

2-Channel, 2-Wire Bus Multiplexer with Capacitance Buffering

FEATURES

- 1:2 2-Wire Multiplexer/Switch
- Connect SDA and SCL Lines with 2-Wire Bus Commands
- Supply Independent Bidirectional Buffer for SDA and SCL Lines Increases Fan-Out
- Programmable Disconnect from Stuck Bus
- Compatible with I²C and SMBus Standards
- Rise Time Accelerator Circuitry
- SMBus Compatible ALERT Response Protocol
- Prevents SDA and SCL Corruption During Live Board Insertion and Removal from Backplane
- ±10kV Human Body Model ESD Ruggedness
- 16-Lead (4mm × 5mm) DFN and SSOP Packages

APPLICATIONS

- Nested Addressing
- 5V/3.3V Level Translator
- Capacitance Buffer/Bus Extender

DESCRIPTION

The LTC[®]4305 is a 2-channel, 2-wire bus multiplexer with bus buffers to provide capacitive isolation between the upstream bus and downstream buses. Through software control, the LTC4305 connects the upstream 2-wire bus to any desired combination of downstream channels. Each channel can be pulled up to a supply voltage ranging from 2.2V to 5.5V, independent of the LTC4305 supply voltage. The downstream channels are also provided with an ALERT1–ALERT2 inputs for fault reporting.

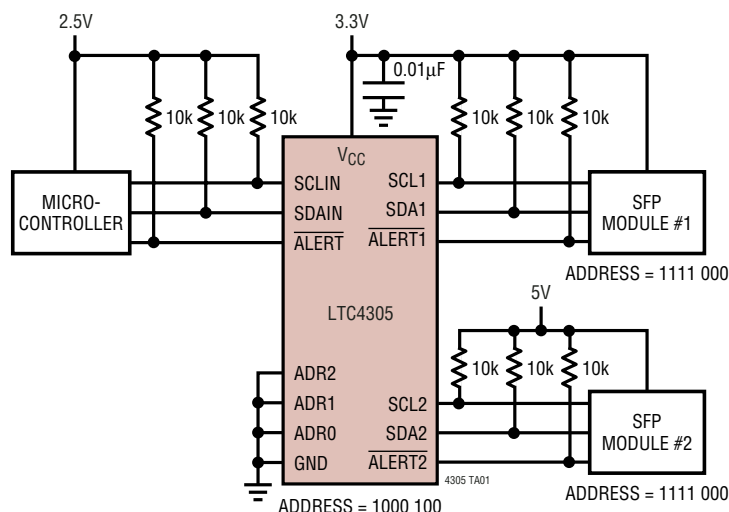
Programmable timeout circuitry disconnects the downstream buses if the bus is stuck low. When activated, rise time accelerators source currents into the 2-wire bus pins to reduce rise time. Driving the ENABLE pin low restores all features to their default states. Three address pins provide 27 distinct addresses.

The LTC4305 is available in 16-lead (4mm × 5mm) DFN and SSOP packages.

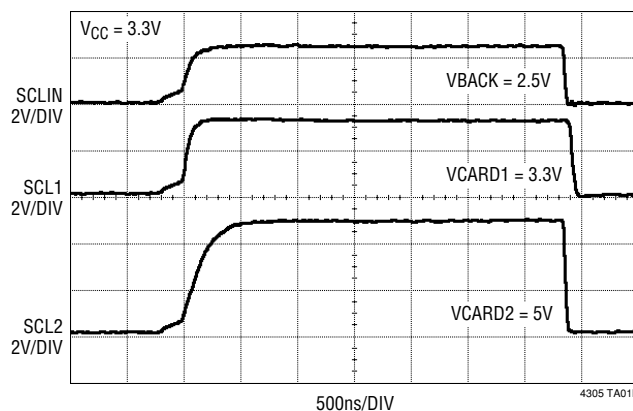
LT, LTC and LT are registered trademarks of Linear Technology Corporation. All other trademarks are the property of their respective owners. Patent Pending.

TYPICAL APPLICATION

A Level-Shifting and Nested Addressing Application



I²C Bus Waveforms



LTC4305

ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage (V_{CC})	–0.3V to 7V	Operating Temperature Range	
Input Voltages (ADRO, ADR1, ADR2, ENABLE, ALERT1, ALERT2)	–0.3V to 7V	LTC4305C	0°C to 70°C
Output Voltages (ALERT, READY)	–0.3V to 7V	LTC4305I	–40°C to 85°C
Input/Output Voltages (SDAIN, SCLIN, SCL1, SDA1, SCL2, SDA2)	–0.3V to 7V	Storage Temperature Range	
Output Sink Current (SDAIN, SCLIN, SCL1, SDA1, SCL2, SDA2, ALERT, READY)	10mA	DHD Package	–65°C to 125°C
		GN Package	–65°C to 150°C
		Lead Temperature (Soldering, 10 sec)	
		GN Package	300°C

PACKAGE/ORDER INFORMATION

<p>TOP VIEW</p> <p>16-LEAD (4mm × 5mm) PLASTIC DFN EXPOSED PAD (PIN 17) PCB CONNECTION OPTIONAL MUST BE CONNECTED TO PCB TO OBTAIN $\theta_{JA} = 43^{\circ}\text{C/W}$ OTHERWISE $\theta_{JA} = 140^{\circ}\text{C/W}$. $T_{JMAX} = 125^{\circ}\text{C}$</p>		<p>TOP VIEW</p> <p>16-LEAD NARROW PLASTIC SSOP $T_{JMAX} = 125^{\circ}\text{C}$, $\theta_{JA} = 135^{\circ}\text{C/W}$</p>	
ORDER PART NUMBER	DHD PART MARKING	ORDER PART NUMBER	GN PART MARKING
LTC4305CDHD	4305	LTC4305CGN	4305
LTC4305IDHD	4305	LTC4305IGN	4305I
<p>Order Options Tape and Reel: Add #TR Lead Free: Add #PBF Lead Free Tape and Reel: Add #TRPBF Lead Free Part Marketing: http://www.linear.com/leadfree/</p>			

Consult LTC Marketing for parts specified with wider operating temperature ranges.

ELECTRICAL CHARACTERISTICS The ● denotes specifications which apply over the full specified temperature range, otherwise specifications are at $T_A = 25^{\circ}\text{C}$. $V_{CC} = 3.3\text{V}$ unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Power Supply/Start-Up						
V_{CC}	Input Supply Range	●	2.7		5.5	V
I_{CC}	Input Supply Current	Downstream Connected, $V_{CC} = 5.5\text{V}$ SCL Bus Low, SDA Bus High	●	5.2	8	mA
$I_{CC \text{ ENABLE} = 0\text{V}}$	Input Supply Current	$V_{\text{ENABLE}} = 0\text{V}$, $V_{CC} = 5.5\text{V}$	●	1.25	2.5	mA
V_{UVLOU}	UVLO Upper Threshold Voltage	●	2.3	2.5	2.7	V
$V_{UVLOHYS}$	UVLO Threshold Hysteresis Voltage	●	100	175	250	mV

4305f

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full specified temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$. $V_{CC} = 3.3\text{V}$ unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Power Supply/Start-Up							
$V_{TH\ EN}$	ENABLE Falling Threshold Voltage		●	0.8	1.0	1.2	V
$V_{EN\ HYST}$	ENABLE Threshold Hysteresis Voltage				60		mV
$t_{PHL\ EN}$	ENABLE Delay, On-Off				60		ns
$t_{PLH\ EN}$	ENABLE Delay, Off-On				20		ns
$I_{IN\ EN}$	ENABLE Input Leakage Current	$V_{ENABLE} = 0\text{V}$, 5.5V , $V_{CC} = 5.5\text{V}$	●		0.1	± 1	μA
$V_{LOW\ READY}$	READY Pin Logic Low Output Voltage	$I_{PULL-UP} = 3\text{mA}$, $V_{CC} = 2.7\text{V}$	●		0.18	0.4	V
$I_{OFF\ READY}$	READY Off State Input Leakage Current	$V_{READY} = 0\text{V}$, 5.5V , $V_{CC} = 5.5\text{V}$	●		0	± 1	μA
ALERT							
$V_{\overline{ALERT}}(OL)$	\overline{ALERT} Output Low Voltage	$I_{\overline{ALERT}} = 3\text{mA}$, $V_{CC} = 2.7\text{V}$	●		0.2	0.4	V
$I_{OFF, \overline{ALERT}}$	\overline{ALERT} Off State Input Leakage Current	$V_{\overline{ALERT}} = 0\text{V}$, 5.5V	●		0	± 1	μA
$I_{IN, \overline{ALERT1-2}}$	$\overline{ALERT1-ALERT2}$ Input Current	$V_{\overline{ALERT1-2}} = 0\text{V}$, 5.5V	●		0	± 1	μA
$V_{\overline{ALERT1-2}}(IN)$	$\overline{ALERT1-ALERT2}$ Pin Input Falling Threshold Voltages		●	0.8	1.0	1.2	V
$V_{\overline{ALERT1-2}}(HY)$	$\overline{ALERT1-ALERT2}$ Pin Input Threshold Hysteresis Voltages				80		mV
Rise Time Accelerators							
$V_{SDA, SCL\ slew}$	Initial Slew Requirement to Activate Rise Time Accelerator Currents	$SDAIN$, $SCLIN$, $SDA1-2$, $SCL1-2$ Pins	●		0.4	0.8	V/ μs
$V_{RISE, DC}$	Rise Time Accelerator DC Threshold Voltage	$SDAIN$, $SCLIN$, $SDA1-2$, $SCL1-2$ Pins	●	0.7	0.8	1	V
I_{BOOST}	Rise Time Accelerator Pull-Up Current	$SDAIN$, $SCLIN$, $SDA1-2$, $SCL1-2$ Pins (Note 3)		4	5.5		mA
Stuck Low Timeout Circuitry							
$V_{TIMER(L)}$	Stuck Low Falling Threshold Voltage	$V_{CC} = 2.7\text{V}$, 5.5V	●	0.4	0.52	0.64	V
$V_{TIMER(HYST)}$	Stuck Low Threshold Hysteresis Voltage				80		mV
T_{TIMER1}	Timeout Time #1	$TIMSET1,0 = 01$	●	25	30	35	ms
T_{TIMER2}	Timeout Time #2	$TIMSET1,0 = 10$	●	12.5	15	17.5	ms
T_{TIMER3}	Timeout Time #3	$TIMSET1,0 = 11$	●	6.25	7.5	8.75	ms
Upstream-Downstream Buffers							
$V_{OS, BUF}$	Buffer Offset Voltage	$R_{BUS} = 10\text{k}$, $V_{CC} = 2.7\text{V}$, 5.5V (Note 4)	●	25	60	100	mV
$V_{OS, UP-BUF}$	Upstream Buffer Offset Voltage $V_{IN, BUFFER} = 0\text{V}$	$V_{CC} = 2.7\text{V}$, $R_{BUS} = 2.7\text{k}$ (Note 4)	●	40	80	120	mV
		$V_{CC} = 5.5\text{V}$, $R_{BUS} = 2.7\text{k}$ (Note 4)	●	70	110	150	mV
$V_{OS, DOWN-BUF}$	Downstream Buffer Offset Voltage $V_{IN, BUFFER} = 0\text{V}$	$V_{CC} = 2.7\text{V}$, $R_{BUS} = 2.7\text{k}$ (Note 4)	●	60	110	160	mV
		$V_{CC} = 5.5\text{V}$, $R_{BUS} = 2.7\text{k}$ (Note 4)	●	80	140	200	mV
V_{OL}	Output Low Voltage, $V_{IN, BUFFER} = 0\text{V}$	SDA , SCL Pins; $I_{SINK} = 4\text{mA}$, $V_{CC} = 3\text{V}$, 5.5V	●			400	mV
V_{OL}	Output Low Voltage, $V_{IN, BUFFER} = 0.2\text{V}$	SDA , SCL Pins; $I_{SINK} = 500\mu\text{A}$, $V_{CC} = 2.7\text{V}$, 5.5V	●			320	mV
$V_{IL, MAX}$	Buffer Input Logic Low Voltage	$V_{CC} = 2.7\text{V}$, 5.5V	●	0.4	0.52	0.64	V
$V_{THSDA, SCL}$	Downstream SDA, SCL Logic Threshold Voltage		●	0.8	1.0	1.2	V
I_{LEAK}	Input Leakage Current	SDA , SCL Pins; $V_{CC} = 0$ to 5.5V ; Buffers Inactive	●			± 5	μA

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full specified temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$. $V_{CC} = 3.3\text{V}$ unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
I²C Interface							
$V_{\text{ADR(H)}}$	ADR0–2 Input High Voltage		●		$0.75 \cdot V_{CC}$	$0.9 \cdot V_{CC}$	V
$V_{\text{ADR(L)}}$	ADR0–2 Input Low Voltage		●	$0.1 \cdot V_{CC}$	$0.25 \cdot V_{CC}$		V
$I_{\text{ADR(IN, L)}}$	ADR0–2 Logic Low Input Current	ADR0–2 = 0V, $V_{CC} = 5.5\text{V}$	●	–30	–60	–80	μA
$I_{\text{ADR(IN, H)}}$	ADR0–2 Logic High Input Current	ADR0–2 = $V_{CC} = 5.5\text{V}$	●	30	60	80	μA
$I_{\text{ADR,FLOAT}}$	ADR0–2 Allowed Input Current	$V_{CC} = 2.7\text{V}, 5.5\text{V}$ (Note 5)	●	± 5	± 13		μA
$V_{\text{SDAIN,SCLIN(TH)}}$	SDAIN, SCLIN Input Falling Threshold Voltages	$V_{CC} = 5.5\text{V}$	●	1.4	1.6	1.8	V
$V_{\text{SDAIN,SCLIN(HY)}}$	SDAIN, SCLIN Hysteresis				30		mV
$I_{\text{SDAIN,SCLIN(OH)}}$	SDAIN, SCLIN Input Current	SCL, SDA = V_{CC}	●			± 5	μA
C_{IN}	SDA, SCL Input Capacitance	(Note 2)			6	10	pF
$V_{\text{SDAIN(OL)}}$	SDAIN Output Low Voltage	$I_{\text{SDA}} = 4\text{mA}$, $V_{CC} = 2.7\text{V}$	●		0.2	0.4	V
I²C Interface Timing							
f_{SCL}	Maximum SCL Clock Frequency	(Note 2)		400			kHz
t_{BUF}	Bus Free Time Between Stop/Start Condition	(Note 2)			0.75	1.3	μs
$t_{\text{HD, STA}}$	Hold Time After (Repeated) Start Condition	(Note 2)			45	100	ns
$t_{\text{SU, STA}}$	Repeated Start Condition Set-Up Time	(Note 2)			–30	0	ns
$t_{\text{SU, STO}}$	Stop Condition Set-Up Time	(Note 2)			–30	0	ns
$t_{\text{HD, DATI}}$	Data Hold Time Input	(Note 2)			–25	0	ns
$t_{\text{HD, DATO}}$	Data Hold Time Output	(Note 2)		300	600	900	ns
$t_{\text{SU, DAT}}$	Data Set-Up Time	(Note 2)			50	100	ns
t_f	SCL, SDA Fall Times	(Note 2)		$20 + 0.1 \cdot C_{\text{BUS}}$		300	ns
t_{SP}	Pulse Width of Spikes Suppressed by the Input Filter	(Note 2)		50	150	250	ns

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

Note 2: Guaranteed by design and not subject to test, unless stated otherwise in the Conditions.

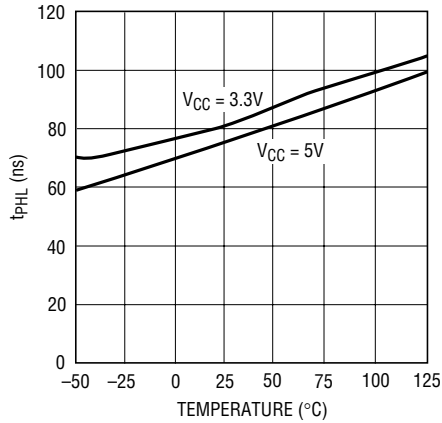
Note 3: The boosted pull-up currents are regulated to prevent excessively fast edges for light loads. See the Typical Performance Characteristics for rise time as a function of V_{CC} and parasitic bus capacitance C_{BUS} and for I_{BOOST} as a function of V_{CC} and temperature.

Note 4: When a logic low voltage V_{LOW} is forced on one side of the upstream-downstream buffers, the voltage on the other side is regulated to a voltage $V_{\text{LOW2}} = V_{\text{LOW}} + V_{\text{OS}}$ is a positive offset voltage. $V_{\text{OS,DOWN-BUF}}$ is the offset voltage when the LTC4305 is driving the upstream pin (e.g., SDAIN) and $V_{\text{OS,DOWN-BUF}}$ is the offset voltage when the LTC4305 is driving the downstream pin (e.g., SDA1). See the Typical Performance Characteristics for $V_{\text{OS,UP-BUF}}$ and $V_{\text{OS,DOWN-BUF}}$ as a function of V_{CC} and bus pull-up current.

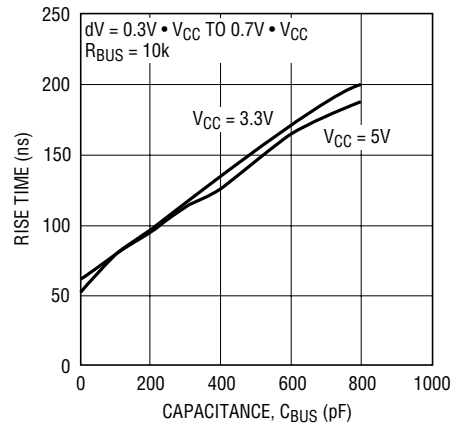
Note 5: When floating, the ADR0–ADR2 pins can tolerate pin leakage currents up to $I_{\text{ADR,FLOAT}}$ and still convert the address correctly.

TYPICAL PERFORMANCE CHARACTERISTICS ($T_A = 25^\circ\text{C}$ unless otherwise specified.)

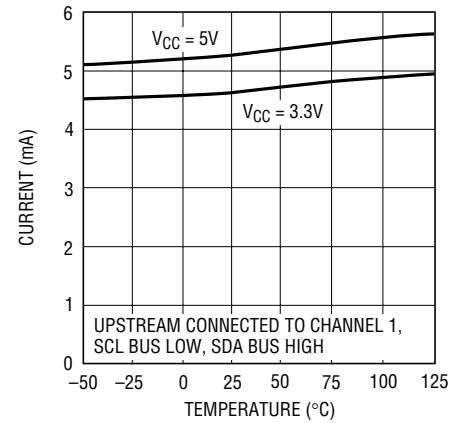
Buffer Circuitry t_{PHL} vs Temperature



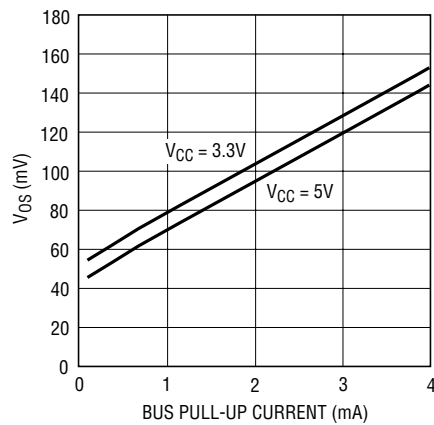
Rise Time vs C_{BUS} vs V_{CC}



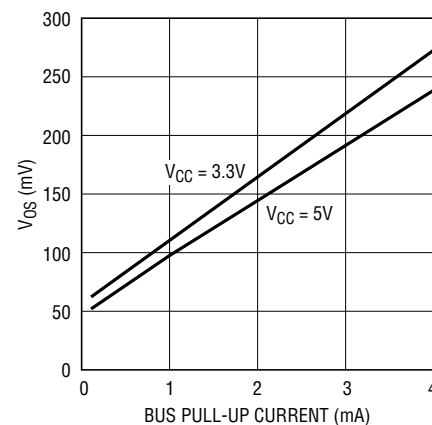
I_{CC} vs Temperature



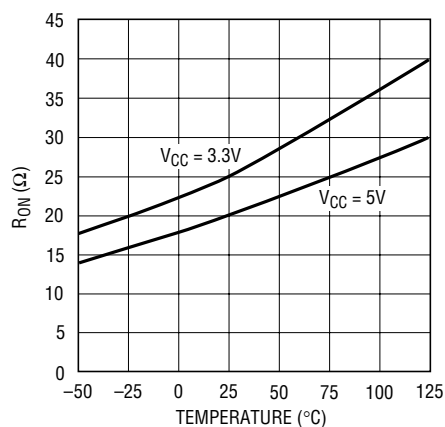
$V_{OS,UP-BUF}$ vs Bus Pull-Up Current



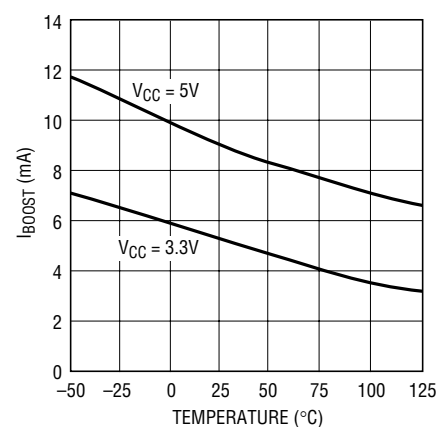
$V_{OS,DOWN-BUF}$ vs Bus Pull-Up Current



Downstream R_{FET} on Resistance vs V_{CC} and Temperature



I_{BOOST} vs Temperature



PIN FUNCTIONS

ALERT1–ALERT2 (Pins 14, 1): Fault Alert Inputs, Channels 1–2. Devices on each of the two output channels can pull their respective pin low to indicate that a fault has occurred. The LTC4305 then pulls the $\overline{\text{ALERT}}$ low to pass the fault indication on to the host. See the “Operation” section below for the details of how $\overline{\text{ALERT}}$ is set and cleared. Connect unused fault alert inputs to V_{CC} .

ALERT (Pin 2): Fault Alert Output. An open-drain output that is pulled low when a fault occurs to alert the host controller. The LTC4305 pulls $\overline{\text{ALERT}}$ low when any of the $\overline{\text{ALERT1}}$ – $\overline{\text{ALERT2}}$ pins is low; when the two-wire bus is stuck low; or when the Connection Requirement bit of register 2 is low and a master tries to connect to a downstream channel that is low. See the “Operation” section below for the details of how $\overline{\text{ALERT}}$ is set and cleared. The LTC4305 is compatible with the SMBus Alert Response Address protocol. Connect a 10k resistor to a power supply voltage to provide the pull-up. Tie to ground if unused.

SDAIN (Pin 3): Serial Bus Data Input and Output. Connect this pin to the SDA line on the master side. An external pull-up resistor or current source is required.

GND (Pin 4): Device Ground.

SCLIN (Pin 5): Serial Bus Clock Input. Connect this pin to the SCL line on the master side. An external pull-up resistor or current source is required.

ENABLE (Pin 6): Digital Interface Enable and Register Reset. Driving ENABLE high enables I²C communication to the LTC4305. Driving ENABLE low disables I²C communication to the LTC4305 and resets the registers to their default state as shown in the Operations section. When ENABLE returns high, masters can read and write the LTC4305 again. If unused, tie ENABLE to V_{CC} .

V_{CC} (Pin 7): Power Supply Voltage. Connect a bypass capacitor of at least 0.01 μ F directly between V_{CC} and GND for best results.

ADR0–ADR2 (Pins 8–10): Three-State Serial Bus Address Inputs. Each pin may be floated, tied to ground, or tied to V_{CC} . There are therefore 27 possible addresses. See Table 1 in Applications Information section. When the pins are floated, they can tolerate $\pm 5\mu$ A of leakage current and still convert the address correctly.

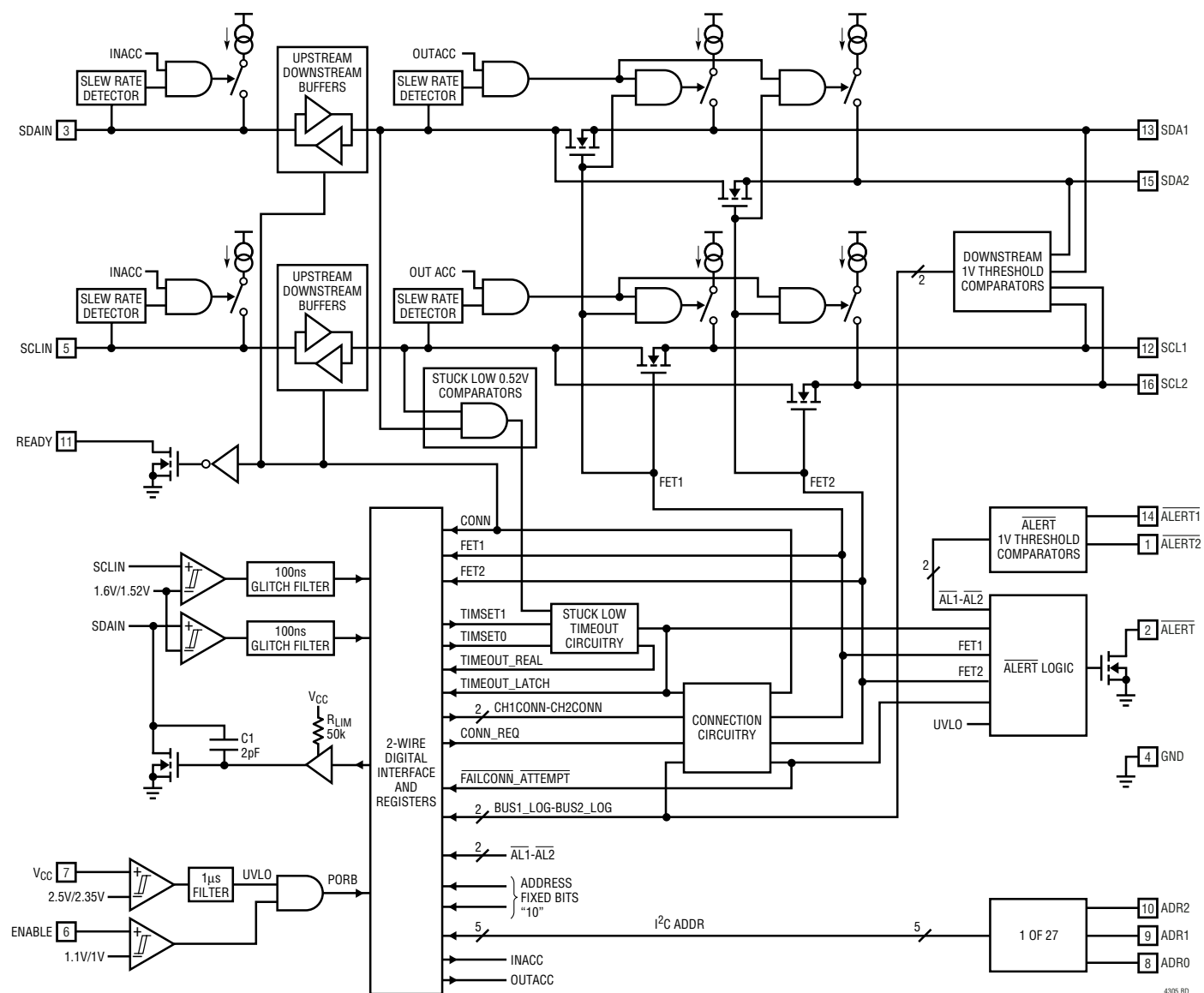
READY (Pin 11): Connection Ready Digital Output. An N-channel MOSFET open-drain output transistor that pulls down when none of the downstream channels is connected to the upstream bus and turns off when one or more downstream channels is connected to the upstream bus. Connect a 10k resistor to a power supply voltage to provide the pull-up. Tie to ground if unused.

SCL1–SCL2 (Pins 12, 16): Serial Bus Clock Outputs Channels 1–2. Connect pins SCL1–SCL2 to the SCL lines on the downstream channels 1–2, respectively. It is acceptable to float any pin that will never be connected to the upstream bus. Otherwise, an external pull-up resistor or current source is required on each pin.

SDA1–SDA2 (Pins 13, 15): Serial Bus Data Output Channels 1–2. Connect pins SDA1–SDA2 to the SDA lines on downstream channels 1–2, respectively. It is acceptable to float any pin that will never be connected to the upstream bus. Otherwise, an external pull-up resistor or current source is required on each pin.

Exposed Pad (Pin 17, DHD Package Only): Exposed pad may be left open or connected to device ground.

BLOCK DIAGRAM



4305 BD

OPERATION

Control Register Bit Definitions

Register 0 (00h)

BIT	NAME	TYPE*	DESCRIPTION
d7	Downstream Connected	R	Indicates if upstream bus is connected to any downstream buses 0 = upstream bus disconnected from all downstream buses 1 = upstream bus connected to one or more downstream buses
d6	ALERT1 Logic State	R	Logic state of $\overline{\text{ALERT1}}$ pin, noninverting
d5	ALERT2 Logic State	R	Logic state of $\overline{\text{ALERT2}}$ pin, noninverting
d4	Reserved	R	Not Used
d3	Reserved	R	Not Used
d2	Failed Connection Attempt	R	Indicates if an attempt to connect to a downstream bus failed because the "Connection Requirement" bit in Register 2 was low and the downstream bus was low 0 = Failed connection attempt occurred 1 = No failed attempts at connection occurred
d1	Latched Timeout	R	Latched bit indicating if a timeout has occurred and has not yet been cleared. 0 = no latched timeout 1 = latched timeout
d0	Timeout Real Time	R	Indicates real-time status of Stuck Low Timeout Circuitry 0 = no timeout is occurring 1 = timeout is occurring

Note: Masters write to Register 0 to reset the fault circuitry after a fault has occurred and been resolved. Because Register 0 is Read-Only, no other functionality is affected.

* For Type, "R/W" = Read Write, "R" = Read Only

Register 1 (01h)

BIT	NAME	TYPE*	DESCRIPTION
d7	Upstream Accelerators Enable	R/W	Activates upstream rise time accelerator currents 0 = upstream rise time accelerator currents inactive (default) 1 = upstream rise time accelerator currents active
d6	Downstream Accelerators Enable	R/W	Activates downstream rise time accelerator currents 0 = downstream rise time accelerator currents inactive (default) 1 = downstream rise time accelerator currents active
d5-d0	Reserved	R	Not Used

* For Type, "R/W" = Read Write, "R" = Read Only

OPERATION

Register 2 (02h)

BIT	NAME	TYPE*	DESCRIPTION
d7	Reserved	R	Not Used
d6	Reserved	R	Not Used
d5	Connection Requirement	R/W	Sets logic requirements for downstream buses to be connected to upstream bus 0 = Bus Logic State bits (see register 3) of buses to be connected must be high for connection to occur (default) 1 = Connect regardless of downstream logic state
d4	Reserved	R	Not Used
d3	Reserved	R	Not Used
d2	Mass Write Enable	R/W	Enable Mass Write Address using address (1011 110)b 0 = Disable Mass Write 1 = Enable Mass Write (default)
d1	Timeout Mode Bit 1	R/W	Stuck Low Timeout Set Bit 1**
d0	Timeout Mode Bit 0	R/W	Stuck Low Timeout Set Bit 0**

* For Type, "R/W" = Read Write, "R" = Read Only

**

TIMSET1	TIMSET0	TIMEOUT MODE
0	0	Timeout Disabled (Default)
0	1	Timeout After 30ms
1	0	Timeout After 15ms
1	1	Timeout After 7.5ms

Register 3 (03h)

BIT	NAME	TYPE*	DESCRIPTION
d7	Bus 1 FET State	R/W	Sets and indicates state of FET switches connected to downstream bus 1 0 = switch open (default) 1 = switch closed
d6	Bus 2 FET State	R/W	Sets and indicates state of FET switches connected to downstream bus 2 0 = switch open (default) 1 = switch closed
d5	Reserved	R	Not Used
d4	Reserved	R	Not Used
d3	Bus 1 Logic State	R	Indicates logic state of downstream bus 1; only valid when disconnected from upstream bus† 0 = SDA1, SCL1 or both are below 1V 1 = SDA1 and SCL1 are both above 1V
d2	Bus 2 Logic State	R	Indicates logic state of downstream bus 2; only valid when disconnected from upstream bus† 0 = SDA2, SCL2 or both are below 1V 1 = SDA2 and SCL2 are both above 1V
d1	Reserved	R	Not Used
d0	Reserved	R	Not Used

* For Type, "R/W" = Read Write, "R" = Read Only

† These bits are meant to give the logic state of disconnected downstream buses to the master, so that the master can choose not to connect to a low downstream bus. A given bit is a "don't care" if its associated downstream bus is already connected to the upstream bus.

OPERATION

The LTC4305 is a 2-channel 2-wire bus multiplexer/switch with bus buffers to provide capacitive isolation between the upstream bus and downstream buses. Masters on the upstream 2-wire bus (SDAIN and SCLIN) can command the LTC4305 to neither, either or both of the 2 downstream buses. Masters can also program the LTC4305 to disconnect the upstream bus from the downstream buses if the bus is stuck low.

Undervoltage Lockout (UVLO) and ENABLE Functionality

The LTC4305 contains undervoltage lockout circuitry that maintains all of its SDA, SCL and ALERT pins in high impedance states until the device has sufficient V_{CC} supply voltage to function properly. It also ignores any attempts to communicate with it via the 2-wire buses in this condition. When the ENABLE pin voltage is low (below 0.8V), all control bits are reset to their default high impedance states, and the LTC4305 ignores 2-wire bus commands. However, with ENABLE low, the LTC4305 still monitors the $\overline{\text{ALERT1}}$ – $\overline{\text{ALERT2}}$ pin voltages and pulls the ALERT pin low if any of $\overline{\text{ALERT1}}$ – $\overline{\text{ALERT2}}$ is low. When ENABLE is high, devices can read from and write to the LTC4305.

Connection Circuitry

Masters on the upstream SDAIN/SCLIN bus can write to the Bus 1 FET State and Bus 2 FET State bits of register 3 to connect to any combination of downstream channels. By default, the Connection Circuitry shown in the block diagram will only connect to downstream channels whose corresponding Bus Logic State bits in register 3 are high at the moment that it receives the connection command. If the LTC4305 is commanded to connect to multiple channels at once, it will only connect to the channels that are high. This prevents the master on the upstream bus from connecting to a downstream channel that may be

stuck low. Masters can override this feature by setting the Connection Requirement Bit of register 2 high. With this bit high, the LTC4305 executes connection commands without regard to the logic states of the downstream channels.

Upon receiving the connection command, the Connection Circuitry shown in the block diagram will activate the Upstream-Downstream Buffers under two conditions: first, the master must be commanding connection to one or more downstream channels, and second, there must be no stuck low condition (see “Stuck Low Timeout Fault” discussion that follows). If the connection command is successful, the Upstream-Downstream Buffer circuitry passes signals between the upstream bus and the connected downstream buses. The LTC4305 also turns off its N-channel MOSFET open-drain pull-down on the READY pin, so that READY can be pulled high by its external pull-up resistor.

Upstream-Downstream Buffers

Once the Upstream-Downstream Buffers are activated, the functionality of the SDAIN and any connected downstream SDA pins is identical. A low forced on any connected SDA pin at any time results in all pins being low. **External devices must pull the pin voltages below 0.4V worst-case with respect to the LTC4305’s ground pin to ensure proper operation.** The SDA pins enter a logic high state only when all devices on all connected SDA pins force a high. The same is true for SCLIN and the connected downstream SCL pins. This important feature ensures that clock stretching, clock arbitration and the acknowledge protocol always work, regardless of the how the devices in the system are connected to the LTC4305.

The Upstream-Downstream Buffers provide capacitive isolation between SDAIN/SCLIN and the downstream connected buses. Note that there is no capacitive isolation between connected downstream buses; they are only

OPERATION

separated by the series combination of their switches' on resistances. While neither, either or both downstream buses may be connected at the same time, logic high levels are corrupted if both downstream buses are active and both the V_{CC} voltage and one downstream bus pull-up voltage are larger than the pull-up supply voltage of the other downstream bus. An example of this issue is shown in Figure 1. During logic highs, DC current flows from V_{BUS1} through the series combination of R1, N1, N2 and R2 and into V_{BUS2} , causing the SDA1 voltage to drop and current to be sourced into V_{BUS2} . To avoid this problem, do not activate bus 1 when bus 2 is active.

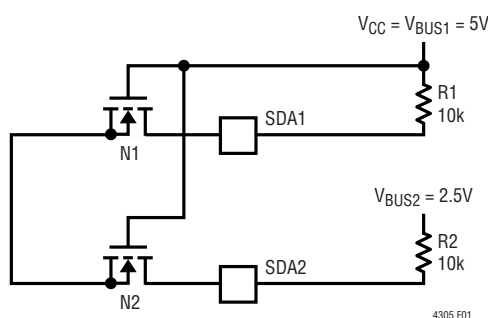


Figure 1. Example of Unacceptable Level Shifting

Rise Time Accelerators

The Upstream Accelerators Enable and Downstream Accelerators Enable bits of register 1 activate the upstream and downstream risetime accelerators, respectively. When activated, the accelerators turn on in a controlled manner and source current into the pins during positive bus transitions.

When no downstream buses are connected, an upstream accelerator turns on when its pin voltage exceeds 0.8V and is rising at a minimum slew rate of 0.8V/ μ s. When one or more downstream buses are connected, the accelerator on a given pin turns on when these conditions are met:

first, the pin's voltage is rising at a minimum slew rate of 0.8V/ μ s; second, the voltages on both the upstream bus and the connected downstream buses exceed 0.8V.

Note that a downstream bus must be connected to the upstream bus in order for its rise time accelerator current to be active. See the Applications Section for choosing a bus pull-up resistor value to ensure that the rise time accelerator switches turn on. **Do not activate boost currents on a bus whose pull-up supply voltage $V_{BUS} < V_{CC}$. Doing so would cause the boost currents to source current from V_{CC} into the V_{BUS} supply during rising edges.**

Downstream Bus Connection Fault

By default, the LTC4305 will only connect to downstream buses whose SDA and SCL pins are both high (above 1V) at the moment that it receives the connection command. In this case, the LTC4305 sets the Failed Connection Attempt bit of register 0 low and pulls the ALERT low when the master tries to connect to a low downstream bus. Note that users can write a high to the Connection Requirement bit of register 2 to program the LTC4305 to connect to downstream buses regardless of their logic state at the moment of connection. In this case, the Downstream Channel Connection Fault never occurs.

Stuck Low Timeout Fault

The Stuck Low Timeout Circuitry monitors the two common internal nodes of the downstream SDA and SCL switches and runs a timer whenever either of the internal node voltages is below 0.52V. The timer is reset whenever both internal node voltages are above 0.6V. If the timer ever reaches the time programmed by Timeout Mode Bits 1 and 0 of register 2, the LTC4305 pulls ALERT low and

OPERATION

disconnects the downstream buses from the upstream bus by de-biasing the Upstream-Downstream Buffers. Note that the downstream switches remain in their existing state. The Timeout Real Time bit of register 0 indicates the real-time status of the stuck low situation. The Latched Timeout Bit of register 0 is a latched bit that is set high when a timeout occurs.

External Faults on the Downstream Channels

When a slave on downstream channel 1 pulls the $\overline{\text{ALERT1}}$ pin below 1V, the LTC4305 passes this information to master on the upstream bus by pulling the $\overline{\text{ALERT}}$ pin low. The functionality is the same for the slaves on downstream channel 2 and the $\overline{\text{ALERT2}}$ pin. Each channel has its own dedicated fault bit in Register 0, so that masters can read Register 0 to determine which channels have faults.

$\overline{\text{ALERT}}$ Functionality and Fault Resolution

When a fault occurs, the LTC4305 pulls the $\overline{\text{ALERT}}$ pin low, as described previously. The procedure for resolving faults depends on the type of fault. If a master on the upstream bus is communicating with devices on a downstream bus via the upstream-downstream buffer circuitry—channel 1, for example—and a device on this bus pulls the $\overline{\text{ALERT1}}$ pin low, the LTC4305 acts transparently, and the master communicates directly with the device that caused the fault via the Upstream-Downstream Buffer circuitry to resolve the fault.

In all other cases, the LTC4305 communicates with the master to resolve the fault. After the master broadcasts the Alert Response Address (ARA), the LTC4305 will respond with its address on the SDAIN line and release the $\overline{\text{ALERT}}$ pin. The $\overline{\text{ALERT}}$ line will also be released if the LTC4305 is addressed by the master.

The $\overline{\text{ALERT}}$ signal will not be pulled low again until a different type of fault has occurred or the original fault is cleared and has occurred again. Figure 2 shows the details of how the fault latches and $\overline{\text{ALERT}}$ pin are set and reset.

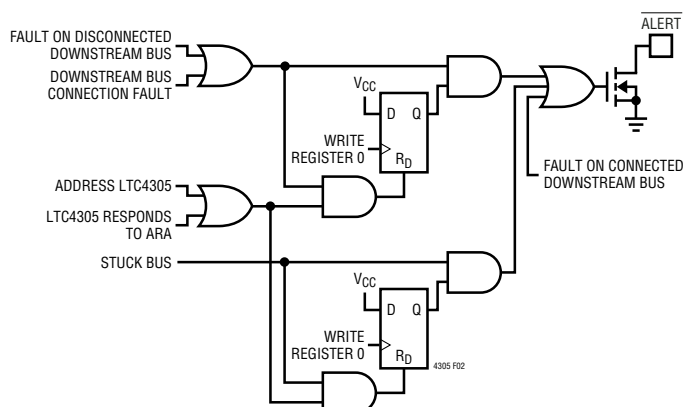


Figure 2. Setting and Resetting the $\overline{\text{ALERT}}$ Pin

occur on unconnected downstream buses are grouped together and generate a single signal to drive $\overline{\text{ALERT}}$. The Stuck Low Timeout Fault has its own dedicated pathway to $\overline{\text{ALERT}}$; however, once a stuck low occurs, another one will not occur until the first one is cleared. For these reasons, once the master has established the LTC4305 as the source of the fault, it should read register 0 to determine the specific problem, take action to solve the problem, and clear the fault promptly. All faults are cleared by writing a dummy databyte to register 0, which is a read-only register.

For example, assume that a fault occurs, the master sends out the ARA, and the LTC4305 successfully writes its address onto SDAIN and releases its $\overline{\text{ALERT}}$ pin. The master reads register 0 and learns that the $\overline{\text{ALERT2}}$ logic state bit is low. The master now knows that a device on downstream bus 2 has a fault and writes to register 3 to connect to bus 2, so that it can communicate with the source of the fault. At this point, the master writes to register 0 to clear the fault.

I²C Device Addressing

Twenty-seven distinct bus addresses are configurable using the three state ADRO, ADRI and ADRI pins. Table 1 shows the correspondence between pin states and addresses. Note that address bits a6 and a5 are internally configured to 1 and 0, respectively. In addition, the LTC4305 responds to two special addresses. Address (1011 110) is a mass write used to write all LTC4305's,

OPERATION

regardless of their individual address settings. The mass write can be masked by setting the mass write enable bit of register 2 to zero. Address (0001 100) is the SMBus Alert Response Address. Figure 3 shows data transfer over a 2-wire bus.

Supported Commands

Users must write to the LTC4305 using the SMBus Write Byte protocol and read from it using the Read Byte protocol. During fault resolution, the LTC4305 also supports the Alert Response Address protocol. The formats for these protocols are shown in Figure 4. Users must follow the Write Byte protocol exactly to write to the LTC4305; if a Repeated Start Bit is issued before a Stop Bit, the LTC4305 ignores the attempted write, and its control bits remain in their preexisting state. When users follow the WriteByte protocol exactly, the new data contained in the Data Byte is written into the register selected by r1 and r0 on the Stop Bit.

Glitch Filters

The LTC4305 provides glitch filters on the SDAIN and SCLIN pins as required by the I²C Fast Mode (400kHz) Specification. The filters prevent signals of up to 50ns (minimum) time duration and rail-to-rail voltage magnitude from passing into the two-wire bus digital interface circuitry.

Fall Time Control

Per the I²C Fast Mode (400kHz) Specification, the two-wire bus digital interface circuitry provides fall time control when forcing logic lows onto the SDAIN bus. The fall time always meets the limits:

$$(20 + 0.1 \cdot C_B) < t_f < 300\text{ns}$$

where t_f is the fall time in ns and C_B is the equivalent bus capacitance in pF. Whenever the upstream-downstream buffer circuitry is active, its output signal will meet the fall time requirements, provided that its input signal meets the fall time requirements.

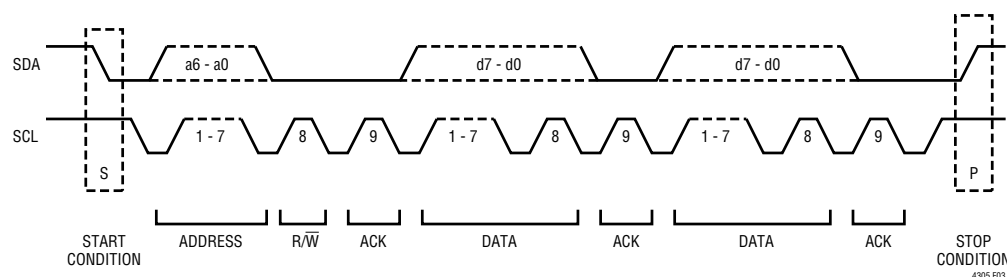


Figure 3. Data Transfer Over I²C/SMBus

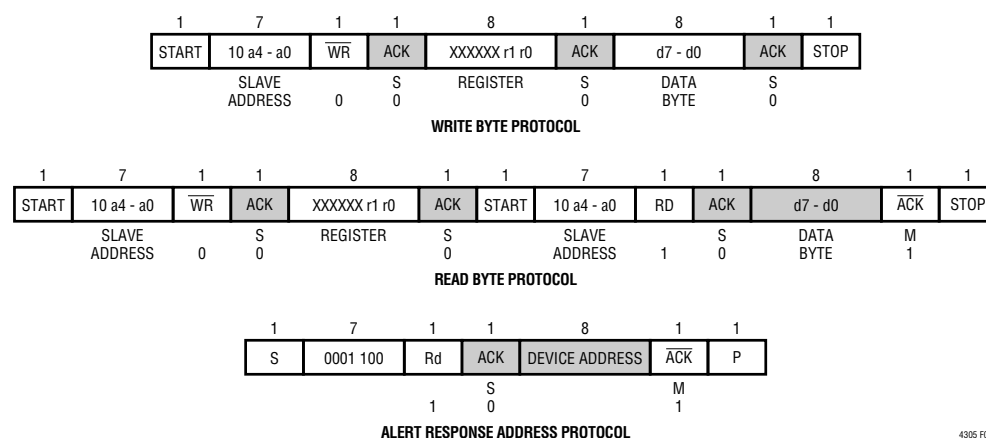


Figure 4. Protocols Accepted by LTC4305

OPERATION

Table 1. LTC4305 I²C Device Addressing

DESCRIPTION	HEX DEVICE ADDRESS	BINARY DEVICE ADDRESS								LTC4305 ADDRESS PINS		
		a6	a5	a4	a3	a2	a1	a0	R/W	ADR2	ADR1	ADR0
Mass Write	BC	1	0	1	1	1	1	0	0	X	X	X
Alert Response	19	0	0	0	1	1	0	0	1	X	X	X
0	80	1	0	0	0	0	0	0	X	L	NC	L
1	82	1	0	0	0	0	0	1	X	L	H	NC
2	84	1	0	0	0	0	1	0	X	L	NC	NC
3	86	1	0	0	0	0	1	1	X	L	NC	H
4	88	1	0	0	0	1	0	0	X	L	L	L
5	8A	1	0	0	0	1	0	1	X	L	H	H
6	8C	1	0	0	0	1	1	0	X	L	L	NC
7	8E	1	0	0	0	1	1	1	X	L	L	H
8	90	1	0	0	1	0	0	0	X	NC	NC	L
9	92	1	0	0	1	0	0	1	X	NC	H	NC
10	94	1	0	0	1	0	1	0	X	NC	NC	NC
11	96	1	0	0	1	0	1	1	X	NC	NC	H
12	98	1	0	0	1	1	0	0	X	NC	L	L
13	9A	1	0	0	1	1	0	1	X	NC	H	H
14	9C	1	0	0	1	1	1	0	X	NC	L	NC
15	9E	1	0	0	1	1	1	1	X	NC	L	H
16	A0	1	0	1	0	0	0	0	X	H	NC	L
17	A2	1	0	1	0	0	0	1	X	H	H	NC
18	A4	1	0	1	0	0	1	0	X	H	NC	NC
19	A6	1	0	1	0	0	1	1	X	H	NC	H
20	A8	1	0	1	0	1	0	0	X	H	L	L
21	AA	1	0	1	0	1	0	1	X	H	H	H
22	AC	1	0	1	0	1	1	0	X	H	L	NC
23	AE	1	0	1	0	1	1	1	X	H	L	H
24	B0	1	0	1	1	0	0	0	X	H	H	L
25	B2	1	0	1	1	0	0	1	X	L	H	L
26	B4	1	0	1	1	0	1	0	X	NC	H	L

APPLICATIONS INFORMATION

Design Example

A typical LTC4305 application circuit is shown in Figure 5. The circuit illustrates the level-shifting, multiplexer/switch and capacitance buffering features of the LTC4305. In this application, the LTC4305 V_{CC} voltage and downstream bus 1 are powered from 3.3V, downstream bus 2 is powered from 5V, and the upstream bus is powered from 2.5V. The following sections describe a methodology for choosing the external components in Figure 5.

SDA, SCL Pull-Up Resistor Selection

The pull-up resistors on the SDA and SCL pins must be strong enough to provide a minimum of 100 μ A pull-up current, per the SMBus Specification. In most systems, the required minimum strength of the pull-up resistors is determined by the minimum slew requirement to guarantee that the LTC4305's rise time accelerators are activated during rising edges. At the same time, the pull-up value should be kept low to maximize the logic low noise margin and minimize the offset voltage of the Upstream-Downstream Buffer circuitry. The LTC4305 is designed to function for a maximum DC pull-up current of 4mA. If multiple downstream channels are active at the same time, this means that the sum total of the pull-up currents from these channels must be less than 4mA. At supply voltages of 2.7V and 5.5V, pull-up resistor values of 10k work well for capacitive loads up to 215pF and 420pF, respectively.

For larger bus capacitances, refer to equation (1) below. The LTC4305 works with capacitive loads up to 2nF.

Assume in Figure 5 that the total parasitic bus capacitance on SDA1 due to trace and device capacitance is 100pF. To ensure that the boost currents are active during rising edges, the pull-up resistor must be strong enough to cause the SDA1 pin voltage to rise at a rate of 0.8V/ μ s as the pin voltage is rising above 0.8V. The equation is:

$$R_{PULL-UP,MAX} [k\Omega] = \frac{\left\{ (V_{BUSMIN} - 0.8V) \cdot 1250 \left[\frac{ns}{V} \right] \right\}}{C_{BUS} [pF]} \quad (1)$$

where V_{BUSMIN} is the minimum operating pull-up supply voltage, and C_{BUS} is the bus parasitic capacitance. In our example, $V_{BUS1} = V_{CC} = 3.3V$, and assuming $\pm 10\%$ supply tolerance, $V_{BUS1MIN} = 2.97V$. With $C_{BUS} = 100pF$, $R_{PULL-UP,MAX} = 27.1k\Omega$. Therefore, we must choose a pull-up resistor smaller (i.e., stronger pull-up) than 27.1k, so a 10k resistor works fine.

ALERT and READY Component Selection

The pull-up resistors on the \overline{ALERT} and \overline{READY} pins must provide a maximum pull-up current of 3mA, so that the LTC4305 is capable of holding the pins at logic low voltages below 0.4V.

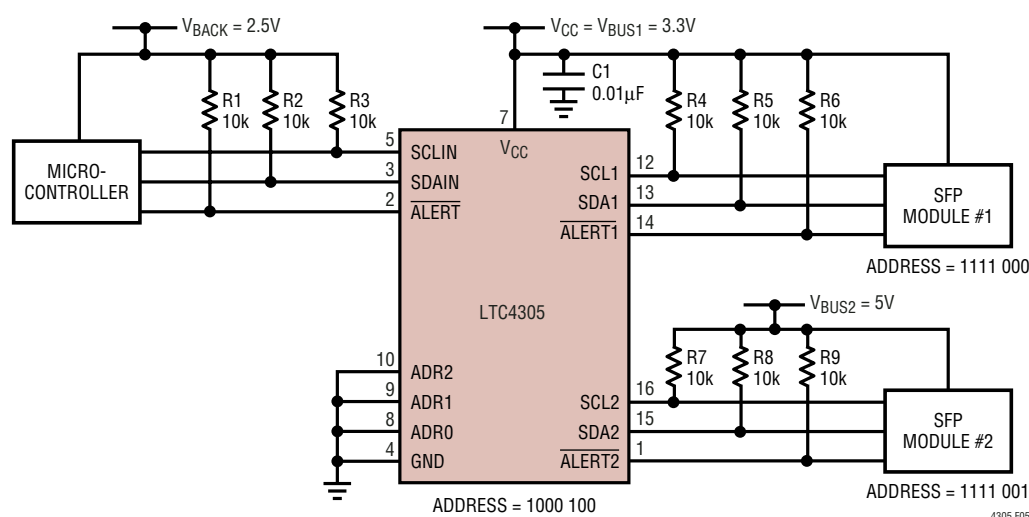


Figure 5. A Level Shifting Circuit

APPLICATIONS INFORMATION

Level Shifting Considerations

In Figure 5, the LTC4305 V_{CC} voltage is less than or equal to both of the downstream bus pull-up voltages, so both downstream buses can be active at the same time. Likewise, the rise time accelerators can be turned on for the downstream buses, but must never be activated on SCLIN and SDAIN, because doing so would result in significant current flow from V_{CC} to V_{BACK} during rising edges.

Other Application Circuits

Figure 6 illustrates how the LTC4305 can be used to expand the number of devices in a system by using nested addressing. Each I/O card contains a temperature sensor having device address 1001 000. If both I/O cards were plugged directly into the backplane, the two sensors would require two unique addresses. However, if masters use the LTC4305 in multiplexer mode, where only one downstream channel is connected at a time, then each I/O card can have a device with address 1001 000 and no problems will occur.

Figures 7 and 8 show two different methods for hot-swapping I/O cards onto a live two-wire bus using the LTC4305. The circuitry of Figure 7 consists of an LTC4305 residing on the edge of an I/O card having two separate downstream buses. Connect a 200k resistor to ground

from the ENABLE pin and make the ENABLE pin the shortest pin on the card connector, so that the ENABLE pin remains at a constant logic low while all other pins are connecting. This ensures that the LTC4305 remains in its default high impedance state and ignores connection transients on its SDAIN and SCLIN pins until they have established solid contact with the backplane 2-wire bus. In addition, make sure that the ALERT card connector pin is shorter than the V_{CC} pin, so that V_{CC} establishes solid contact with the I/O card pull-up supply pin and powers the pull-up resistors on ALERT1–ALERT2 before ALERT makes contact.

Figure 8 illustrates an alternate SDA and SCL hot-swapping technique, where the LTC4305 is located on the backplane and an I/O card plugs into downstream channel 2. Before plugging and unplugging the I/O card, make sure that channel 2's downstream switch is open, so that it does not disturb any 2-wire transaction that may be occurring at the moment of connection/disconnection. Note that pull-up resistor R10 on ALERT2 should be located on the backplane and not the I/O card to ensure proper operation of the LTC4305 when the I/O card is not present. The pull-up resistors on SCL2 and SDA2—R8 and R9, respectively—may be located on the I/O card, provided that downstream bus 2 is never activated when the I/O card is not present. Otherwise, locate R8 and R9 on the backplane.

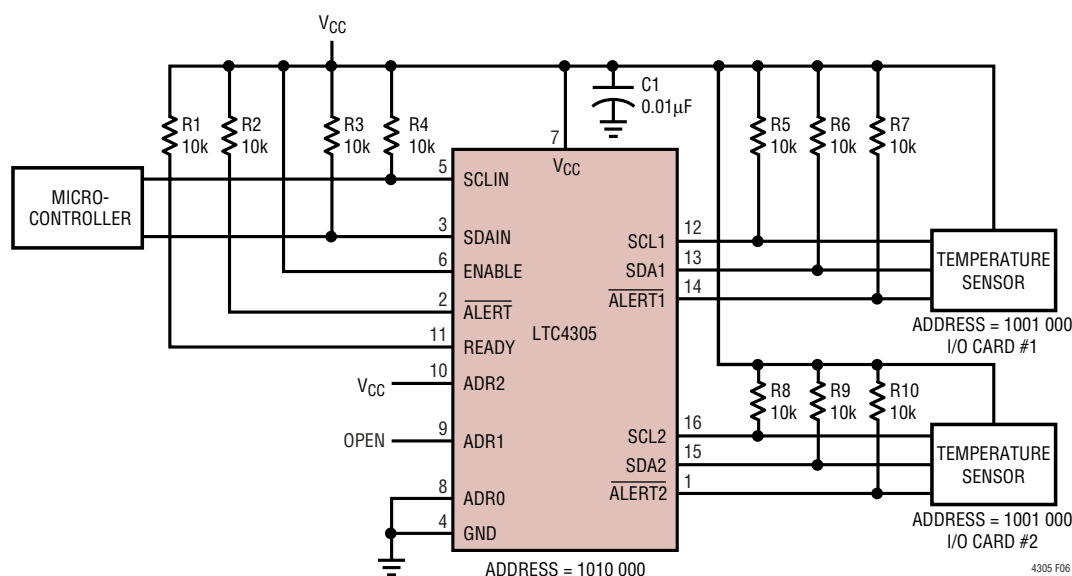


Figure 6. Nested Addressing Application

4305f

APPLICATIONS INFORMATION

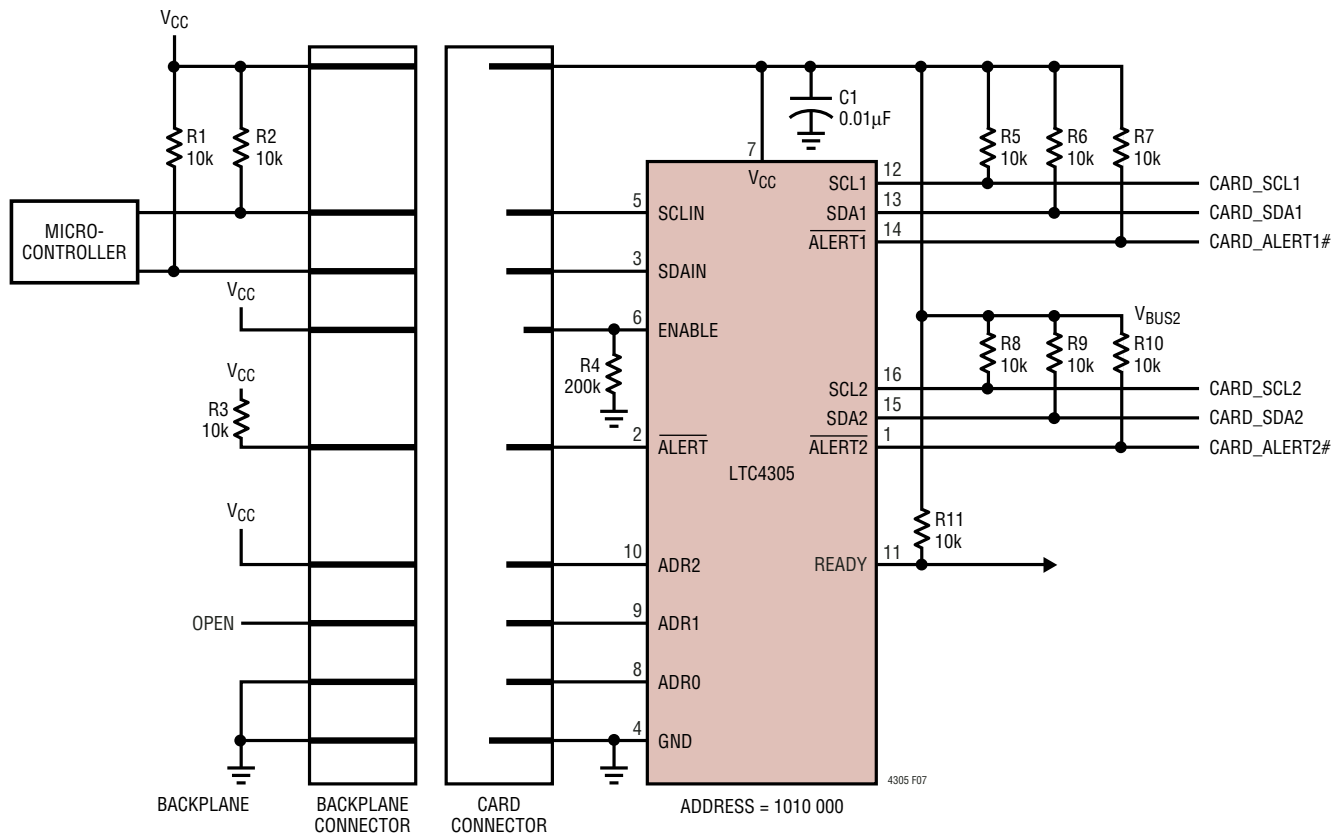


Figure 7. Hot-Swapping Application

Top view of the package showing dimensions and pin locations. The package outline is rectangular. The overall width is 4.50 ± 0.05 . The overall height is 3.10 ± 0.05 . The pin pitch is 0.70 ± 0.05 . The pin width is 2.44 ± 0.05 (2 SIDES). The pin length is 0.25 ± 0.05 . The pin spacing is 0.50 BSC. The overall pin width is 4.34 ± 0.05 (2 SIDES). The package outline is indicated by a dashed line.

5.00 ± 0.10
(2 SIDES)

4.00 ± 0.10
(2 SIDES)

PIN 1
TOP MARK
(SEE NOTE 6)

0.200 REF

0.75 ± 0.05

0.00 - 0.05

R = 0.20 TYP

2.44 ± 0.10
(2 SIDES)

R = 0.115 TYP

9

16

8

1

0.25 ± 0.05

0.50 BSC

4.34 ± 0.10
(2 SIDES)

PIN 1 NOTCH

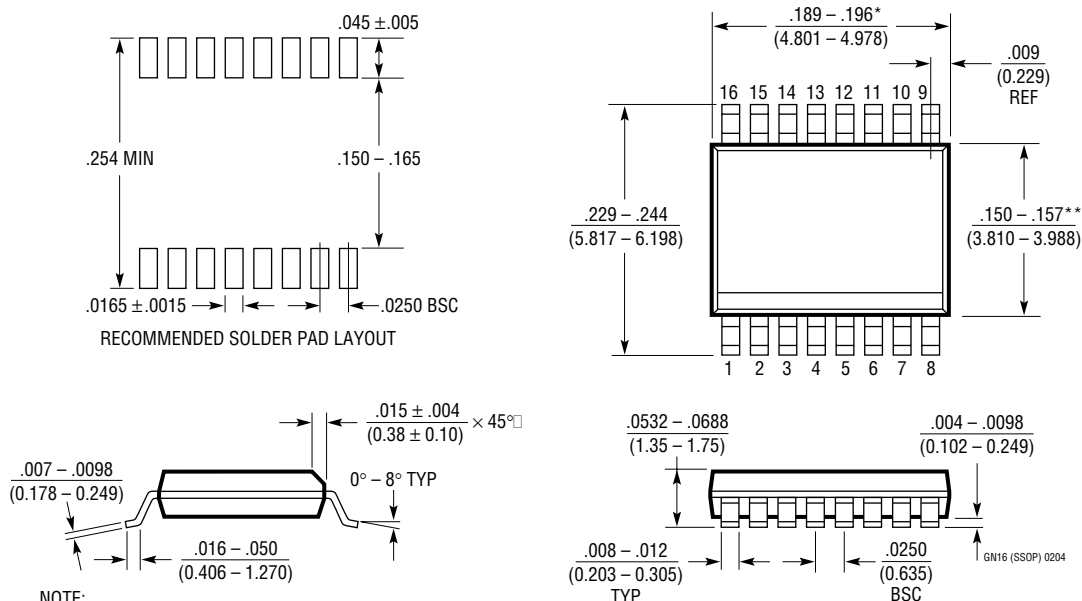
(DHD16) DFN 0504

BOTTOM VIEW—EXPOSED PAD

1. DRAWING PROPOSED TO BE MADE VARIATION OF VERSION (WJGD-2) IN JEDEC PACKAGE OUTLINE MO-229
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
5. EXPOSED PAD SHALL BE SOLDER PLATED
6. SHADED AREA IS ONLY A REFERENCE FOR PIN 1 LOCATION ON THE TOP AND BOTTOM OF PACKAGE

PACKAGE DESCRIPTION

GN Package 16-Lead Narrow Plastic SSOP (Reference LTC DWG # 05-08-1641)



NOTE:

1. CONTROLLING DIMENSION: INCHES
2. DIMENSIONS ARE IN $\frac{\text{INCHES}}{\text{MILLIMETERS}}$
3. DRAWING NOT TO SCALE

*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

**DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

TYPICAL APPLICATION

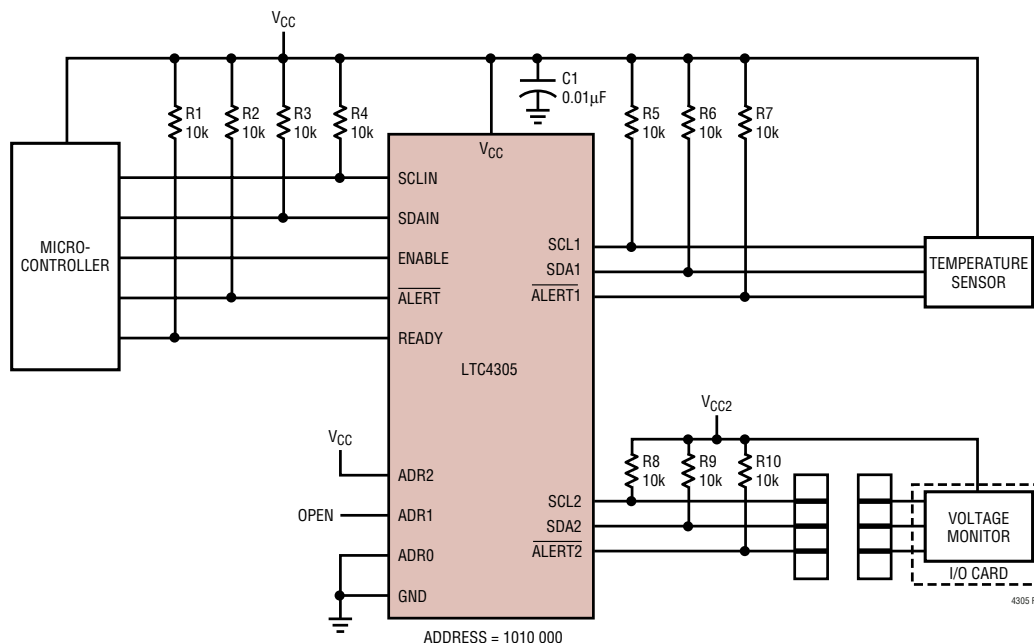


Figure 8. Alternate Hot-Swapping Application

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC1380/LTC1393	Single-Ended 8-Channel/Differential 4-Channel Analog Mux with SMBus Interface	Low R_{ON} : 35Ω Single-Ended/70Ω Differential, Expandable to 32 Single or 16 Differential Channels
LTC1427-50	Micropower, 10-Bit Current Output DAC with SMBus Interface	Precision 50µA \pm 2.5% Tolerance Over Temperature, 4 Selectable SMBus Addresses, DAC Powers up at Zero or Midscale
LTC1623	Dual High Side Switch Controller with SMBus Interface	8 Selectable Addresses/16-Channel Capability
LTC1663	SMBus Interface 10-Bit Rail-to-Rail Micropower DAC	DNL < 0.75LSB Max, 5-Lead SOT-23 Package
LTC1694/LTC1694-1	SMBus Accelerator	Improved SMBus/I ² C Rise-Time, Ensures Data Integrity with Multiple SMBus/I ² C Devices
LT1786F	SMBus Controlled CCFL Switching Regulator	1.25A, 200kHz, Floating or Grounded Lamp Configurations
LTC1695	SMBus/I ² C Fan Speed Controller in ThinSOT™	0.75Ω PMOS 180mA Regulator, 6-Bit DAC
LTC1840	Dual I ² C Fan Speed Controller	Two 100µA 8-Bit DACs, Two Tach Inputs, Four GPIO
LTC4300A-1/LTC4300A-2	Hot Swappable 2-Wire Bus Buffer	Isolates Backplane and Card Capacitances
LTC4300A-3	Hot Swappable 2-Wire Bus Buffer	Provides Level Shifting and Enable Functions
LTC4301	Supply Independent Hot Swappable 2-Wire Bus Buffer	Supply Independent
LTC4301L	Hot Swappable 2-Wire Bus Buffer with Low Voltage Level Translation	Allows Bus Pull-Up Voltages as Low as 1V on SDAIN and SCLIN
LTC4302-1/LTC4302-2	Addressable 2-Wire Bus Buffer	Address Expansion, GPIO, Software Controlled
LTC4303/LTC4304	Hot Swappable 2-Wire Bus Buffer with Stuck Bus Recovery	Provides Automatic Clocking to Free Stuck I ² C Busses
LTC4306	4-Channel 2-Wire Multiplexer with Capacitance Buffering	4 Selectable Downstream Buses, Stuck Bus Disconnect, Rise Time Accelerators, Fault Reporting, \pm 10kV HBM ESD Tolerance

ThinSOT is a trademark of Linear Technology Corporation.