ACS37610H

Coreless, High Precision, Hall-Effect Current Sensor IC
with Common-Mode Field Rejection, Overcurrent and Overtemperature Detection

FEATURES AND BENEFITS

- Eliminates need for concentrator core or shield
- Contactless, lossless, noninvasive current sensing
- Suited for applications where current flows through busbar or PCB
- High operating bandwidth: DC to 200 kHz
- Overcurrent (OCF) and overtemperature (OTF) detection on fault pin
- Differential Hall sensing rejects common-mode magnetic fields
- Very fast response time (<2 µs typical)
- Very high sensitivity (40 to 60 mV/G)
  - □ Ideal for sensing currents on a PCB from 50 A
- Factory-programmed segmented linear temperature compensation (TC) provides low thermal drift
  - □ Sensitivity ±1% (typical)
  - □ Offset ±3 mV (typical)
- Customer-programmable, high-resolution offset and sensitivity trim
- Wide Hall-element spacing for improved SNR and thermal performance
- Ultra-sensitive Hall elements for improved noise performance

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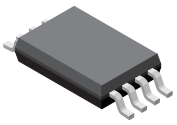
PACKAGE:

8-pin TSSOP package (suffix LU)



Not to scale

DESCRIPTION

The Allegro ACS37610H current sensor IC enables low-cost solutions for AC and DC current sensing without the need for an external field concentrator core or a U-shaped magnetic shield. It is designed for applications where hundreds of amps or more flow through a busbar or PCB.

Current flowing through a busbar or PCB trace generates a magnetic field that is sensed by the monolithic, low-offset, linear Hall IC. The differential sensing topology virtually eliminates all types of errors due to common-mode stray magnetic fields. The wide spacing between the differential Hall elements (2.58 mm) coupled with the increased sensitivity of each Hall element enable the ACS37610H to achieve superior signal to noise (SNR) and improved resolution. While not mandatory, a notch or slit in the current-carrying busbar or PCB copper trace provides further improvements to system SNR. High isolation is achieved via the no-contact nature of this simple assembly.

The ACS37610H is offered with regular and low-power modes, enabling customers to achieve optimal SNR and power consumption. A dedicated user-programmable overcurrent and overtemperature fault pin and a slew of built-in diagnostics, including broken ground and VCC detection, make it ideal for

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TYPICAL APPLICATIONS

- High-voltage traction motor inverter
- 48 V/12 V auxiliary inverter
- Heterogeneous redundant battery monitoring
- Overcurrent detection
- DC/DC converter
- Smart fuse
- Power distribution unit (PDU)
- Power supply

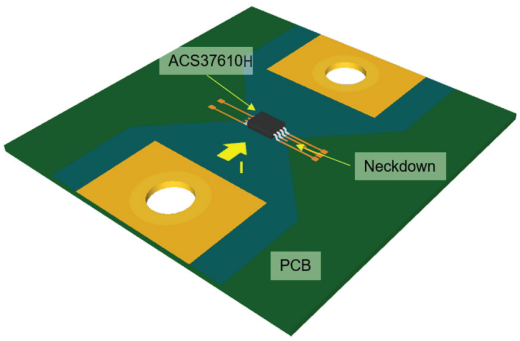


Figure 1: Current Through PCB

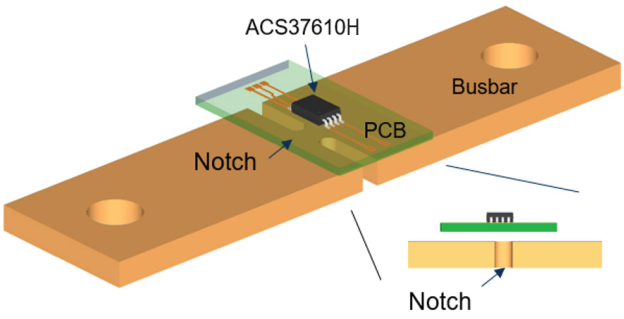


Figure 2: Current Through Busbar

FEATURES AND BENEFITS (continued)

- Wide ambient temperature range: –40°C to 150°C
- 3.3 or 5 V single-supply operation
- Programmable through output pin or through dedicated programming pin for easier device programming
- AEC-Q100 Grade 0, automotive qualified
- Monolithic Hall IC for high reliability
- Surface-mount, small-footprint, low-profile TSSOP8 package

DESCRIPTION (continued)

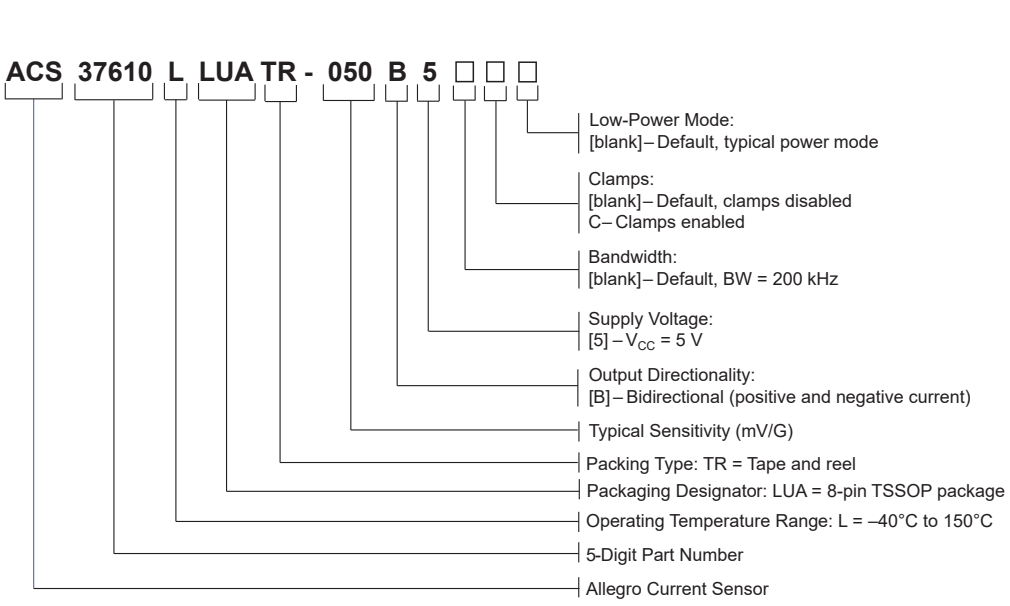
safety-critical applications. The accuracy and flexibility of this device is enhanced by user programmability, performed via the output pin or through the dedicated programming pin, which allows the device to be optimized in the application and cancels errors due to mechanical assembly tolerances on the PCB. Device specifications apply across an extended ambient temperature range: –40°C to 150°C.

The ACS37610H is suitable for space-constrained applications because of its low-profile 8-pin surface-mount thin-shrink small-outline package (TSSOP; Allegro suffix LU) that is lead (Pb) free, with 100% matte tin leadframe plating. The sensor can be mounted in a horizontal or vertical orientation relative to the busbar, providing superior flexibility in mechanical assemblies.

SELECTION GUIDE

Part Number	Nominal Supply Voltage (V)	Differential Magnetic Input Range, (G)	Sensitivity Sens (Typ.) (mV/G) [1]	Sensitivity Trim Range (mV/G) [1]	T_A (°C)	Packing [2]
ACS37610LLUATR-050B5	5	±40	50	40 to 60	–40 to 150	4000 pieces per 13-inch reel

[1] Measured at nominal supply voltage. Contact Allegro for other sensitivity options.
[2] Contact Allegro for additional packing options.



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ABSOLUTE MAXIMUM RATINGS

Characteristic	Symbol	Notes	Rating	Unit
Supply Voltage	V_{CC}	For a maximum duration of 1 minute	7.5	V
Reverse Supply Voltage	V_{RCC}		–0.5	V
Output Voltage	V_{OUT}		6.5	V
Reverse Output Voltage	V_{ROUT}		–0.5	V
Fault Voltage	V_F		6.5	V
Reverse Fault Output Voltage	V_{FR}		–0.5	V
Output Source Current	$I_{OUT(Source)}$	VOUT to GND	25	mA
Output Sink Current	$I_{OUT(Sink)}$	Maximum survivable sink or source current on the output	10	mA
Nominal Operating Ambient Temperature	T_A	Range L	–40 to 150	°C
Maximum Junction Temperature	$T_{J(max)}$		165	°C
Storage Temperature	T_{stg}		–65 to 165	°C

ESD RATINGS

Characteristic	Symbol	Test Conditions	Value	Unit
Human Body Model	V_{HBM}	Per JEDEC JS-001	9	kV
Charged Device Model	V_{CDM}	Per JEDEC JS-002	1	kV

THERMAL CHARACTERISTICS: May require derating at maximum conditions; see application information

Characteristic	Symbol	Test Conditions [1]	Value	Unit
Package Thermal Resistance	$R_{\theta JA}$	TSSOP-8 on 4-layer PCB based on JEDEC standard	145	°C/W

[1] Additional thermal information available on the Allegro website.

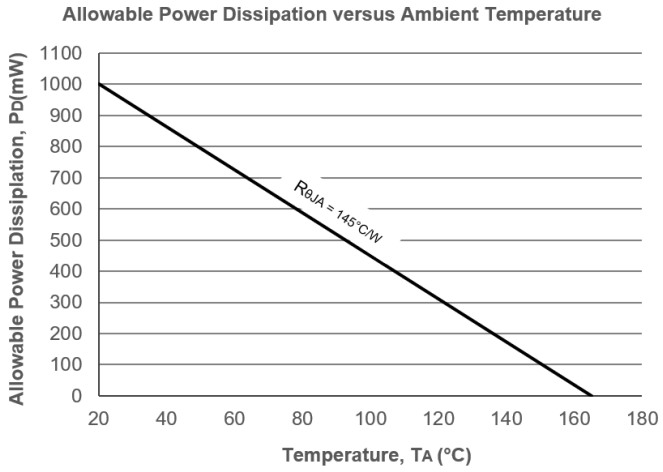

Figure 3: Allowable Power Dissipation

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TYPICAL APPLICATION CIRCUITS

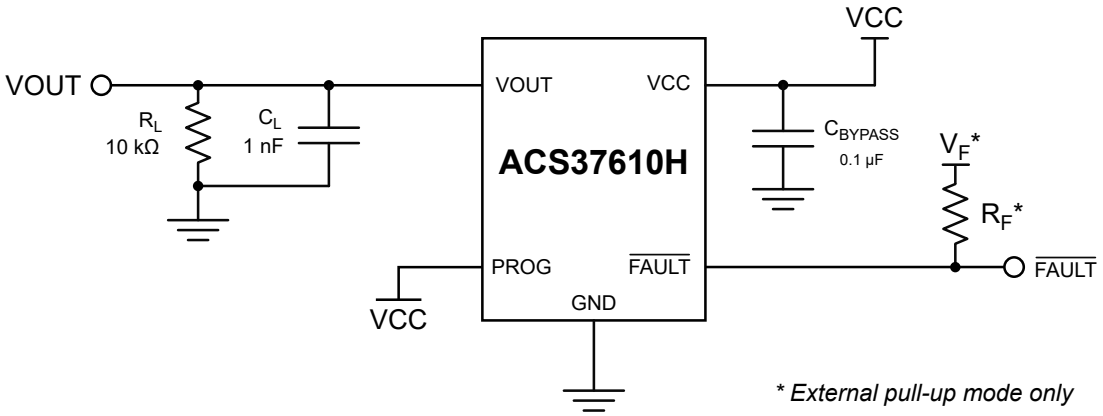

Figure 4: Typical Application Circuit (Programming Pin Not Used)

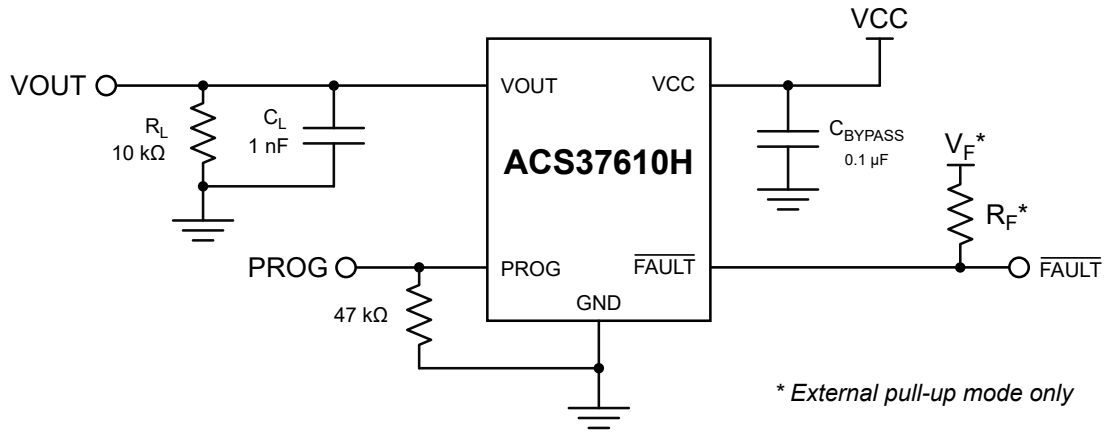

Figure 5: Typical Application Circuit (Programming Pin Used)

The ACS37610H outputs an analog signal, V_{OUT}, that varies linearly with the bidirectional AC or DC field sensed, within the range specified. C_L is for optimal noise management, with values that depend on the application. R_L is an optional pulldown to GND or pullup to VCC for broken wire detection. For broken GND function, it is recommended to tie the PROG pin to VCC when not used. R_F is an optional pull-up resistor to V_F, to be used when disabling the device internal pull-up in memory.

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PINOUT DIAGRAM AND PINOUT LIST

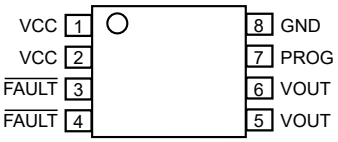

Figure 6: Pinout Diagram

Pinout List

Number	Name	Description
1,2	VCC	Input power supply; also used for programming
3,4	$\overline{\text{FAULT}}$	Fault output; overcurrent, overtemperature
5,6	VOUT	Analog output signal; also used for programming
7	PROG	Bidirectional programming pin
8	GND	Ground pin

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FUNCTIONAL BLOCK DIAGRAM

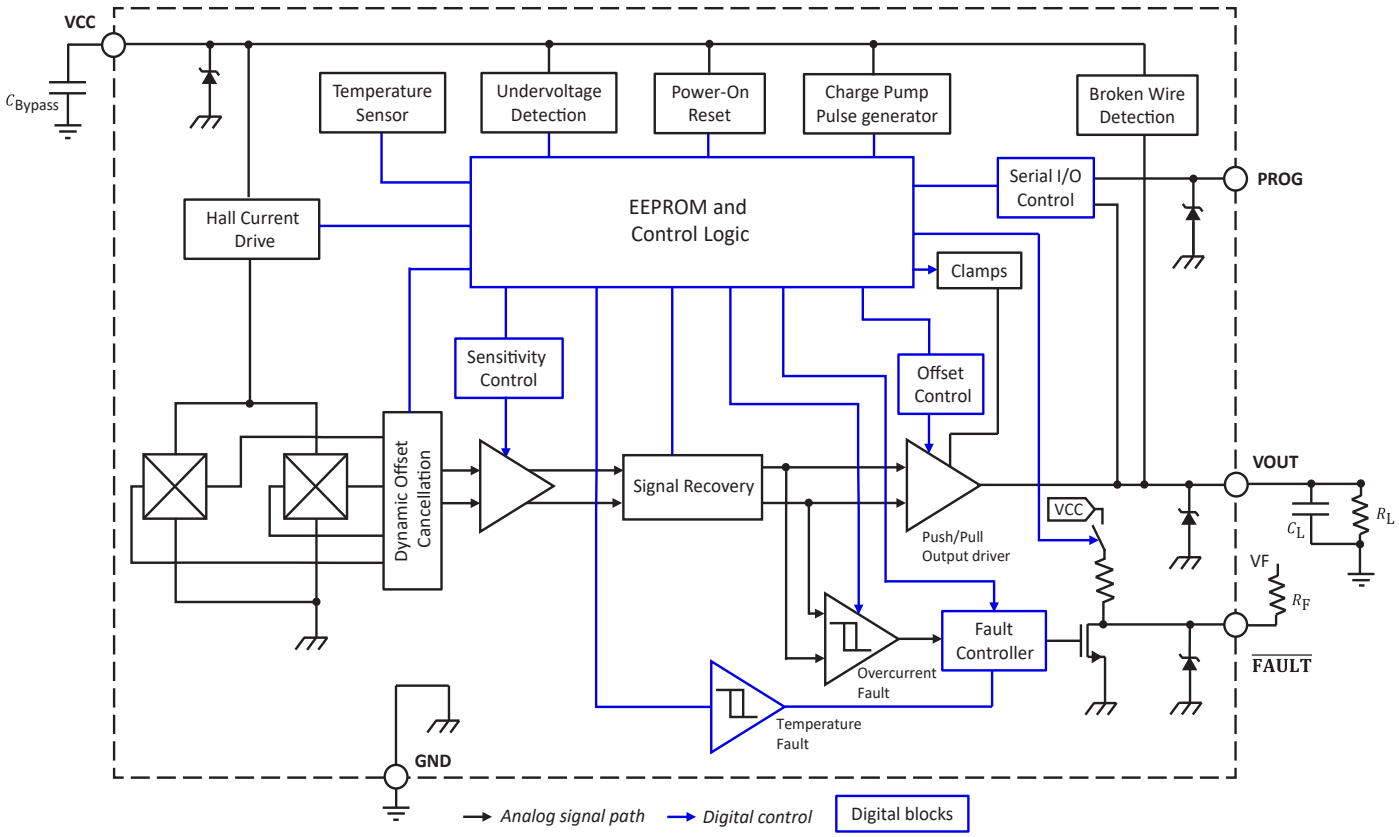

Figure 7: Functional Block Diagram

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COMMON OPERATING CHARACTERISTICS: Valid through full range of T_A and V_{CC}, C_{BYPASS} = 100 nF, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
ELECTRICAL CHARACTERISTICS						
Supply Voltage	V_{CC}	5 V nominal supply voltage variant	4.5	5	5.5	V
		3.3 V nominal supply voltage variant	3	3.3	3.6	V
Supply Current	I_{CC}	5 V nominal supply voltage variant; $V_{CC}(min) \le V_{CC} \le V_{CC}(max)$, no load on output	–	16.5	21	mA
		5 V nominal supply voltage variant; low-power mode, no load on output	–	13.5	18	mA
		3.3 V nominal supply voltage variant; $V_{CC}(min) \le V_{CC} \le V_{CC}(max)$, no load on output	–	14.5	19	mA
		3.3 V nominal supply voltage variant; low-power mode, no load on output	–	10.5	14	mA
Power-On Time	t_{PO}	T_A = 25°C, C_L (of test probe) = 10 pF, C_{BYPASS} = open	–	70	–	µs
Temperature Compensation Power-On Time	t_{TC}	Time after power-on time (t_{PO}) required to get valid temperature-compensated output; T_A = 150°C, C_{BYPASS} = open, C_L = 1 nF	–	45	–	µs
Fault Power-On Time	$t_{PO(FAULT)}$	Time from when $V_{CC} > V_{UVLOD}$ to when OCF reacts to overcurrent event	–	270	–	µs
Overvoltage Detection Threshold	V_{OVDE}	T_A = 25°C, V_{CC} rising and device function disabled	6.35	6.9	7.2	V
	V_{OVDD}	T_A = 25°C, V_{CC} falling and device function enabled	5.75	6	6.25	V
	V_{OVHYS}	T_A = 25°C	–	450	–	mV
OVD Enable/Disable Delay Time	t_{OVDE}	T_A = 25°C, C_{BYPASS} = open, C_L = 1 nF	–	60	–	µs
	t_{OVDD}	T_A = 25°C, C_{BYPASS} = open, C_L = 1 nF	–	3	–	µs
Undervoltage Lockout (UVLO) Threshold	V_{UVLOD}	V_{CC} rising, 5 V variant only	–	4.1	4.3	V
	V_{UVLOE}	V_{CC} falling, 5 V variant only	3.45	3.75	–	V
Undervoltage Lockout (UVLO) Hysteresis	$V_{UVLO(HYS)}$	5 V variant only	–	450	–	mV
UVD Enable/Disable Delay Time	t_{UVLOE}	Time measured from falling $V_{CC} < V_{UVLOE}$ to UVLO enabled; T_A = 25°C, C_{BYPASS} = open, C_L = 1 nF	–	65	–	µs
	t_{UVLOD}	Time measured from rising $V_{CC} > V_{UVLOD}$ to UVLO disabled; T_A = 25°C, C_{BYPASS} = open, C_L = 1 nF	–	8	–	µs
Power-On Reset Voltage	V_{PORH}	V_{CC} rising	2.7	2.9	3	V
	V_{PORL}	V_{CC} falling	2.5	2.7	2.9	V
Power-On Reset Hysteresis	$V_{HYS(POR)}$		50	150	–	mV
Power-On Reset Release Time	t_{PORR}	Time V_{CC} must be held above V_{PORH} to start counting for t_{UVLOD} after $V_{CC} > V_{UVLOD}$ and transition from high impedance to typical operation; T_A = 25°C, V_{CC} rising	–	65	–	µs
Internal Bandwidth [1]	BW_i	–3 dB, C_L = 1 nF, T_A = 25°C	–	200	–	kHz
Rise Time [1]	t_r	T_A = 25°C, C_L= 1 nF, 1 V step on output, BW_i = 200 kHz	–	2.4	–	µs

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COMMON OPERATING CHARACTERISTICS (continued): Valid through full range of T_A and V_{CC}, C_{BYPASS} = 100 nF, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Propagation Delay [1]	t_{PD}	T_A = 25°C, C_L= 1 nF, 1 V step on output, BW_i = 200 kHz	–	1.1	–	µs
Response Time [1]	$t_{RESPONSE}$	T_A = 25°C, C_L= 1 nF, 1 V step on output, BW_i = 200 kHz	–	2	–	µs
DC Output Impedance	R_{OUT}		–	< 1	–	Ω
Output Load Resistance	R_L	VOUT to GND	4.7	10	–	kΩ
Output Load Capacitance	C_L	VOUT to GND	–	1	10	nF
Delay to Clamp	t_{CLP}	T_A = 25°C; C_L = 1 nF; Step from 75% output range to 150%	–	5	–	µs
Output Full-Scale Range	$V_{OUT(FSR)}$	Full-scale output, 5 V variant, bidirectional	–	±2	–	V
		Full-scale output, 3.3 V variant, bidirectional	–	±1.32	–	V
		Full-scale output, 5 V variant, unidirectional	–	4	–	V
Output Voltage Clamp	$V_{CLP(HIGH)}$	V_{CC} = 5 V, $R_{L(PULLDOWN)}$ = 10 kΩ to GND	4.48	–	4.75	V
		V_{CC} = 3.3 V, $R_{L(PULLDOWN)}$ = 10 kΩ to GND	2.94	–	3.18	V
	$V_{CLP(LOW)}$	V_{CC} = 5 V, $R_{L(PULLUP)}$ = 10 kΩ to VCC	0.25	–	0.5	V
		V_{CC} = 3.3 V, $R_{L(PULLUP)}$ = 10 kΩ to VCC	0.15	–	0.33	V
Output Saturation Voltage	$V_{SAT(HIGH)}$	$R_{L(PULLDWN)}$ = 10 kΩ to GND	V_{CC} – 0.2	–	–	V
	$V_{SAT(LOW)}$	$R_{L(PULLUP)}$ = 10 kΩ to VCC	–	–	200	mV
Broken Wire Voltage	$V_{BRK(High)}$	$R_{L(PULLUP)}$ = 10 kΩ to VCC	V_{CC} – 0.1	V_{CC}	V_{CC}	V
	$V_{BRK(Low)}$	$R_{L(PULLDOWN)}$ = 10 kΩ to GND	0	0	100	mV
ERROR COMPONENTS						
Clamp Ratiometry Error	Rat_{ERRCLP}	V_{CC} = ±3% variation of nominal supply voltage	–	< ±0.5	–	%
Common Mode Field Rejection Ratio	CMFRR	Measured at 100 G uniform magnetic field	–	40	–	dB
Noise Density	B_{ND}	Typical power mode, 5 V/3.3 V variant, T_A = 25°C, C_L = 1 nF	–	0.9	–	mG /√(Hz)
		Low-power mode, 5 V/3.3 V variant, T_A = 25°C, C_L = 1 nF	–	1.2	–	mG /√(Hz)

[1] Timing specified does not include potential effect of skin effect on conductor; value depends on busbar/PCB design.

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FAULT CHARACTERISTICS

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Positive Field Fault Switch Point Range [1]	OCF_PThres	Programmable using OCF positive threshold bits. In percent of full-scale positive output (2.5 to 4.5 V) on bidirectional variant.	50	–	200	%FS(+)
		Programmable using OCF positive threshold bits. In percent of full-scale output (0.5 to 4.5 V) on unidirectional variant.	50	–	200	%FS
Negative Field Fault Switch Point Range [1]	OCF_NThres	Programmable using OCF negative threshold bits. In percent of full-scale negative output (2 V typical, 2.5 to 0.5 V) on bidirectional variant	50	–	200	%FS(–)
Overcurrent Fault Switch Point Step Size	OCF_step	Overcurrent fault threshold programming step size	–	1.6	–	%FS
Overcurrent Fault Accuracy	OCF_acc	Overcurrent fault threshold accuracy through full range of T_A	–10	±2	+10	%FS
Overcurrent Fault Response Time	t_{OCF}	$R_{F(PULLUP)}$ = 10 kΩ from FAULT to VF, VOUT step from $V_{OUT(Q)}$ to V_{OUT} = ($V_{OUT(Q)}$ + OCF_PThres [V]); BW_i = 200 kHz, OCF qualifier = 0	–	2.5	–	µs
Overtemperature Fault Sampling Rate	OTFs	Rate at which the temperature is sampled	–	8	–	ms
Fault Clear Time	$t_{C(F)}$	Time to release FAULT pin (go back to VF) when fault condition is no longer present. R_F = 10 kΩ, external 100 pF from FAULT to VCC	–	8	–	µs
		Time to release FAULT pin (go back to VCC) when fault condition is no longer present. Internal fault pull-up enabled	–	15	–	µs
Fault Jitter	OCF_Jitt	T_A = 25°C, 1 sigma	–	100	–	ns
Overcurrent Fault Hysteresis Level Range [1]	OCF_Hyst	Hysteresis in percent of trip level, T_A = 25°C, OCF_HYST bit = 0	–	11	–	%
		Hysteresis in percent of trip level, T_A = 25°C, OCF_HYST bit = 1	–	22	–	%
		Hysteresis in percent of trip level, T_A = 25°C, OCF_HYST bit = 2	–	45	–	%
		Hysteresis in percent of trip level, T_A = 25°C, OCF_HYST bit = 3	–	75	–	%
Overtemperature Fault Accuracy [1]	OTF_acc		–10	±3	+10	°C
Overtemperature Fault Threshold Range [1]	OTF_thresh		80	160	165	°C
Overtemperature Fault Step size			–	7	–	°C
Overtemperature Fault Hysteresis [1]	OTF_Hyst	Overtemperature fault fixed hysteresis value	10	15	20	°C
FAULT Pin Low Output Voltage	V_{FAULT}	$R_{F(PULLUP)}$ = 4.7 kΩ from FAULT to VCC	–	–	0.4	V
FAULT Pin Leakage Current	I_{FLeak}	$R_{F(PULLUP)}$ = 4.7 kΩ from FAULT to VCC	–	–	1.3	µA
External Pull-Up Supply Voltage [1]	$V_{F(PULLUP)}$		1.65	V_{CC}	V_{CC}	V
External FAULT Pullup Resistor [1]	$R_{F(PULLUP)}$		4.7	–	500	kΩ
External FAULT Capacitance [1]	C_F		–	–	10	nF
Internal FAULT Pull-Up Resistor	$R_{IF(PULLUP)}$	Internal pull up to V_{CC}; set FAULTR_DIS bit to 1 in EEPROM to disable.	–	10	–	kΩ

[1] Limits guaranteed by design and characterization data, not tested in production.

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-050B5 PERFORMANCE CHARACTERISTICS: Valid over full range of T_A and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
NOMINAL PERFORMANCE						
Differential Magnetic Range	B_{DIFF}	Corresponding full-scale magnetic range based on typical sensitivity	–40	–	40	G
Initial Factory-Programmed Sensitivity	Sens	Factory-programmed sensitivity; T_A = 25°C	49	50	51	mV/G
Initial Quiescent Output Voltage	$V_{OUT(Q)}$	Factory-programmed quiescent output voltage; T_A = 25°C	2.485	2.5	2.515	V
Noise	V_N	T_A = 25°C, C_L = 1 nF, BW_i = 200 kHz	–	25	–	mV_{RMS}
Nonlinearity	E_{LIN}	Tested up to full-scale output	–1	±0.25	1	%
SENSITIVITY ERROR						
Sens Ratiometry Error [1]	$Rat_{ErrSens}$	V_{CC} = ±3% variation of nominal supply voltage	–1.75	±0.25	1.75	%
Sensitivity Drift Over Temperature	$\Delta Sens_{TC}$	T_A = 25°C to 150°C	–1.75	±1	1.75	%
		T_A = –40°C to 25°C	–1.75	±1	1.75	%
		T_A = 25°C to 150°C, ±20% sensitivity change	–2.2	±1	2.2	%
		T_A = –40°C to 25°C, ±20% sensitivity change	–2.2	±1	2.2	%
QUIESCENT VOLTAGE OUTPUT ERROR						
QVO Ratiometry Error [1]	$V_{RatErrQVO}$	V_{CC} = ±3% variation of nominal supply voltage	–12.5	±2	12.5	mV
Quiescent Voltage Output Temperature Error	$V_{OUT(Q)TC}$	T_A = 25°C to 150°C	–15	±4	15	mV
		T_A = –40°C to 25°C	–15	±4	15	mV
		T_A = 25°C to 150°C, ±20% sensitivity change	–20	±4	20	mV
		T_A = –40°C to 25°C, ±20% sensitivity change	–20	±4	20	mV
LIFETIME DRIFT CHARACTERISTICS [2]						
QVO Lifetime Drift	$V_{OUT(Q)LIFE}$	Initial sensitivity	–	±31.5	–	mV
Sens Lifetime Drift	$Sens_{LIFE}$	Initial sensitivity	–	1.9	–	%

[1] For lower V_{CC} variations than test conditions, ratiometry error linearly scales with V_{CC}; e.g., ±1.5% variations on V_{CC}, instead of ±3%, leads to $Rat_{ErrSens}$ and $V_{RatErrQVO}$ to be divided by 2.

[2] Lifetime drift characteristics are based on the AEC-Q100 qualification results from reads at zero hours. Typical values are the worst-case observed mean ±3-sigma drift during AEC-Q100 qualification from any of the –40°C, 25°C, or 150°C temperatures.

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FUNCTIONAL DESCRIPTION

Principle of Operation

When AC or DC current flows through a PCB copper trace or a busbar, as shown in Figure 8, the ACS37610H device senses the magnetic field difference induced between its two Hall elements, H_L and H_R, represented by the field components B_L and B_R, respectively. The device output is proportional to the differential field sensed, B_{diff}, which is proportional to the applied current. The relationship between applied current and generated field is described as:

$$B_{diff} = CF \times I,$$

where B_{diff} is the differential field ($H_L - H_R$), CF is the differential coupling factor (G/A), and I is the current through the busbar/PCB trace. As demonstrated in this equation, the differential coupling factor (CF) is the linear relationship between the differential field sensed and the current flowing in the conductor. Different busbar shapes can be used to best answer application requirements; for more details, see the Application Information section.

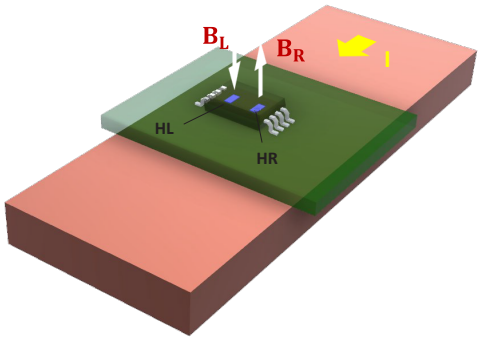

Figure 8: Current-Sensing Principle

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Device Diagnostics

The ACS37610H device offers multiple built-in diagnostics with the effects and programmability described in Table 1.

Table 1: Device Diagnostics Table

Diagnostic	Effect on V_{OUT}	Effect on FAULT	Note
Overvoltage Detection	V_{OUT} goes to a high-impedance state if V_{CC} is higher than V_{OVDE} for more than t_{OVDE} (64 µs typical).	FAULT goes to a high-impedance state, pulled up to V_{FAULT}.	NOTE 1: When V_{OUT} goes to the high-impedance state, the voltage on V_{OUT} is pulled down to GND or pulled up to V_{CC}, depending on the application wiring. If the COM_LOCK bit is set, the OVD feature is disabled.
Undervoltage Detection	V_{OUT} is pulled to GND if V_{CC} drops below V_{UVLOE} for more than t_{UVLOE} (64 µs typical). V_{OUT} goes a high-impedance state if V_{CC} drops farther below V_{PORL}.	FAULT goes to a high-impedance state, pulled up to V_{FAULT}.	See NOTE 1.
Broken Wire	V_{OUT} goes to a high-impedance state.	FAULT goes to a high-impedance state, pulled up to V_{FAULT}.	See NOTE 1.
Overcurrent	No effect.	FAULT pin is pulled to GND.	Overcurrent threshold is programmable and can be enabled/disabled in EEPROM.
Overtemperature	No effect.	FAULT pin is pulled to GND.	Overtemperature threshold is programmable and can be enabled/disabled in EEPROM.
Clamps	V_{OUT} can range from $V_{CLP(Low)}$ to $V_{CLP(High)}$.	No effect.	Clamps can be enabled/disabled in EEPROM.
EEPROM Error Checking and Correction	If an uncorrectable error occurrs in EEPROM, V_{OUT} goes to a high-impedance state.	FAULT goes to a high-impedance state.	See NOTE 1.

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Broken Wire Detection

If the GND pin is disconnected, such that node A becomes open (Figure 9), the VOUT pin and FAULT pin go to a high-impedance state. The output voltage goes to: $V_{BRK(HIGH)}$, if load resistor $R_{L(PULLUP)}$ is connected to VCC; or $V_{BRK(LOW)}$, if load resistor $R_{L(PULLDOWN)}$ is connected to GND.

If the VCC pin is disconnected, such that node B becomes open (Figure 9), the VOUT pin and FAULT pin go to a high-impedance state. The output voltage goes to $V_{BRK(LOW)}$ if load resistor $R_{L(PULLDWN)}$ is connected to GND.

Detection for broken VCC can only be guaranteed when a pull-down resistor is used.

Following a broken wire event, the device does not respond to any applied magnetic field. If load resistor $R_{F(PULLUP)}$ is connected to the FAULT pin, the fault voltage goes to the $V_{F(PULLUP)}$ voltage.

If the disconnected wire is reconnected, the device resumes typical operation.

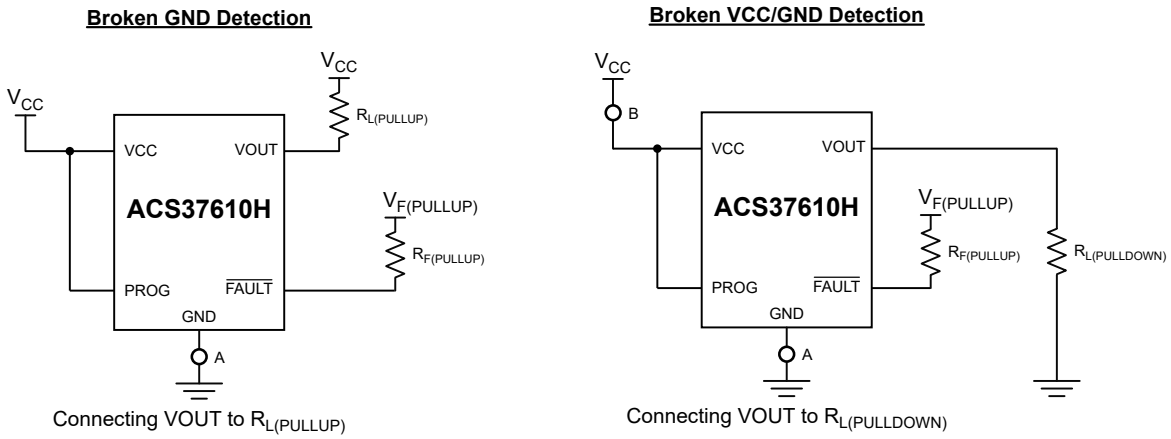

Figure 9: Connection for Detecting Broken Ground Wire

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DEVICE PROGRAMMING

- The serial interface uses Manchester protocol to communicate.
- Device programming can be achieved with bidirectional communication on VOUT or on the dedicated PROG pin.
- The device has an internal charge pump to generate the EEPROM pulses.
- The PROG pin can be left unconnected or tied to GND or VCC when not used.

Serial Communication

The serial interface allows an external controller to read and write registers, including EEPROM, in the device using a point-to-point command/acknowledge protocol. The device does not initiate communication; it only responds to commands from the external controller. Each transaction consists of a command from the controller. If the command is a write, there is no acknowledgement from the device. If the command is a read, the device responds by transmitting the requested data. Two modes are available for device communication.

Mode 1, Programming on VOUT pin (see Figure 10): To enable bidirectional programming on VOUT, voltage is raised on V_{CC} (V_{OVDE}) for at least t_{OVDE}, followed by the access code on VOUT. If the COM_LOCK bit is set (= 1), bidirectional programming on VOUT is disabled. If the COM_LOCK bit is not set (= 0), there is no timeout limit to send the access code as long as V_{CC} stays above V_{OVDE} for at least t_{OVDE}. The start of any Manchester command should begin with holding the output low for t_{BIT} to ensure a reset of the Manchester state machine occurs. If an incorrect access code is sent, VOUT remains in the typical analog mode (responds to magnetic stimulus) and the device remains locked for communication on VOUT until a power reset occurs.

When writing into nonvolatile memory (EEPROM), V_{CC} must not exceed 5 V to ensure safe EEPROM writing. To achieve this, two methods can be used:

Method 1 (to write EEPROM in Mode 1):

Locks VOUT into communication mode such that VCC can be returned to the typical supply voltage (5 V/3.3 V):

1. Set V_{CC} to V_{OVDE} (OVD)
2. Send access code + COMM_EN
3. Set V_{CC} back to typical level (5 V/3.3 V)
4. Send EEPROM write commands
5. Power-cycle the device to re-enable analog output on VOUT

Method 2 (to write EEPROM in Mode 1)

Reduces VCC back to typical supply voltage (5 V/3.3 V) after sending the EEPROM write sequence:

1. Set V_{CC} to V_{OVDE} (OVD)
2. Send access code
3. Send EEPROM write commands
4. Set V_{CC} to typical level (5 V/3.3 V)
5. Wait 20 ms for EEPROM write

With method 2, the PROG pin must not be connected to GND (can be left floating or can be connected to VCC).

For more details, see the Access section and the figures in the Manchester Protocol section. When not used, it is recommended to tie the PROG pin to VCC (for the broken GND feature).

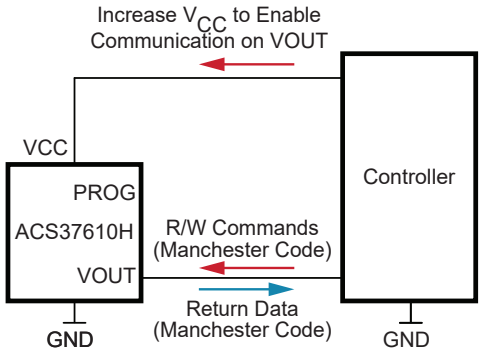

Figure 10: Programming Connection—Mode 1

Mode 2, Programming on PROG pin (see Figure 11): V_{CC} remains 5 V (below V_{OVDE}), and bidirectional programming is achieved on the PROG pin by sending an access code (independently of the COM_LOCK value). No pull-up is required on the PROG pin.

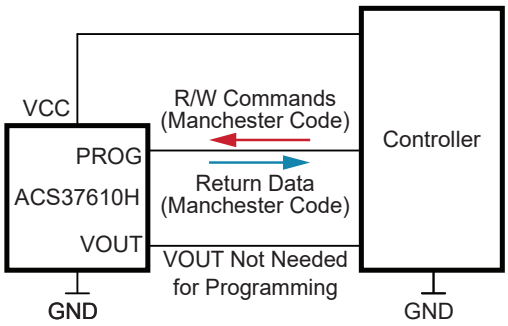

Figure 11: Programming Connections—Mode 2

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Manchester Protocol

The serial interface uses a Manchester-encoding-based protocol per G.E. Thomas (0 = rising edge, 1 = falling edge), with address and data transmitted MSB first. Four commands are recognized by the device: write access code, write to volatile memory, write to nonvolatile memory (EEPROM), and read. One frame type, read acknowledge, is sent by the device in response to a read command.

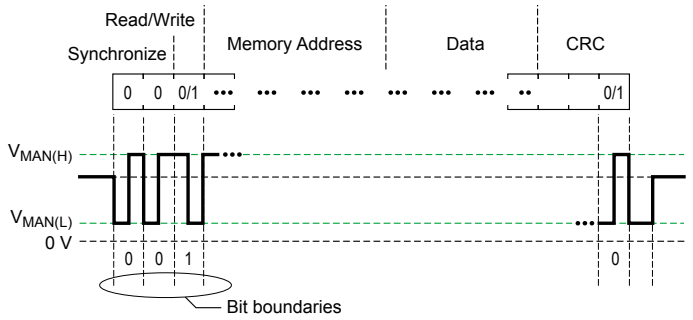

Figure 12: General Format For Serial Interface Commands

Read (Controller to Device)

The fields for the read command are:

- Sync (2 bits, both set to 0)
- Read/Write (1 bit; must be set to 1 for read)
- CRC (3 bits)

The sequence for a read command is shown in Figure 13.

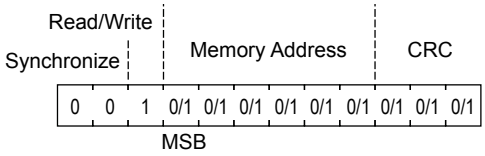

Figure 13: Read Sequence

Read Acknowledge (Device to Controller)

The fields for the data return frame are:

- Sync (2 zero bits)
- Data (32 bits):
  - □ [31:28] Not relevant
  - □ [27:26] ECC pass/fail
  - □ [25:0] Data

The read acknowledge sequence is shown in Figure 14. For instructions about how to detect read/write synchronize memory address data (32 bits) and ECC failure, refer to the Detecting ECC Error section.

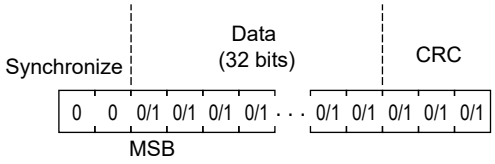

Figure 14: Read Acknowledge Sequence

Write (Controller to Device)

The fields for the write command are:

- Sync (2 bits, both set to 0)
- Read/Write (1 bit; must be set to 0 for write)
- Address (6 bits)
- Data (32 bits):
  - □ [31:26] Not relevant
  - □ [25:0] Data
- CRC (3 bits)

The sequence for a write command is shown in Figure 15. Bits [31:26] are not relevant because the device automatically generates 6 ECC bits based on the content of bits [25:0]. These ECC bits are later stored in EEPROM at locations [31:26].

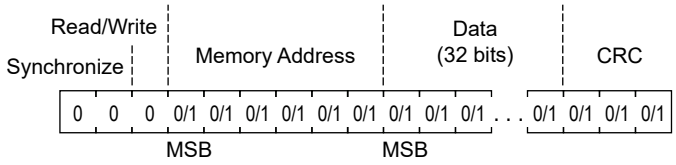

Figure 15: Write Sequence

Write Access Code (Controller to Device)

The fields for the access code command are:

- Sync (2 bits, both set to 0)
- Read/Write (1 bit; must be set to 0 for write)
- Address (6 bits)
- Data (32 bits)
- CRC (3 bits)

The sequence for an access code command is shown in Figure 16.

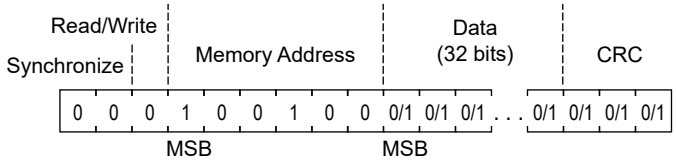

Figure 16: Write Access Code

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The controller must open the serial communication with the device by sending an access code. An access code can be sent at any time on the PROG pin to enable communication on the PROG pin. For VOUT communication, an OVD event must be sent followed by an access code on VOUT. The OVD event must be maintained during the first full transaction.

Register Address	Address(Hex)	Data(Hex)
Customer Access	0x31	0x2C413736
Customer Access + COM_ENABLE	0x31	0x2C413737

The LSB of the 32-bit customer access code is used to disable the output and leave the device in communication mode until a reset occurs. When the output is disabled, V_{CC} can be restored to a level inferior to V_{OVDE} without altering the Manchester communication and, thus, until a reset occurs.

Using the COM_LOCK bit

This bit prevents VOUT from changing state following an unwanted OVD event in the application. If the COM_LOCK bit is set, the OVD is disabled and the device can only be programmed using the PROG pin (communication mode 2).

WRITE_LOCK bit

This is the lock bit used after EEPROM has been programmed by the user. When the WRITE_LOCK bit is set to 1 and VCC is power-cycled, the ability to write to any EEPROM register is permanently disabled; writing to the volatile register is still possible.

EEPROM Error Checking and Correction (ECC)

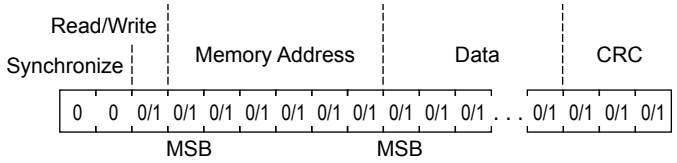
Hamming code methodology is implemented for EEPROM checking and correction. The device has ECC enabled after power-up. The device always returns 32 bits.The message received from the controller is analyzed by the device EEPROM driver, and the ECC bits are added. The first 6 bits received from device to controller are dedicated to ECC.

The Manchester serial interface uses a 3-bit cyclic redundancy check (CRC) for data-bit error checking (sychronized bits are ignored during the check). The CRC algorithm is based on the polynomial $g(x) = x^3 + x + 1$ and is initialized to 111 when first powered up. Write commands written to the peripheral controller are checked against the embedded CRC field.

Detecting ECC Error

If an uncorrectable error has occurred, bits [27:26] are set to 10, the VOUT pin goes to a high-impedance state, and the device does not respond to the applied magnetic field.

Bits	Name	Description
31:28	–	No meaning
27:26	ECC	00 = No error 01 = Error detected and message corrected 10 = Uncorrectable error 11 = No meaning
25:0	Data[25:0]	EEPROM data



Quantity of Bits	Name	Values	Description
2	Synchronization	00	Used to identify the beginning of a serial interface command
1	Read/Write	0	[As required] Write operation
		1	[As required] Read operation
6	Address	0/1	[Read/Write] Register address (volatile memory or EEPROM)
32	Data	0/1	26 data bits and 6 ECC bits. For a read command frame, the data consists of 32 bits: [31:28] not relevant, [27:26] ECC pass/fail, and [25:0] data, where bit 0 is the LSB. For a write command frame, the data consists of 32 bits: [31:26] not relevant and [25:0] data, where bit 0 is the LSB.
3	CRC	0/1	Bits to check the validity of frame.

Figure 17: Command Frame General Format

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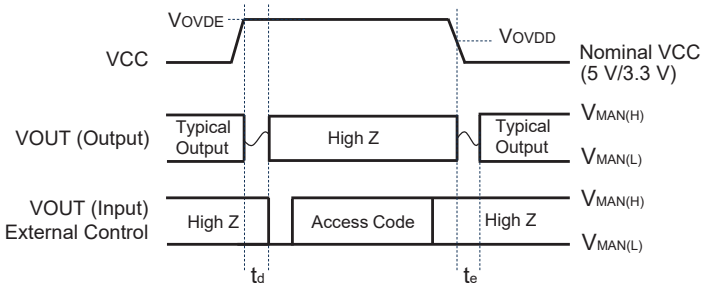

**Figure 18: VOUT Programming (Mode 1)
Write Access Code**

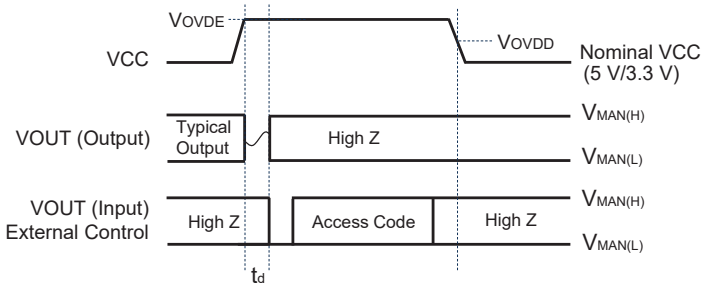

**Figure 19: VOUT Programming (Mode 1)
Write Access Code + COMM_EN**

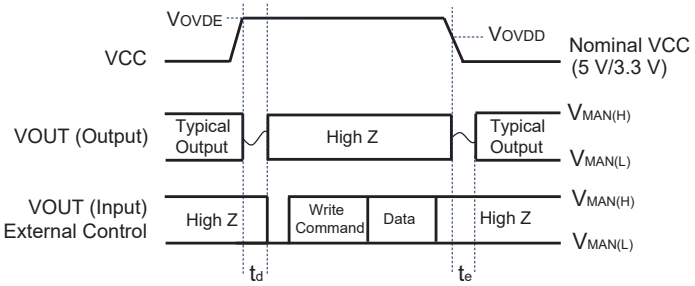

**Figure 20: VOUT Programming (Mode 1)
Write Volatile Memory**

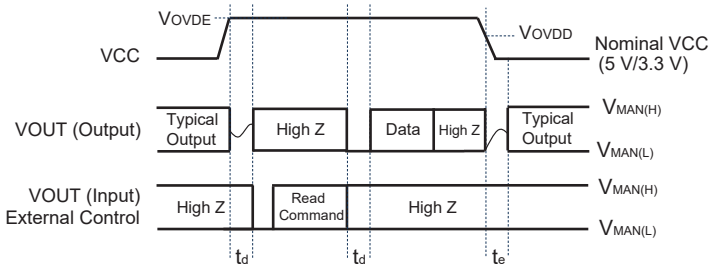

**Figure 21: VOUT Programming (Mode 1)
Read Memory**

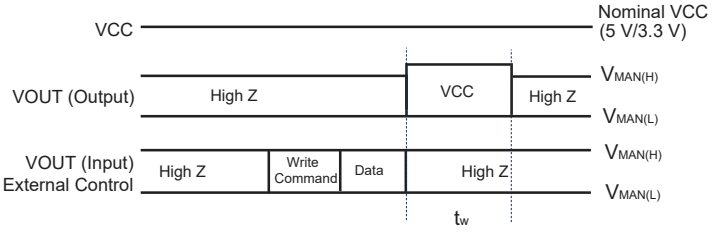

**Figure 22: VOUT Programming (Mode 1)
Write to EEPROM (Method 1, COMM_EN = 1)**

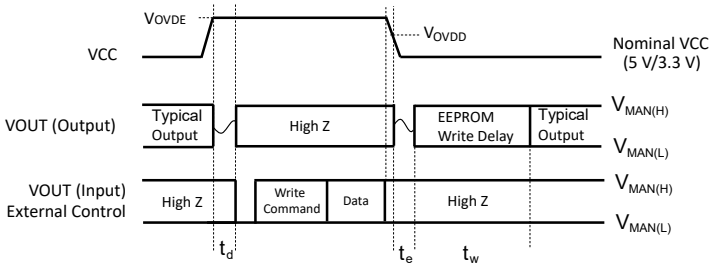

**Figure 23: VOUT Programming (Mode 1)
Write to EEPROM (Method 2)**

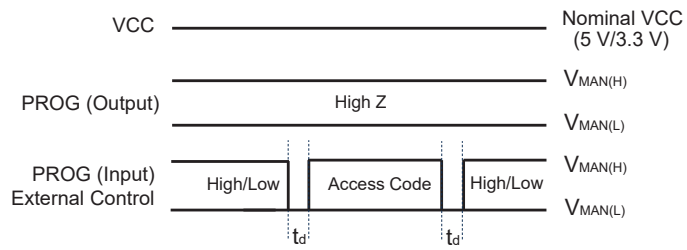

**Figure 24: PROG Programming (Mode 2)
Write Access Code**

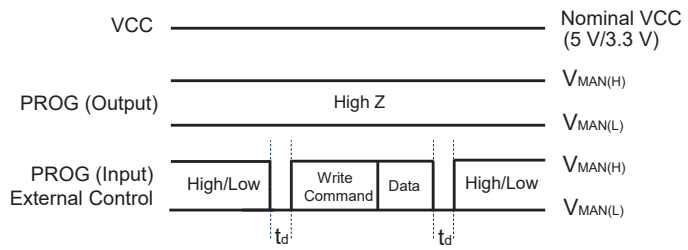

**Figure 25: PROG Programming (Mode 2)
Write Volatile Memory**

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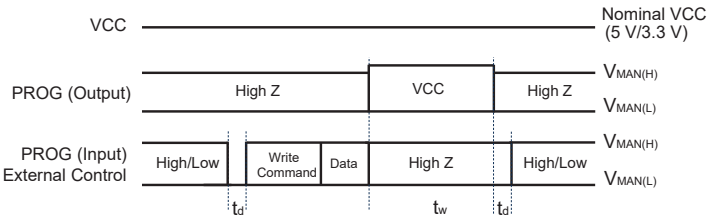

Figure 26: PROG Programming (Mode 2) Write to EEPROM

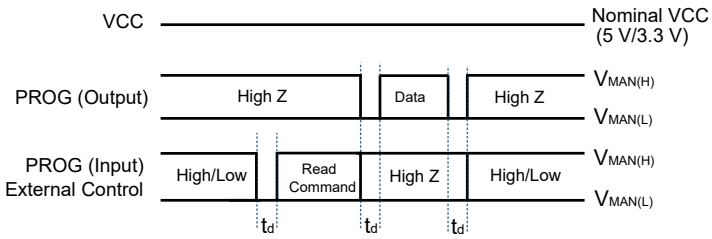

Figure 27: PROG Programming (Mode 2) Read Memory

Table 2: Programming Parameters, C_{BYPASS} = 0.1 µF, V_{CC} = 5 V

Characteristics	Symbol	Note	Min.	Typ.	Max. [1]	Unit
Program Time Delay	t_d	Delay between consecutive read/writes during same Manchester event	–	74	–	µs
Program Write Delay	t_w	Delay between EEPROM writes	–	25	35	ms
Manchester High Voltage	$V_{MAN(H)}$	Data pulses on VOUT/PROG pin, V_{CC} = 5 V	4	5	V_{CC}	V
		Data pulses on VOUT/PROG pin, V_{CC} = 3.3 V	2.4	3.3	V_{CC}	V
Manchester Low Voltage	$V_{MAN(L)}$	Data pulses on VOUT/PROG pin, V_{CC} = 5 V	0	–	1	V
		Data pulses on VOUT/PROG pin, V_{CC} = 3.3 V	0	–	0.75	V
Bit Rate	t_{BITR}	Communication rate	1	30	133	kbps
Bit Time	t_{BIT}	Data-bit pulse width	1000	33	7.5	µs
Output Enable Delay	t_e	External capacitance (CLX) on VOUT may increase the output enable delay	–	125	–	µs

[1] Limit guaranteed by design and characterization.

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EEPROM and Programming Parameters

EEPROM PROGRAMMABLE PARAMETERS: Valid through full range of T_A and V_{CC}, unless otherwise specified

Parameter	Symbol	Description	Min.	Typ. [1]	Max.	Unit	Bit	Typ. Step Size
Overcurrent Positive Fault [1]	OCF_P_THRES	Programmable overcurrent/field fault positive	50	–	200	% FS	7	1.6 %
Overcurrent Negative Fault [1]	OCF_N_THRES	Programable overcurrent/field fault negative	50	–	200	% FS	7	1.6 %
Sensitivity Fine [2]	SENS_FINE	Sensitivity fine adjustment; signed 2's complement	40	50	60	mV/G	9	60 µV/G
QVO [2]	QVO	Quiescent output voltage adjustment ($V_{OUT(Q)}$); signed 2's complement V_{CC} = 5 V, bidirectional	2.4	2.5	2.6	V	9	1 mV
Fault Pull-Up Disconnect	FAULTR_DIS	Disconnect fault pull-up resistor	0	0	1	–	1	–
Polarity	POL	Output polarity	0	0	1	–	1	–
OCF Qualifier [1]	OCF_QUAL	Overcurrent fault qualifier/delay, typical programmable values	0	0	12.7	µs	3	–
Fault Latch	FAULT_LAT	Fault latch enable	0	0	1	–	1	–
OCF Hysteresis [1]	OCF_HYST	Overcurrent fault hysteresis, typical programmable values	11	11	75	%	2	–
OCF Disable	OCF_DIS	Overcurrent fault disable	0	0	1	–	1	–
OTF Threshold [1]	OTF_THRES	Overtemperature fault threshold	80	160	165	°C	4	7
OTF Fault Disabled	OTF_DIS	Overtemperature fault disable	0	1	1	–	1	–
Communication Lock	COM_LOCK	Used to disable Manchester communication	0	0	1	–	1	–
Disabled Positive OCF Trip Point	OCF_P_DIS	Disable the positive overcurrent fault trip point	0	0	1	–	1	–
Disabled Negative OCF Trip Point	OCF_N_DIS	Disable the negative overcurrent fault trip point	0	0	1	–	1	–
Clamp Enable	CLAMP_EN	Enable clamps on the output	0	0	1	–	1	–
Customer Scratch	SCRATCH_C	Customer scratch pad	–	–	–	–	26	–

[1] Limits guaranteed by design and characterization data, not tested in production.
[2] Real programming range can exceed this range; programming sensitivity beyond ±20% of change from initial value causes $V_{OUT(Q)TC}$ and ΔSensTC drift to deteriorate beyond the specified values.

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Lock Bits Mechanism

The device has two lock bits to disable communication and EEPROM programming. The achieved behavior is summarized Table 3.

Table 3: Lock Bit Mechanism

write_lock	com_lock	EEPROM Write	EEPROM Read
0	0	Yes: PROG pin or VOUT with OVD	Yes: PROG pin or VOUT with OVD
0	1	Yes: PROG pin	Yes: PROG pin
1	0	No	Yes: PROG pin or VOUT with OVD
1	1	No	Yes: PROG pin

Programming Sensitivity and Quiescent Voltage Output

Sensitivity and $V_{OUT(Q)}$ can be adjusted by programming the SENS_FINE and QVO bits, as illustrated in Figure 28 and Figure 29. The SENS_FINE and QVO codes use a two's complement encoding to either reduce or increase sensitivity and $V_{OUT(Q)}$. Neither sensitivity nor $V_{OUT(Q)}$ should be programmed beyond the maximum or minimum programming ranges specified in the Operating Characteristics table. Exceeding the specified limits causes the sensitivity and $V_{OUT(Q)}$ drift over the temperature range (E_{Drift} and V_{OED}) to deteriorate beyond the specified values. Programming sensitivity might cause a small drift in $V_{OUT(Q)}$. As a result, it is recommended that sensitivity be programmed first, then $V_{OUT(Q)}$.

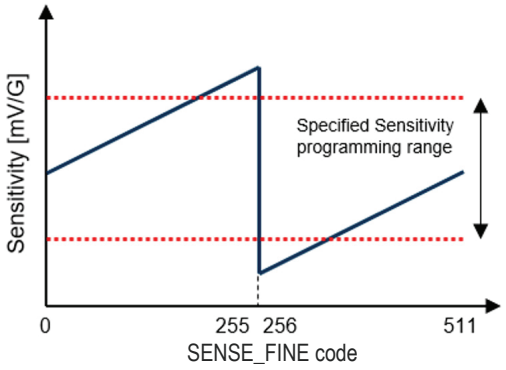

Figure 28: Sensitivity Trim Range

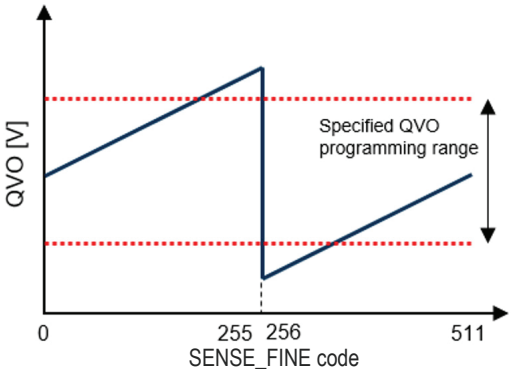

Figure 29: QVO Trim Range

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Polarity (POL)

The device output polarity (POL) bit is programable to 1 (default) or 0; this allows output polarity to be reversed. The default polarity (POL = 1) corresponds to an increasing output from 2.5 to 4.5 V typical (0.5 to 4.5 V on unidirectional versions) when positive current flows from pin 1 to pin 4 (or from pin 8 to pin 5) as shown in Figure 30 and Figure 31.

NOTE: Changing device polarity from the initial programmed value can cause offset error $V_{OUT(Q)TC}$ to exceed specification limits.

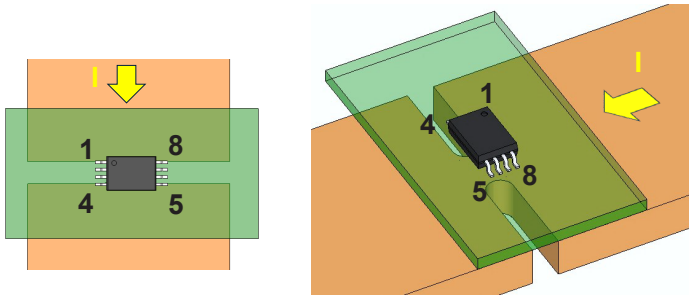

Figure 30: Polarity Definition in Planar Configuration

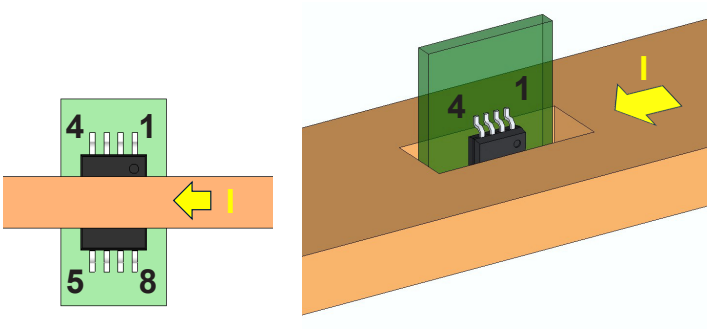

Figure 31: Polarity Definition in Vertical Configuration

Positive Overcurrent Fault Threshold

This sets the threshold for the OCF when current induces a positive output response on VOUT (increasing V_{OUT} value from 2.5 to 4.5 V on 5 V bidirectional variant or 0.5 to 4.5 V for 5 V unidirectional variant); see Figure 32. Threshold can be set independently using the OCF_N_THRES bit and can be disabled in device memory by setting the OCF_P_DIS bit to 1.

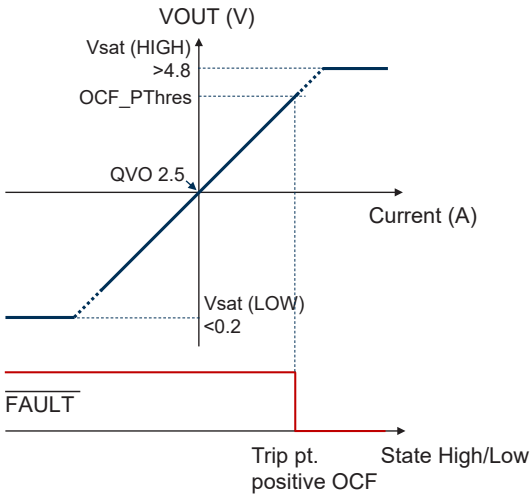

Figure 32: Positive OCF Threshold

Negative Overcurrent Fault Threshold

This sets the threshold for the OCF when current induces a negative output response on VOUT (decreasing V_{OUT} value from 2.5 to 0.5 V on 5 V bidirectional variant); see Figure 33. Threshold can be set independently from the OCF_P_THRES bit and can be disabled in device memory by setting the OCF_N_DIS bit to 1. The OCF_N_THRES feature is only usable in the bidirectional variant.

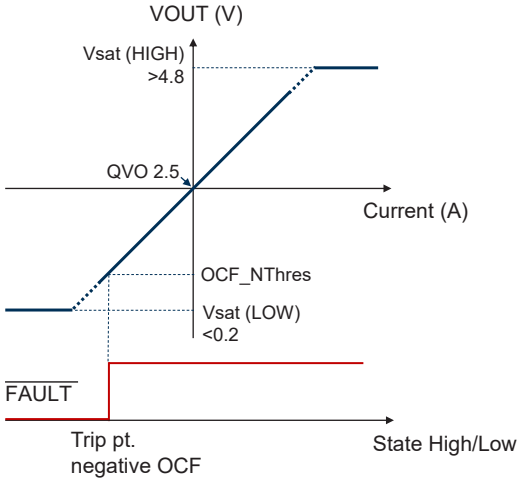

Figure 33: Negative OCF threshold

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Fault Latch (FAULT_LATCH)

When the FAULT_LATCH bit is set to 1, the device needs to be power-cycled to release the fault condition (following an over-current or overtemperature event). By default, this bit is set to 0 (disabled).

When the FAULT_LATCH bit is disabled, the device relies on the programmed hysteresis value to release the fault.

The fault output behavior following an overcurrent condition is shown in Figure 34. When the FAULT_LATCH bit is set to 1, the fault remains activated (low state) until the device is power-cycled.

The fault output behavior following an overcurrent condition is shown in Figure 35. When the FAULT_LATCH bit is set to 0, the fault is released once the current has reduced below the overcurrent threshold hysteresis level (OCF_p_thresh minus OCF_hyst for positive OCF threshold and OCF_n_thresh minus OCF_hyst for negative OCF threshold).

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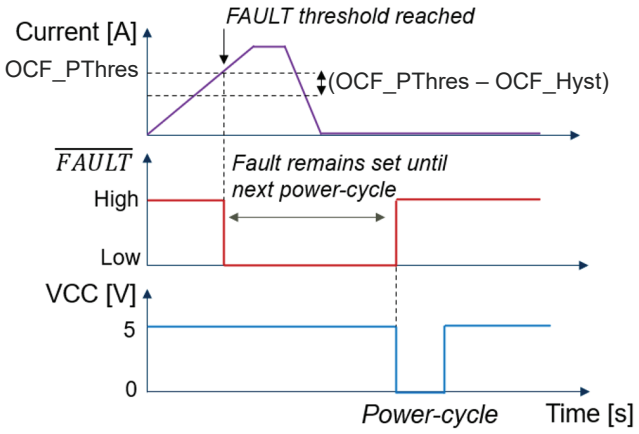

Figure 34: Fault Behavior with FAULT_LATCH = 1

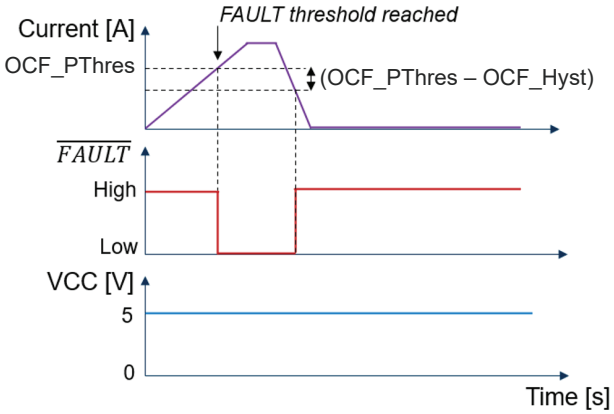

Figure 35: Fault Behavior with FAULT_LATCH = 0

Overcurrent Fault Qualifier (OCF_QUAL)

Overcurrent fault qualifier sets the amount of time the overcurrent condition must be detected before triggering the fault output. This acts as a filter on the fault condition to prevent incorrect triggering of the fault output in case of quick current spikes or ripples.

Overcurrent must be above the specified threshold for the duration of the fault qualifier (OCF_QUAL) in order to be flagged, as shown in the example in Figure 36 and Figure 37.

This delay does not apply to the condition for releasing the fault. Once the hysteresis condition is fulfilled, the fault is released after $t_{C(F)}$.

OCF_QUAL range is described in Table 4.

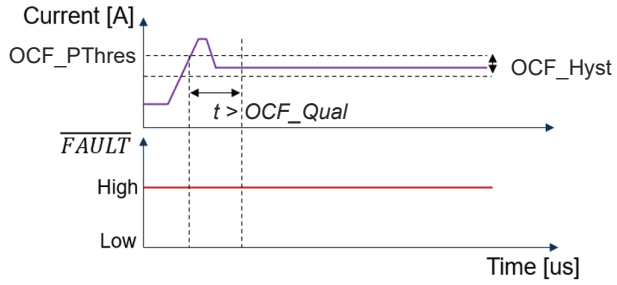

Figure 36: Fault not triggered if current is above the OCF threshold for less than OCF_QUAL.

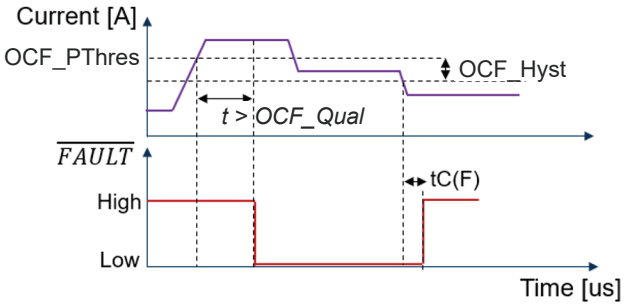

Figure 37: Fault triggered when current is above OCF threshold for more than OCF_QUAL, the fault is then released when current is below hysteresis

Table 4: Overcurrent Fault Qualifier

Setting	Typ. Added Delay	Typ. Delay to Fault	Units
0	0	2.5	µs
1	0.4	2.9	µs
2	2.2	4.7	µs
3	4.2	6.7	µs
4	6.2	8.7	µs
5	8.2	10.7	µs
6	10.3	12.8	µs
7	12.7	15.2	µs

Overcurrent Fault Hysteresis (OCF_HYST)

This sets the hysteresis value applied to the OCF threshold such that, once triggered, the current must return below the hysteresis level to release the fault output. This feature prevents chattering of the FAULT pin due to noise.

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The hysteresis principle is shown in Figure 38; e.g., *OCF_PThres* = 110%, where *OCF_Hyst* = 12.5% corresponds to a fault trip point at 110% (2.2 V output sweep if V_{CC} = 5 V) and a release point at 97.5% (2.2 V output sweep if V_{CC} = 5 V).

Programming values of the OCF_HYST bit are shown in Table 5.

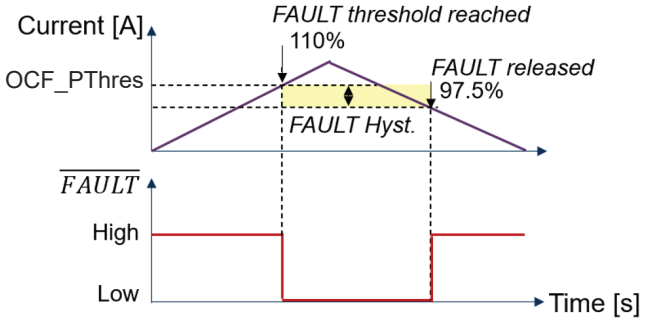

Figure 38: Hysteresis Effect on Fault

Table 5: Overcurrent Fault Hysteresis

Setting	Typ. Value [1]	Units
0	11	%
1	22	%
2	42	%
3	75	%

[1] Hysteresis value cannot be greater than the minimum OCF threshold specified minus 25%; e.g., if OCF_P is set at 50%, the maximum hysteresis value is 50 – 25 = 25%, such that OCF_HYST = 2 or 3 results in a maximum hysteresis value of 25%.

Temperature Output (TEMP_OUT)

This feature allows reading of the device temperature stored as a 12-bit digital value.

The following formula can be used to convert the digital temperature value into the ambient temperature in degree Celsius:

TempAmbient [°C] = (TEMP_OUT – 2200)/13.5 + 25

NOTE: Due to device self-heating, the temperature reaches 90% of its steady state approximately 10 seconds after power-on.

Temperature accuracy is indicated in the Fault Characteristics section and is guaranteed by characterization only.

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MEMORY MAP

Register Name	Address	Parameter Name	Description	Access	Size	MSB	LSB
EEPROM: (EE_CUST0) Shadow Register [1]: (SH_CUST0)	EEPROM: (0x09) Shadow Register [1]: (0x19)	WRITE_LOCK	Lock the device	R/W	1	25	25
		COM_LOCK	Disable communication on VOUT/disable OVD	R/W	1	24	24
		SPARE	–	R/W	1	23	23
		OTF_DIS	Disable overtemperature fault	R/W	1	22	22
		POL	Change output polarity	R/W	1	21	21
		CLAMP_EN	Enable output clamps	R/W	1	20	20
		FAULT_DIS	Disable fault	R/W	1	19	19
		FAULTPUP_DIS	Disconnect fault internal pull-up resistor	R/W	1	18	18
		QVO	Offset adjustment	R/W	9	17	9
		SNS_FINE	Sensitivity fine adjustment	R/W	9	8	0
EEPROM: (EE_CUST1) Shadow Register [1]: (SH_CUST1)	EEPROM: (0x0A) Shadow Register [1]: (0x1a)	OCF_HYST	Overcurrent fault hysteresis	R/W	2	25	24
		FAULT_LATCH	Enable fault latch	R/W	1	23	23
		OCF_P_DIS	Disable positive overcurrent fault	R/W	1	22	22
		OCF_N_DIS	Disable negative overcurrent fault	R/W	1	21	21
		OCF_QUAL	Overcurrent fault qualifier/short pulse filter	R/W	3	20	18
		OTF_THRESH	Overtemperature fault threshold	R/W	4	17	14
		OCF_N_THRES	Negative overcurrent fault threshold	R/W	7	13	7
		OCF_P_THRES	Positive overcurrent fault threshold	R/W	7	6	0
EEPROM: (EE_CUST2)	EEPROM: (0x0B)	C_SPARE	Customer scratchpad No effect on device functionality	R/W	26	25	0
Volatile Register: (FAULT_STATUS)	Volatile Register: (0x20)	TEMP_OUT	Temperature output	R	12	27	16
		UV_STAT	Undervoltage status	R	1	12	12
		OV_STAT	Overvoltage status	R	1	11	11
		OC_STAT	Overcurrent status	R	1	10	10
		OT_STAT	Overtemperature status	R	1	9	9
		FP_STAT	FAULT pin status	R	1	8	8
		UV_EV	Undervoltage event	R	1	4	4
		OV_EV	Overvoltage event	R	1	3	3
		OC_EV	Overcurrent event	R	1	2	2
		OT_EV	Overtemperature event	R	1	1	1
		FP_EV	FAULT pin event	R	1	0	0

[1] Shadow registers are volatile memory; upon startup, device loads EEPROM memory into shadow registers. Shadow registers can be used to test different programming options without erasing EEPROM (e.g., finding sensitivity and QVO codes before writing into EEPROM).

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DEFINITIONS OF ACCURACY CHARACTERISTICS

SENSITIVITY (Sens)

The amount of the output voltage increase is proportional to the magnitude of the magnetic field applied. This proportionality is specified as the magnetic sensitivity, Sens (mv/G), of the device, and it is defined as:

$$Sens = \frac{V_{OUT(B1)} - V_{OUT(B2)}}{B1 - B2}$$

where B1 and B2 are two different magnetic field levels.

SENSITIVITY ERROR

The sensitivity error is the percent difference between the measured sensitivity and the ideal sensitivity. For example, in the case of V_{CC} = 5 V:

$$E_{Sens} = \frac{Sens_{Meas(5V)} - Sens_{Ideal(5V)}}{Sens_{Ideal(5V)}} \times 100\ (\%)$$

NONLINEARITY (E_{LIN})

Nonlinearity is a measure of how linear the output of the sensor IC is over the full current measurement range. The nonlinearity is calculated as:

$$E_{LIN} = \left\{1 - \left[\frac{Sens_{BPRMax}}{Sens_{BPRHalf}}\right]\right\} \times 100\ (\%)$$

where $Sens_{BPRMax}$ is the sensitivity measured at the full range output level and $Sens_{BPRHalf}$ is the sensitivity measured at half of the full range output level.

RATIOMETRY

The device features a ratiometric output. This means that the quiescent voltage output, $V_{OUT(Q)}$, and the magnetic sensitivity, Sens, are proportional to the supply voltage, V_{CC}. The ratiometric change in the quiescent voltage output is defined as:

$$V_{RatERRQVO} = \left[\left(V_{OUTQ(5V)} \times \frac{V_{CC}}{5\ V}\right) - V_{OUTQ(VCC)}\right] \times 1000\ (mV)$$

and the ratiometric change (%) in sensitivity is defined as:

$$Rat_{ERRSens} = \left[1 - \frac{\left(\frac{Sens_{(VCC)}}{Sens_{(5V)}}\right)}{\left(\frac{V_{CC}}{5\ V}\right)}\right] \times 100\ (\%)$$

QUIESCENT OUTPUT VOLTAGE—QVO (ZERO FIELD OUTPUT VOLTAGE)

This is the output of the sensor when the sensed differential field is zero (in typical applications when no current is flowing in the busbar/PCB). It nominally remains at 0.5 × V_{CC} for a bidirectional device and 0.1 × V_{CC} for a unidirectional device. For example, in the case of a bidirectional output device, V_{CC} = 5 V translates into $V_{OUT(Q)}$ = 2.5 V. Variation in $V_{OUT(Q)}$ can be attributed to the resolution of the Allegro linear IC quiescent voltage trim and thermal drift.

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POWER-ON RESET VOLTAGE (V_{POR})

On power-up, to initialize to a known state and avoid current spikes, the device is held in the reset state. The reset signal is disabled when V_{CC} reaches V_{PORH} and time t_{PORR} has elapsed, allowing the output voltage to go from a high-impedance state into typical operation. After t_{PORR}, the output remains high impedance until V_{CC} exceeds V_{UVLOD} for more than t_{UVLOD}. During power-down, the reset signal is enabled when V_{CC} reaches V_{PORL}, causing the output voltage to go into a high-impedance state.

POWER-ON RESET RELEASE TIME (t_{PORR})

When V_{CC} rises to V_{PORH}, the power-on reset counter starts. The device output voltage transitions from a high-impedance state to typical operation only when the power-on reset counter has reached t_{PORR} and V_{CC} has been maintained above V_{PORH}.

OVERVOLTAGE DETECTION (V_{OVD})

When V_{CC} is raised above the overvoltage detection enable voltage (V_{OVDE}), the ACS37610H output stage enters high impedance. V_{OUT} will float to V_{CC} with a pull-up R_L or to GND with a pull-down R_L when (V_{OVDE}) is reached. When programming the ACS37610 using V_{OUT} (Mode 1), overvoltage detection must be active for communication. The device output will resume normal operation after V_{CC} is below the overvoltage detection disable voltage (V_{OVDD}).

If the COM_LOCK bit is set, overvoltage detection is disabled and the device output does not react to the overvoltage condition.

NOTE: Supply voltage limits still apply for operating characteristics. Following an overvoltage condition, the supply voltage should not exceed 7.5 V for more than 1 minute. For more details, refer to the Overvoltage Detection section.

OUTPUT SATURATION VOLTAGE (V_{SAT})

When output voltage clamps are disabled, the output voltage can swing to a maximum of $V_{SAT(HIGH)}$ and to a minimum of $V_{SAT(LOW)}$.

BROKEN WIRE VOLTAGE (V_{BRK})

If the GND pin is disconnected (broken wire event), output voltage goes to $V_{BRK(HIGH)}$ (if a load resistor is connected to VCC) or to $V_{BRK(LOW)}$ (if a load resistor is connected to GND).

UNDERVOLTAGE DETECTION (V_{UVLO})

When V_{CC} reduces below the undervoltage detection enable voltage (V_{UVLOE}), the ACS37610H output stage reduces beyond the clamp or saturation voltage—almost to GND. Once V_{CC} exceeds the undervoltage detection disable voltage (V_{UVLOD}), the device output resumes typical operation.

Undervoltage detection is only active on the 5 V variant.

For more details, refer to the Undervoltage Detection section

LOW-POWER MODE

The device is available in a low-power mode variant, where the current drawn by the IC is reduced through factory programing. In this variant, the output noise is increased by ~30% compared to the typical power mode variant.

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DEFINITIONS OF DYNAMIC RESPONSE CHARACTERISTICS

Power-On Time (t_{PO}). When the supply is ramped to its operating voltage, the device requires a finite time to power its internal components before responding to an input magnetic field. Power-on time, t_{PO}, is defined as the time it takes for the output voltage to settle within ±10% of its steady-state value under an applied magnetic field, after the power supply has reached its minimum specified operating voltage, V_{CC}(min), as shown in Figure 39.

Temperature Compensation Power-On Time (t_{TC}). After the power-on time (t_{PO}) has elapsed, t_{TC} is also required before there can be a valid temperature-compensated output.

Response Time ($t_{RESPONSE}$). The time interval between a) when the sensed current reaches 90% of its final value, and b) when the sensor output reaches 90% of its full-scale value, as shown in Figure 41.

Rise Time (t_r). The time interval between a) when the sensor reaches 10% of its full-scale value, and b) when it reaches 90% of its full-scale value, as shown in Figure 40.

Propagation Delay (t_{pd}). The time interval between a) when the sensed current reaches 20% of its full-scale value, and b) when the sensor output reaches 20% of its full-scale value, as shown in Figure 40.

Delay to Clamp (t_{CLP}). A large magnetic input step may cause the clamp to overshoot its steady-state value. The delay-to-clamp time, t_{CLP}, is defined as: the time it takes for the output voltage to settle within ±1% of the clamp voltage dynamic range, after initially passing through its steady-state voltage, as shown in Figure 42.

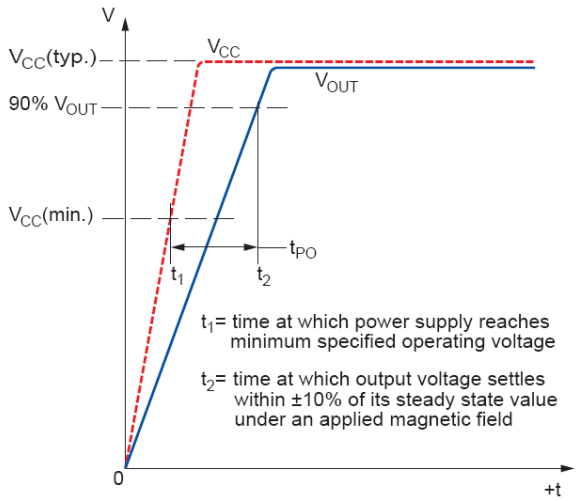

Figure 39: Power-On Time (t_{PO})

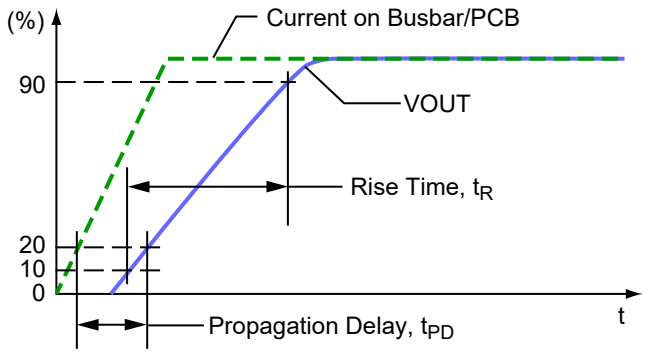

Figure 40: Propagation Delay (t_{PD}) and Rise Time (t_r)

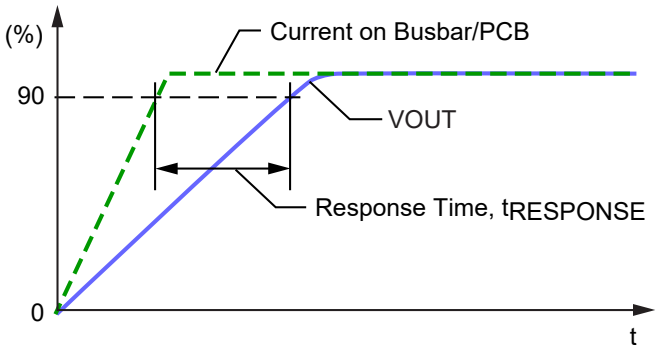

Figure 41: Response Time ($t_{RESPONSE}$)

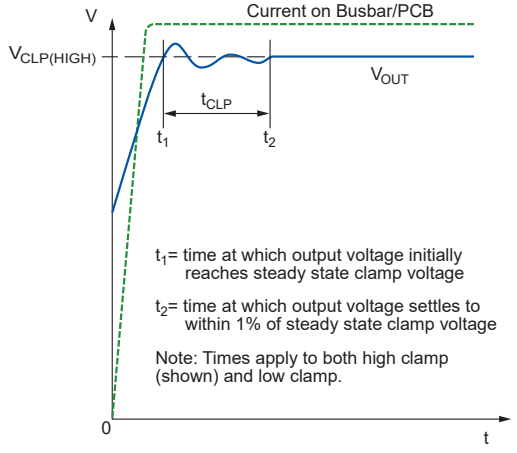

Figure 42: Delay to Clamp

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POWER-ON RESET, UNDERVOLTAGE AND OVERVOLTAGE DETECTION OPERATION

The descriptions in this section assume: temperature = 25°C, no output load (R_L, C_L), and no significant magnetic field is present.

Power-Up. At power-up, as V_{CC} ramps up, the output is in a high-impedance state. When V_{CC} crosses V_{PORH} (location [1] in Figure 43 and [1'] in Figure 44), the POR release counter starts counting for t_{PORR}. At this point, if V_{CC} exceeds V_{UVLOD} [2'], the output goes to $V_{CC}/2$ after t_{UVLOD} [3'].
If V_{CC} does not exceed V_{UVLOD} [2], the output remains in the high-impedance state until V_{CC} reaches V_{UVLOD} [3], then goes to $V_{CC}/2$ after t_{UVLOD} [4].

V_{CC} drops below V_{CC}(min) = 4.5 V. If V_{CC} drops below V_{UVLOE} [4', 5], the UVLO enable counter starts counting. If V_{CC} is still below V_{UVLOE} when the counter reaches t_{UVLOE}, the UVLO function is enabled and the output is pulled near GND [6]. If V_{CC} exceeds V_{UVLOE} before the UVLO enable counter reaches t_{UVLOE} [5'], the output continues to be $V_{CC}/2$.

Coming out of UVLO. If V_{CC} exceeds V_{UVLOD} [7] while UVLO is enabled [6], UVLO becomes disabled after t_{UVLOD} and the output becomes $V_{CC}/2$ [8].

Power-Down. As V_{CC} ramps down below V_{UVLOE} [6', 9], the UVLO enable counter starts counting. If V_{CC} is higher than V_{PORL} when the counter reaches t_{UVLOE}, the UVLO function becomes enabled and the output becomes pulled near GND [10]. The output enters a high-impedance state as V_{CC} goes below V_{PORL} [11]. If V_{CC} falls below V_{PORL} before the UVLO enable counter reaches t_{UVLOE}, the output transitions directly into a high-impedance state [7'].

Overvoltage. If V_{CC} rises above V_{OVDE}, the OVD enable counter starts counting. If the internal pull-up mode is used, the fault pull-up voltage follows V_{CC}; otherwise, it remains at the V_F level. If V_{CC} continues to exceed V_{OVDE} when the counter reaches t_{OVDE}, the OVD function is enabled and the output goes into a high-impedance state. Upon entering a high-impedance state, the FAULT pin becomes disabled.

Coming Out of OVD. While OVD is enabled, if V_{CC} drops below V_{OVDD}, OVD becomes disabled after t_{OVDD}, and the output returns to typical operation in analog mode $V_{CC}/2$. The FAULT pin becomes active and returns to typical operation.

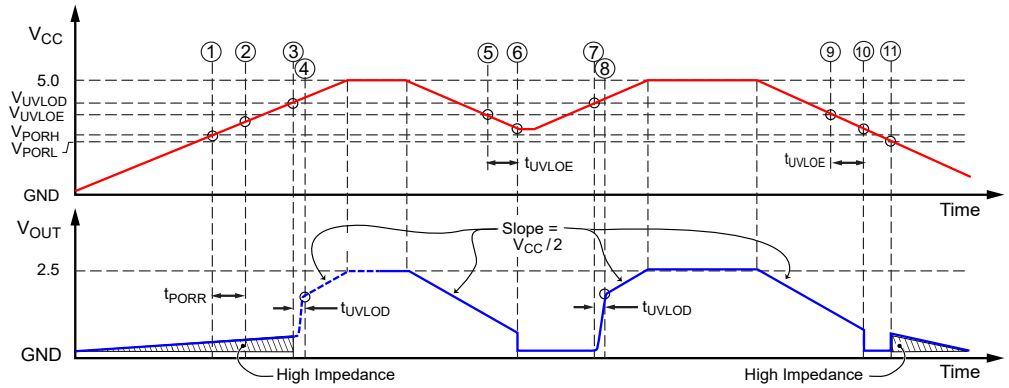

Figure 43: POR and UVLO Operation, Slow Rise-Time Case, 5 V Variant

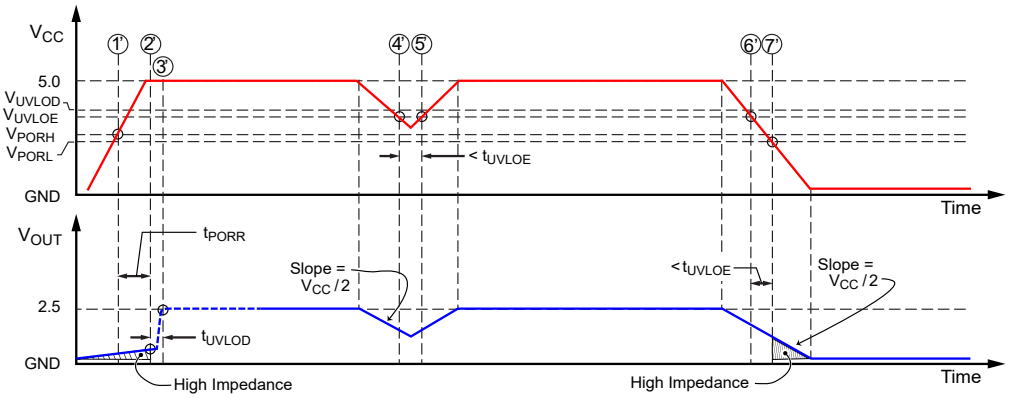

Figure 44: POR and UVLO Operation, Fast Rise-Time Case, 5 V Variant

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Power-On Reset (POR); Undervoltage Lockout (UVLO) Disabled— Nominal Supply Voltage = 3.3 V

Power-Up

At power-up, as V_{CC} ramps up, the output is in a high-impedance state. When V_{CC} crosses V_{PORH} (location [1] in Figure 45 and [1'] in Figure 46), the POR release counter starts counting for t_{PORR} [2], [2'], and the output goes to $V_{CC}/2$ after t_{PORD} [3], [3']. The temperature-compensation engine then adjusts the device sensitivity and QVO after time t_{TC} [4], [4'].

V_{CC} drops below V_{CC}(min) = 3 V

If V_{CC} drops below V_{PORH} [5'] but remains higher than V_{PORL} [6'], the output continues to be $V_{CC}/2$.

Power-Down

As V_{CC} ramps down below V_{PORL} [5],[7'], the output enters a high-impedance state.

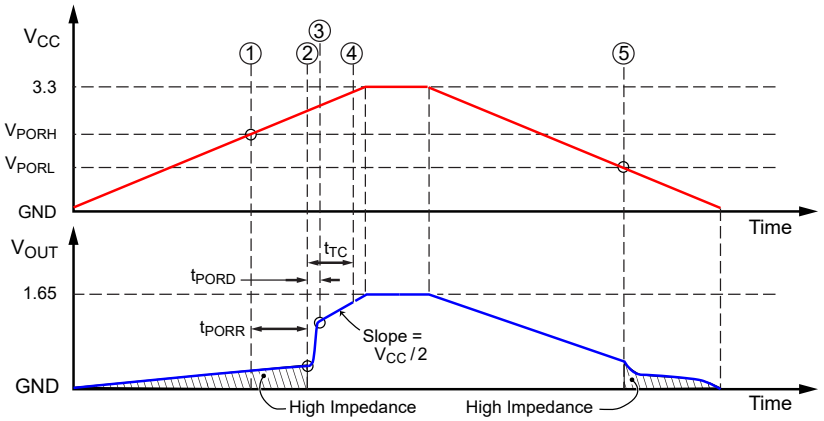

Figure 45: POR and UVLO Operation, Slow Rise-Time Case, 3.3 V Mode

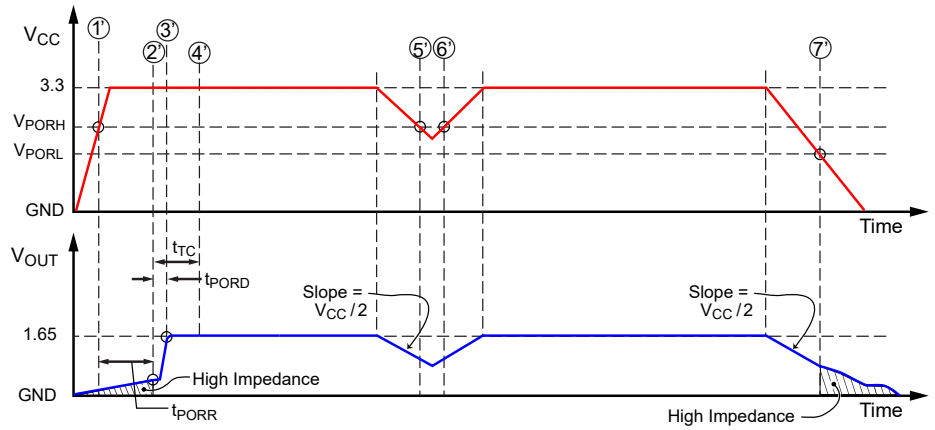

Figure 46: POR and UVLO Operation, Fast Rise-Time Case, 3.3 V Mode

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APPLICATION INFORMATION

Typical Application—Busbar Current Sensing

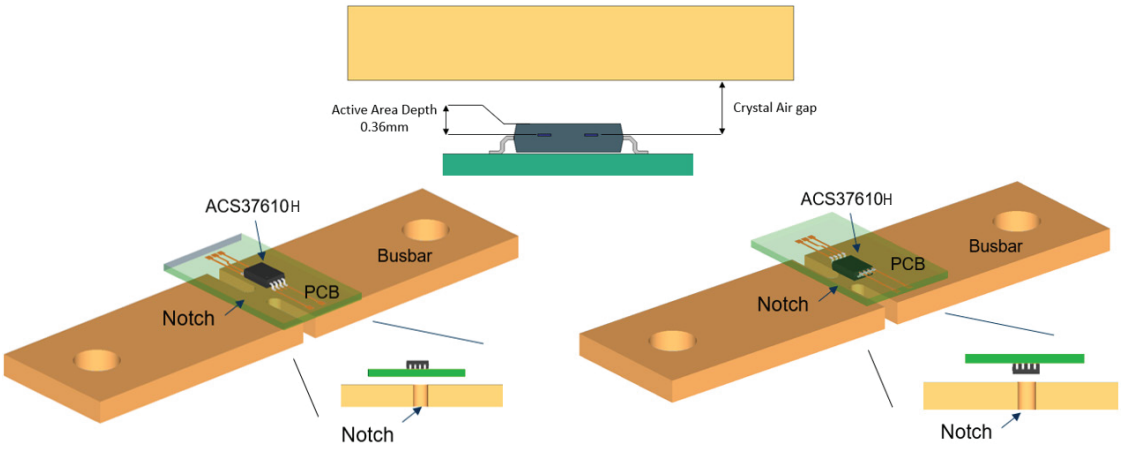

Figure 47: Busbar Current-Sensing Application—Reference Busbar Design with Notch

The ACS37610H is ideal for busbar current-sensing applications. For a given current flowing through the busbar, the magnitude of the differential magnetic field sensed by the IC depends on the air gap between the busbar and the IC. Adding a notch (width reduction) to the busbar at the location where the sensor is placed significantly increases the magnitude of the magnetic field, improving SNR.

Keeping the notch length short (2 to 3 mm) results in virtually no increase in the resistance of the busbar or degradation of its thermal performance.

Different busbar and notch dimensions can be used to optimize system performance and respond to application constraints. Figure 47 and Table 6 highlight the dimensions of an Allegro evaluation board designed to measure ±1000 A.

NOTE: Comparing the busbar described in Figure 47 to a bare busbar (without notch), the busbar with the 3 mm notch increased the overall impedance by less than 10 μΩ, increasing busbar temperature by only few degrees during testing.

Skin Effect Consideration

Skin effect in the conductor tends to reduce the magnitude of the differential magnetic field measured by the IC at high frequencies (coupling factor) and therefore influences the bandwidth of the system and the response time to transient current.

Skin effect depends on busbar dimensions, sensor mounting orientation, and distance between the busbar and the IC.

Table 6: Current Range Based on Reference Busbar Design

Busbar Application	Cross Section [mm²]	Notch Cross Section [mm²]	Max. Current [2] [A]	Coupling Factor [1] [G/A]	Diff. Field [1] [G]	IC Sensitivity [1] [mV/G]
16 × 4 mm Busbar + 4.5 mm Notch	64	18	±1100	0.17	±200	10

[1] Considering a distance from Hall elements to busbar of 3 mm.
[2] Full-scale current is required to cover the full-scale output range (bidirectional = ±2 V).

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Multiple Busbar Design Options

The ACS37610H offers many different mounting possibilities, addressing different needs (bandwidth, mounting tolerances, and crosstalk). Different mounting options are shown in Figure 48 through Figure 51.

For application notes explaining the tradeoffs between different topologies, refer to Allegro's website (https://www.allegromicro.com).

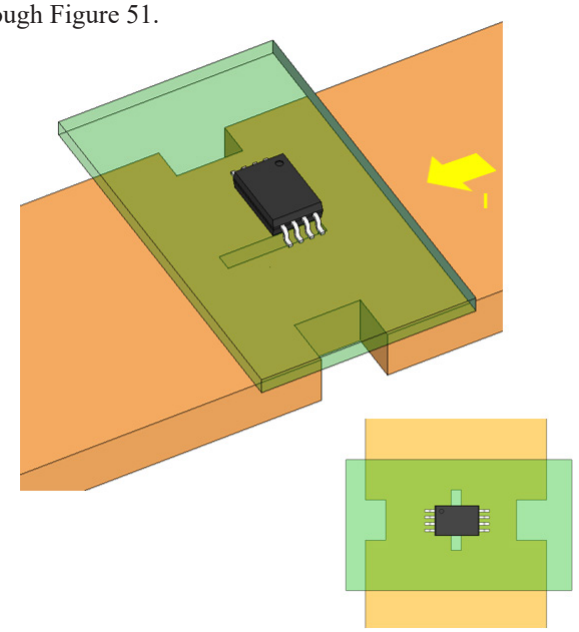

Figure 48: Rift Busbar Design
High mounting tolerances, medium coupling factor, high skin effect.
For DC to low-frequency AC applications <1 kHz.

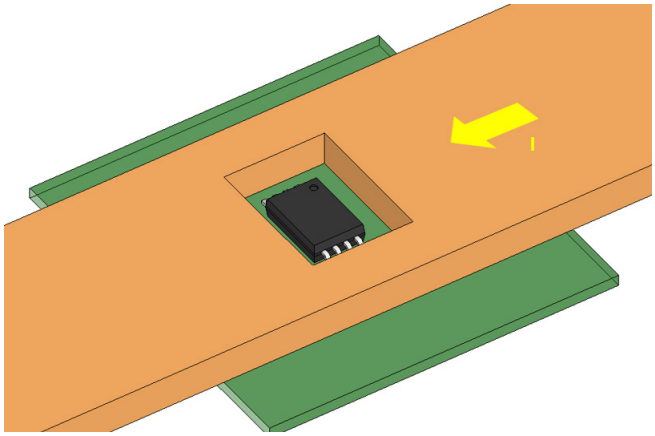

Figure 49: Slit Busbar Design
High mounting tolerances, medium coupling factor, medium skin effect.
For DC to medium-frequency AC applications <100 kHz.

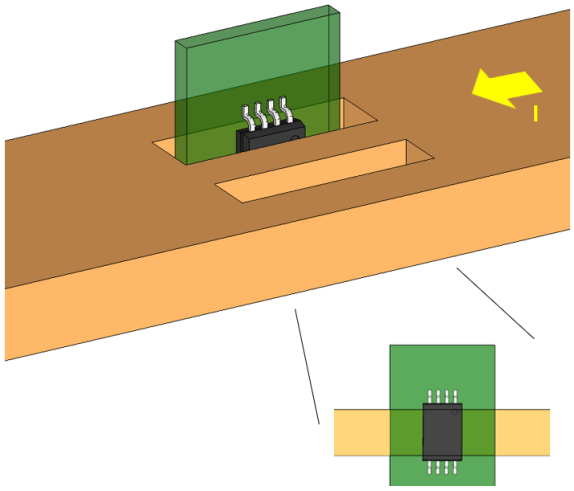

Figure 50: Dual Vertical-Slit Busbar Design
High mounting tolerances, high coupling factor, low skin effect.
For DC to high-frequency AC applications >100 kHz.

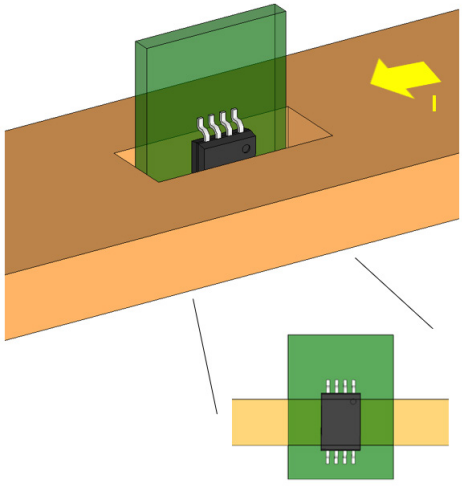

Figure 51: Vertical-Slit Busbar Design
High mounting tolerances, high coupling factor, low skin effect.
For DC to high-frequency AC applications >100 kHz.

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Typical Application—PCB Sensing

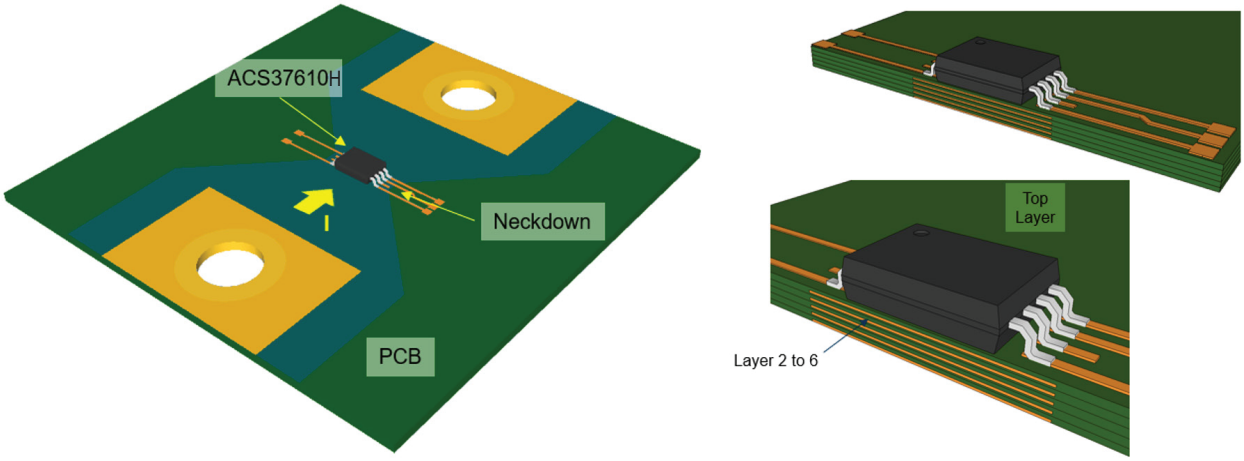

Figure 52: PCB Current-Sensing Application—Six-Layer Reference PCB Example

The ACS37610H can also be used in PCB applications where the current flows directly in the PCB instead of on a busbar.

Multiple copper layers can be used to carry the current. Reducing the width of the copper traces under the sensor (neckdown) increases the magnitude of the differential magnetic field measured by the IC.

Different copper layer dimensions and stackups can be used to optimize performance and are specific to the constraints of the application. For example, in higher-voltage applications, the top layer would only be used for signal routing in order to use the PCB replaced by dielectric layer for isolation.

Figure 52 and Table 7 highlight the dimensions of three Allegro evaluation boards designed to measure a wide current range.

Care must be taken when routing the device signal to prevent noise coupling to the supply or output lines.

The power plane in the neckdown area should also be avoided to prevent disturbing the magnetic field measured.

Skin Effect Consideration

Skin effect in the PCB current-carrying traces tends to reduce the differential magnetic field measured by the IC at high frequencies (coupling factor) and therefore influences the bandwidth of the system and the response time to transient current.

The skin effect is generally limited in PCB applications due to the thinness of the copper-layer; however, the effect depends on the PCB copper trace dimensions, number of layers, and layer thickness.

Table 7: Current range based on reference PCB design:

PCB Application [1]	Maximum Current (A) [2]	Coupling Factor (G/A) [1]	Differential Field (G) [1]	IC Sensitivity (mV/G) [1]
8 Layers – Ref designs [3]	±100	0.9	±90	22.2
	±200	0.9	±180	11.1

[1] Typical values, not including device placement and PCB manufacturing tolerances.
[2] Full-scale current required to serve the full-scale output range (bidirectional = ±2 V).
[3] Maximum continuous current without proper cooling on this Allegro evaluation PCB design should not exceed 150 A.

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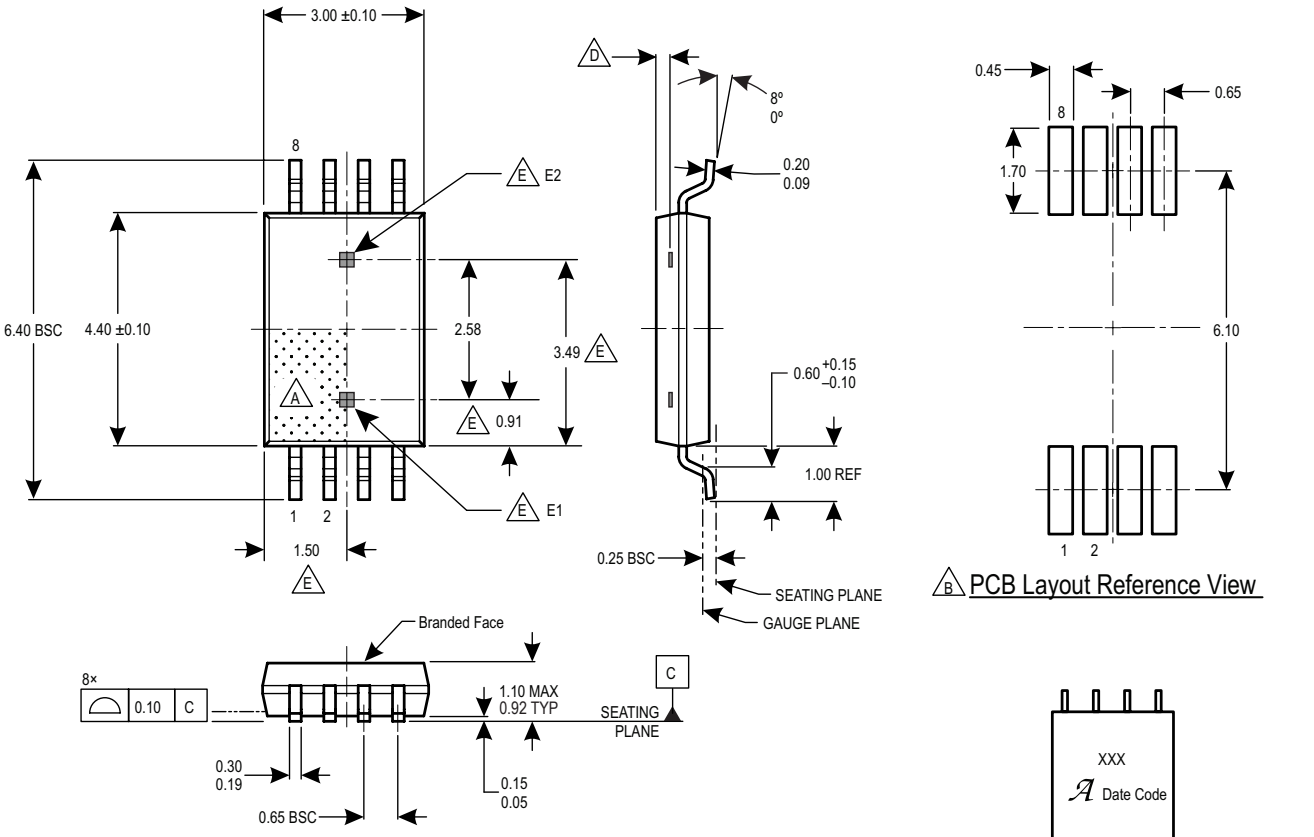
PACKAGE OUTLINE DRAWING

For Reference Only – Not for Tooling Use

(Reference Allegro DWG-0000381, Rev. 1 and JEDEC MO-153AA)
NOT TO SCALE
Dimensions in millimeters
Dimensions exclusive of mold flash, gate burrs, and dambar protrusions
Exact case and lead configuration at supplier discretion within limits shown



A Terminal #1 mark area

B Reference land pattern layout (reference IPC7351 SOP65P640X110-8M); all pads a minimum of 0.20 mm from all adjacent pads; adjust as necessary to meet application process requirements and PCB layout tolerances; when mounting on a multilayer PCB, thermal vias can improve thermal dissipation (reference EIA/JEDEC Standard JESD51-5)

C Branding scale and appearance at supplier discretion

D Active Area Depth 0.36 mm REF

E Hall elements (E1, E2); not to scale.

Figure 53: Package LU, 8-Pin TSSOP Package

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Revision History

Number	Date	Description
–	August 16, 2023	Initial release

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