0 to 25 (“00000” to “11001” binary) and increases as the cable length is increased. [Figure 5](#) shows typical CLI values vs. Belden 1694A cable length. CLI is valid for Belden 1694A cable lengths of 0-120m at 2.97 Gbps, 0-200m at 1.485 Gbps, and 0-400m at 270 Mbps.



**FIGURE 5. CLI vs. Belden 1694A Cable Length**

## Output Mode (Cable Driver) Description

#### INPUT INTERFACING

The LMH0387 cable driver accepts differential input signals which can be DC or AC coupled.

#### OUTPUT INTERFACING

The LMH0387 cable driver uses 75Ω internally terminated current mode outputs. The output level is 800 mV<sub>P-P</sub> with an R<sub>REF</sub> resistor of 715Ω. The R<sub>REF</sub> resistor is connected between the R<sub>REF</sub> pin and V<sub>CC</sub>, and should be placed as close as possible to the R<sub>REF</sub> pin.

The output should be AC coupled as shown in the [Typical Application Circuit](#) diagram. The TERM<sub>TX</sub> output must be properly terminated with a 4.7 μF capacitor followed by a 75Ω resistor to ground as shown.

#### OUTPUT SLEW RATE CONTROL

The LMH0387 cable driver output rise and fall times are selectable for either SMPTE 259M or SMPTE 424M / 292M compliance via the SD/ $\overline{\text{HD}}$  pin. For slower rise and fall times, or SMPTE 259M compliance, SD/ $\overline{\text{HD}}$  is set high. For faster rise and fall times, or SMPTE 424M and SMPTE 292M compliance, SD/ $\overline{\text{HD}}$  is set low. SD/ $\overline{\text{HD}}$  has an internal pulldown.

#### OUTPUT ENABLE

The LMH0387 cable driver can be enabled or disabled with the TX\_EN pin. When set low, the cable driver is powered off. TX\_EN has an internal pullup to enable the cable driver by default. When using the LMH0387 in the input mode (as an equalizer), the cable driver must be disabled by setting the TX\_EN pin low.

## Application Information

### PCB LAYOUT RECOMMENDATIONS

For information on layout and soldering of the laminate TCSP package, please refer to the following application note: **AN-1125, "Laminate CSP/FBGA."**

**For a CSP package, it is a general requirement not to have any metal (traces or vias) on the top layer in the area directly underneath the device, other than the footprint. This is intended to provide a flat planar surface for the package.**

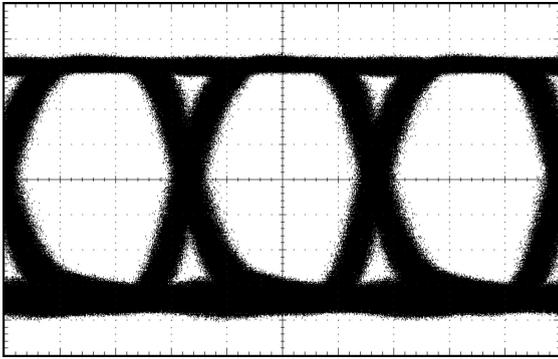
The SMPTE 424M, 292M, and 259M standards have stringent requirements for the input and output return loss of receivers and transmitters, which essentially specify how closely they must resemble a  $75\Omega$  network. Any non-idealities in the network between the BNC and the LMH0387 will degrade the return loss. Care must be taken to minimize impedance discontinuities both for the BNC footprint and for the trace between the BNC and the LMH0387 to ensure that the characteristic impedance is  $75\Omega$ . Best return loss performance is achieved with the LMH0387 placed closely to the BNC to minimize the trace length between the BNC and the

LMH0387's BNC\_IO pin. Please consider the following PCB recommendations:

- Place the LMH0387 in close proximity to the BNC.
- Use surface mount components, and use the smallest components available. In addition, use the smallest size component pads.
- Select trace widths that minimize the impedance mismatch between the BNC and the LMH0387.
- Select a board stack up that supports both  $75\Omega$  single-ended traces and  $100\Omega$  loosely-coupled differential traces.
- Maintain symmetry on the complimentary signals.
- Route  $100\Omega$  traces uniformly (keep trace widths and trace spacing uniform along the trace).
- Avoid sharp bends in the signal path; use  $45^\circ$  or radial bends.
- Place bypass capacitors close to each power pin, and use the shortest path to connect device power and ground pins to the respective power or ground planes.
- Remove ground plane under input/output components to minimize parasitic capacitance.

# Typical Performance Characteristics

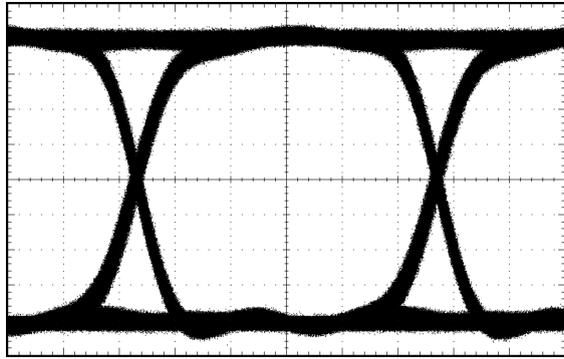
Equalizer Output at 2.97 Gbps with 120m Belden 1694A



H: 100 ps / div, V: 50 mV / div  
(SDO output shown)

30104421

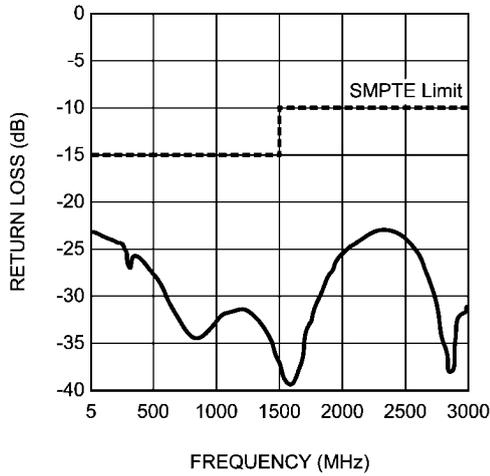
Cable Driver Output at 2.97 Gbps



H: 62.5 ps / div, V: 100 mV / div  
(BNC\_IO output shown)

30104420

Output Return Loss



30104422

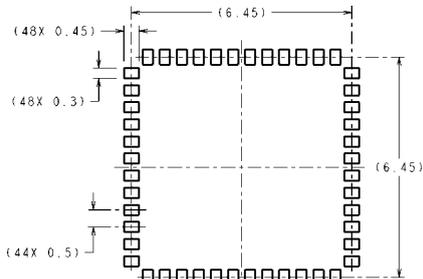
## SPI Registers

TABLE 1. SPI Registers

Address	R/W	Name	Bits	Field	Default	Description
00h	R/W	General Control	7	Carrier Detect		Read only. 0: No carrier detected on BNC_IO pin. 1: Carrier detected on BNC_IO pin.
			6	Mute	0	0: Normal operation. 1: Equalizer outputs muted.
			5	Reserved	0	Reserved as 0. Always write 0 to this bit.
			4:3	Sleep Mode	01	Equalizer sleep mode control. Sleep has precedence over Mute. 00: Never sleep. Disable sleep mode (force equalizer to stay enabled). 01: Auto sleep. Sleep mode active when no input signal detected. 10: Force sleep. Force equalizer into sleep mode (powered down) regardless of whether there is an input signal or not. 11: Reserved.
			2	Extended 3G Reach Mode	0	Extended 3G reach mode to extend the equalizable cable length for 2.97 Gbps applications. 0: Normal operation. 1: Extended 3G reach mode.
			1:0	Reserved	00	Reserved as 00. Always write 00 to these bits.
01h	R/W	Output Driver	7:5	Output Swing	011	Equalizer output driver swing ( $V_{SSP-P}$ ). 000: $V_{SSP-P} = 400 \text{ mV}_{P-P}$ . 001: $V_{SSP-P} = 500 \text{ mV}_{P-P}$ . 010: $V_{SSP-P} = 600 \text{ mV}_{P-P}$ . 011: $V_{SSP-P} = 700 \text{ mV}_{P-P}$ . 100: $V_{SSP-P} = 800 \text{ mV}_{P-P}$ . 101, 110, 111: Reserved.
			4:2	Offset Voltage	001	Equalizer output driver offset voltage (common mode voltage). 000: $V_{OS} = 1.05\text{V}$ . 001: $V_{OS} = 1.25\text{V}$ . 010: $V_{OS} = 1.45\text{V}$ . 011: $V_{OS} = 1.65\text{V}$ . 100: $V_{OS} = 1.85\text{V}$ . 101: $V_{OS}$ referenced to positive supply. 110, 111: Reserved.
			1:0	Reserved	00	Reserved as 00. Always write 00 to these bits.

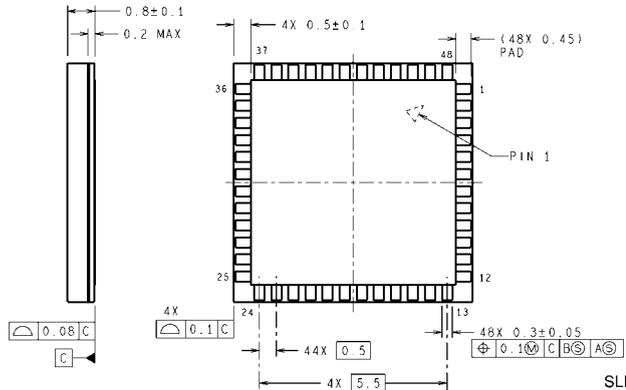
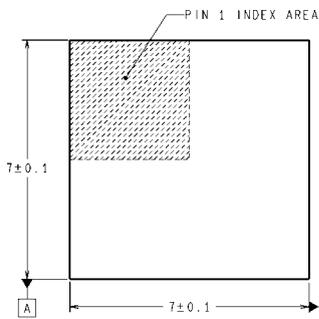
Address	R/W	Name	Bits	Field	Default	Description
02h	R/W	Launch Amplitude	7	Coarse Control	0	Coarse launch amplitude optimization for equalizer input. 0: Normal optimization with no external attenuation (800 mV <sub>P-P</sub> launch amplitude). 1: Optimized for 6 dB external attenuation (400 mV <sub>P-P</sub> launch amplitude).
			6:3	Fine Control	0000	Launch amplitude optimization fine tuning for equalizer input. 0000: +20% from nominal. 0001: +16% from nominal. 0010: +12% from nominal. 0011: +9% from nominal. 0100: +6% from nominal. 0101: +3% from nominal. <b>0110: Nominal.</b> (The default setting must be changed to this nominal setting for most applications). 0111: -2% from nominal. 1001: +24% from nominal. 1010: +29% from nominal. 1011: +34% from nominal. 1100: +40% from nominal. 1101: +46% from nominal. 1110: +53% from nominal. 1111: +60% from nominal. 1000: Reserved.
			2:0	Reserved	000	Reserved as 000. Always write 000 to these bits.
03h	R	CLI	7:3	CLI		Cable Length Indicator. Provides an indication of the length of cable attached to the equalizer input. CLI increases as the cable length increases.
			2:0	Reserved	000	Reserved.

**Physical Dimensions** inches (millimeters) unless otherwise noted



**RECOMMENDED LAND PATTERN**  
1:1 RATIO WITH PACKAGE SOLDER PADS

**DIMENSIONS ARE IN MILLIMETERS**  
DIMENSIONS IN ( ) FOR REFERENCE ONLY



**48-Pin Laminate TCSP**  
**Order Number LMH0387SL**  
**NS Package Number SLD48A**

SLD48A (Rev B)

# Notes

LMH0387

## Notes

For more National Semiconductor product information and proven design tools, visit the following Web sites at:  
[www.national.com](http://www.national.com)

Products		Design Support	
Amplifiers	<a href="http://www.national.com/amplifiers">www.national.com/amplifiers</a>	WEBENCH® Tools	<a href="http://www.national.com/webench">www.national.com/webench</a>
Audio	<a href="http://www.national.com/audio">www.national.com/audio</a>	App Notes	<a href="http://www.national.com/appnotes">www.national.com/appnotes</a>
Clock and Timing	<a href="http://www.national.com/timing">www.national.com/timing</a>	Reference Designs	<a href="http://www.national.com/refdesigns">www.national.com/refdesigns</a>
Data Converters	<a href="http://www.national.com/adc">www.national.com/adc</a>	Samples	<a href="http://www.national.com/samples">www.national.com/samples</a>
Interface	<a href="http://www.national.com/interface">www.national.com/interface</a>	Eval Boards	<a href="http://www.national.com/evalboards">www.national.com/evalboards</a>
LVDS	<a href="http://www.national.com/lvds">www.national.com/lvds</a>	Packaging	<a href="http://www.national.com/packaging">www.national.com/packaging</a>
Power Management	<a href="http://www.national.com/power">www.national.com/power</a>	Green Compliance	<a href="http://www.national.com/quality/green">www.national.com/quality/green</a>
Switching Regulators	<a href="http://www.national.com/switchers">www.national.com/switchers</a>	Distributors	<a href="http://www.national.com/contacts">www.national.com/contacts</a>
LDOs	<a href="http://www.national.com/ldo">www.national.com/ldo</a>	Quality and Reliability	<a href="http://www.national.com/quality">www.national.com/quality</a>
LED Lighting	<a href="http://www.national.com/led">www.national.com/led</a>	Feedback/Support	<a href="http://www.national.com/feedback">www.national.com/feedback</a>
Voltage References	<a href="http://www.national.com/vref">www.national.com/vref</a>	Design Made Easy	<a href="http://www.national.com/easy">www.national.com/easy</a>
PowerWise® Solutions	<a href="http://www.national.com/powerwise">www.national.com/powerwise</a>	Applications & Markets	<a href="http://www.national.com/solutions">www.national.com/solutions</a>
Serial Digital Interface (SDI)	<a href="http://www.national.com/sdi">www.national.com/sdi</a>	Mil/Aero	<a href="http://www.national.com/milaero">www.national.com/milaero</a>
Temperature Sensors	<a href="http://www.national.com/tempensors">www.national.com/tempensors</a>	SolarMagic™	<a href="http://www.national.com/solarmagic">www.national.com/solarmagic</a>
PLL/VCO	<a href="http://www.national.com/wireless">www.national.com/wireless</a>	PowerWise® Design University	<a href="http://www.national.com/training">www.national.com/training</a>

THE CONTENTS OF THIS DOCUMENT ARE PROVIDED IN CONNECTION WITH NATIONAL SEMICONDUCTOR CORPORATION ("NATIONAL") PRODUCTS. NATIONAL MAKES NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS PUBLICATION AND RESERVES THE RIGHT TO MAKE CHANGES TO SPECIFICATIONS AND PRODUCT DESCRIPTIONS AT ANY TIME WITHOUT NOTICE. NO LICENSE, WHETHER EXPRESS, IMPLIED, ARISING BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT.

TESTING AND OTHER QUALITY CONTROLS ARE USED TO THE EXTENT NATIONAL DEEMS NECESSARY TO SUPPORT NATIONAL'S PRODUCT WARRANTY. EXCEPT WHERE MANDATED BY GOVERNMENT REQUIREMENTS, TESTING OF ALL PARAMETERS OF EACH PRODUCT IS NOT NECESSARILY PERFORMED. NATIONAL ASSUMES NO LIABILITY FOR APPLICATIONS ASSISTANCE OR BUYER PRODUCT DESIGN. BUYERS ARE RESPONSIBLE FOR THEIR PRODUCTS AND APPLICATIONS USING NATIONAL COMPONENTS. PRIOR TO USING OR DISTRIBUTING ANY PRODUCTS THAT INCLUDE NATIONAL COMPONENTS, BUYERS SHOULD PROVIDE ADEQUATE DESIGN, TESTING AND OPERATING SAFEGUARDS.

EXCEPT AS PROVIDED IN NATIONAL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, NATIONAL ASSUMES NO LIABILITY WHATSOEVER, AND NATIONAL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY RELATING TO THE SALE AND/OR USE OF NATIONAL PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

#### LIFE SUPPORT POLICY

**NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS PRIOR WRITTEN APPROVAL OF THE CHIEF EXECUTIVE OFFICER AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION.** As used herein:

Life support devices or systems are devices which (a) are intended for surgical implant into the body, or (b) support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in a significant injury to the user. A critical component is any component in 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.

National Semiconductor and the National Semiconductor logo are registered trademarks of National Semiconductor Corporation. All other brand or product names may be trademarks or registered trademarks of their respective holders.

Copyright© 2011 National Semiconductor Corporation

For the most current product information visit us at [www.national.com](http://www.national.com)



**National Semiconductor Americas Technical Support Center**  
 Email: [support@nsc.com](mailto:support@nsc.com)  
 Tel: 1-800-272-9959

**National Semiconductor Europe Technical Support Center**  
 Email: [europe.support@nsc.com](mailto:europe.support@nsc.com)

**National Semiconductor Asia Pacific Technical Support Center**  
 Email: [ap.support@nsc.com](mailto:ap.support@nsc.com)

**National Semiconductor Japan Technical Support Center**  
 Email: [jpn.feedback@nsc.com](mailto:jpn.feedback@nsc.com)