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September 2017

FXWA9306
Dual Bi-Directional I²C-Bus® and SMBus Voltage-Level Translator

Features

- 2-Bit Bi-Directional Translator for SDA and SCL Lines in Mixed-Mode I²C-Bus Applications
- Standard-Mode, Fast-Mode, and Fast-Mode-Plus I²C-Bus and SMBus Compatible
- Less than 1.5ns Maximum Propagation Delay to Accommodate Standard-Mode and Fast-Mode I²C-Bus Devices and Multiple Masters
- Allows Voltage Level Translation Between:
  - V_{CCA} = 1.0 to 3.6V and V_{CCB} = 1.8- 5.0V
- Supports I²C Clock Stretching and Multi-Master
- Provides Bi-directional Voltage Translation without Direction Pin
- Low 3.5Ω On-State Connection Between Input and Output Ports; Provides Less Signal Distortion
- Open-Drain I²C-Bus I/O Ports (A0, A1, B0, and B1)
- 5V-Tolerant I²C-Bus I/O Ports to Support Mixed-Mode Signal Operation
- Lock-Up-Free Operation
- Flow-Through Pinout for Simpler Printed-Circuit Board Trace Routing
- Packaged in 8-Terminal Leadless MicroPak™ (1.6mm x 1.6mm) and MSOP8 (TSSOP8)

Description

The FXWA9306 is a dual, bi-directional, I²C-bus and SMBus, voltage-level translator with an enable (OE) input that is operational from 1.0V to 3.6V (V_{CCA}) and 1.8V to 5.5V (V_{CCB}) without requiring a direction pin.

As with standard I²C-bus systems, pull-up resistors are required to provide the logic HIGH levels on the translator's bus. The FXWA9306 has a standard open-drain configuration of the I²C-bus. The size of these pull-up resistors depends on the system, but each side of the translator must have a pull-up resistor. The device is designed to work with Standard-Mode, Fast-Mode, and Fast Mode Plus I²C-bus devices in addition to SMBus devices. The maximum frequency is dependent on the RC time constant, but generally supports > 2MHz.

All channels have the same electrical characteristics and there is a minimum deviation from one output to another in voltage or propagation delay. This is a benefit over discrete transistor voltage translation solutions, since the fabrication of the switch is symmetrical. The translator provides excellent ESD protection to lower voltage devices and at the same time protects less-ESD resistant devices.

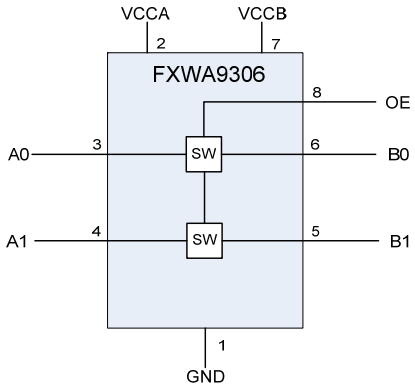


Figure 1. Block Diagram

Ordering Information

Part Number	Operating Temperature Range	Top Mark	Package	Packing Method
FXWA9306L8X	-40 to +85°C	LT	8-Lead, MicroPak™, 1.6mm Wide	5000 Units on Tape and Reel
FXWA9306MUX	-40 to +85°C	9306	8-Lead, MSOP Package, 3mm Wide	4000 Units on Tape and Reel

Pin Configuration

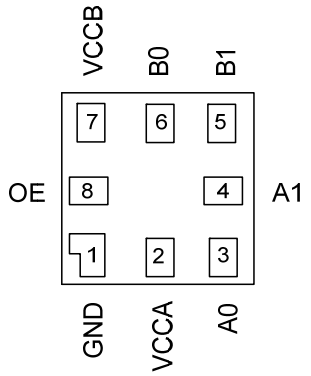


Figure 2. MicroPak™ (Top-Through View)

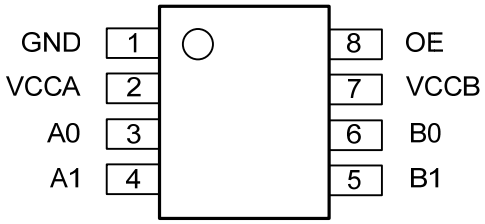


Figure 3. MSOP (Top-Through View)

Pin Definitions

Pin #	Name	Description
1	GND	Ground
2	V_{CCA}	Low Voltage A-Side Power Supply
3	A_0	A-Side Input or 3-State Output. Connect to V_{CCA} through a pull-up resistor.
4	A_1	A-Side Input or 3-State Output. Connect to V_{CCA} through a pull-up resistor.
5	B_1	B-Side Input or 3-State Output. Connect to V_{CCB} through a pull-up resistor.
6	B_0	B-Side Input or 3-State Output. Connect to V_{CCB} through a pull-up resistor.
7	V_{CCB}	High Voltage B-Side Power Supply
8	OE	Output Enable Input; connect to V_{CCB} and pull-up through a high resistor.

Truth Table

Control	Outputs
OE	
LOW Logic Level	3-State
HIGH Logic Level	Normal Operation; A0 = B0, A1 = B1

Note:
1. If the OE pin is driven LOW, the FXWA9306 is disabled and the A_0, A_1, B_0, and B_1 pins are forced into 3-state.
2. OE references V_{CCB} and the OE logic levels should be at least 1V higher than V_{CCA}, for best translator operation.

Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.

Symbol	Parameter		Min.	Max.	Units
V_{CCA}, V_{CCB}	Supply Voltage		–0.5	7.0	V
V_{IN}	DC Input Voltage	A Port	–0.5	7.0	V
		B Port	–0.5	7.0	
		Control Input (OE)	–0.5	7.0	
V_O	Output Voltage[3]	A_n Outputs 3-State	–0.5	7.0	V
		B_n Outputs 3-State	–0.5	7.0	
		A_n Outputs Active	–0.5	V_{CCA} + 0.5V	
		B_n Outputs Active	–0.5	V_{CCB} + 0.5V	
I_{CH}	DC Channel Current			90	mA
I_{IK}	DC Input Diode Current	At V_{IN} < 0V		–50	mA
I_{OK}	DC Output Diode Current	At V_O < 0V		–50	mA
		At V_O > V_{CC}		+50	
I_{OH} / I_{OL}	DC Output Source/Sink Current		–50	+50	mA
I_{CC}	DC V_{CC} or Ground Current per Supply Pin			±100	mA
T_{STG}	Storage Temperature Range		–65	+150	°C
$I_{LATCHUP}$	Latch-up Performance Above V_{CC} and below GND at 125°C			±100	mA
ESD	Electrostatic Discharge Capability	Human Body Model, JESD22-A114-A		> 4000	V
		Human Body Model, Pin to Pin, B Port[4]		> 8000	
		Charged Device Model, JESD22-A115-A		> 1000	

Notes:
3. I_O absolute maximum rating must be observed.
4. Test conditions: B0 and B1 vs. V_{CCB}, B0 and B1 vs. GND, V_{CCB} vs. GND

Recommended Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. ON Semiconductor does not recommend exceeding them or designing to Absolute Maximum Ratings.

Symbol	Parameter		Min.	Max.	Units
V_{CCA}	Power Supply Operating		1.0	5.5	V
V_{CCB}	Power Supply Operating		1.8	5.5	V
V_{IN}	Input Voltage	A Port	0	5.5	V
		B Port	0	5.5	
		Control Input (OE)	0	5.5	
Θ_{JA}	Thermal Resistance, Junction to Ambient			470	C°/W
$I_{SW(pass)}$	Pass Switch Current		0	64	mA
T_A	Free Air Operating Temperature		–40	+85	°C

Notes:
5. All unused inputs and I/O pins must be held at V_{CCI} or GND.
6. $V_{CCA} \leq V_{CCB}$ -1V for best results in level-shifting applications.

DC Electrical Characteristics

Unless otherwise noted, values are at T_A = –40°C to +85°C; all typical values are at T_A = 25°C.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
V_{IK}	Input Clamping Voltage	I_I = -18mA; $V_{I(OE)}$ = 0V				-1.2	V
I_{IH}	High-Level Input Current	V_I = 5V; $V_{I(OE)}$ = 0V				5	µA
$C_{i(OE)}$	OE Pin Input Capacitance	V_I = 3V or 0V			7.1		pF
$C_{i/O(off)}$	Off-State I/O Pin Capacitance A0, A1, B0, B1	V_O = 3V or 0V; $V_{I(OE)}$ = 0V			4	6	pF
$C_{i/O(on)}$	On-State I/O Pin Capacitance A0, A1, B0, B1	V_O = 3V or 0V; $V_{I(OE)}$ = 3V			9.3	12.5	pF
R_{ON}(7)	On-State Resistance A0/B0, A1/B1	V_I = 0V; I_O = 64mA	$V_{I(OE)}$ = 4.5V		2.4	5.0	Ω
			$V_{I(OE)}$ = 3V		3.0	6.0	
			$V_{I(OE)}$ = 2.3V		3.8	8.0	
			$V_{I(OE)}$ = 1.5V		9.0	20.0	
V_{OL}	Voltage Output Low	V_{CCA} = 1V, V_{PUD} = 5V, I_{OL} = 3mA (B->A Dir)	V_{IN} (B0 or B1) = 0.1V			0.15	V
			V_{IN} (B0 or B1) = 0.2V			0.25	
			V_{IN} (B0 or B1) = 0.3V			0.35	
			V_{IN} (B0 or B1) = 0.4V			0.45	

Notes:

7. Measured by the voltage drop between the A0 and B0 or A1 and B1 terminals at the indicated current through the switch. On-state resistance is determined by the lowest voltage of the two terminals.

AC Electrical Characteristics

T_A = –40°C to +85°C. Direction is from B port to A port (translating down). Values guaranteed by design.

Symbol	Parameter	Conditions	Load Condition:	Min:	Max.	Units
t_{PLH}	Low-to-High Propagation Delay, from (Input) B0 or B1 to (Output) A0 or A1	$V_{I(OE)}$ = 3.3V; V_{IH} = 3.3V; V_{IL} = 0V; V_M = 1.15V; V_{CCA} = 2.3V	C_L = 15pF	0	0.60	ns
			C_L = 30pF	0	1.20	
			C_L = 50pF	0	2.00	
t_{PHL}	High-to-Low Propagation Delay, from (Input) B0 or B1 to (Output) A0 or A1		C_L = 15pF	0	0.75	ns
			C_L = 30pF	0	1.50	
			C_L = 50pF	0	2.00	
t_{PLH}	Low-to-High Propagation Delay, from (Input) B0 or B1 to (Output) A0 or A1	$V_{I(OE)}$ = 2.5V; V_{IH} = 2.5V; V_{IL} = 0V; V_M = 0.75V; V_{CCA} = 1.5V	C_L = 15pF	0	0.60	ns
			C_L = 30pF	0	1.20	
			C_L = 50pF	0	2.00	
t_{PHL}	High-to-Low Propagation Delay, from (Input) B0 or B1 to (Output) A0 or A1		C_L = 15pF	0	0.75	ns
			C_L = 30pF	0	1.50	
			C_L = 50pF	0	2.00	
t_{PLH}	Low-to-High Propagation Delay, from (Input) A0 or A1 to (Output) B0 or B1	$V_{I(OE)}$ = 3.3V; V_{IH} = 2.3V; V_{IL} = 0V; V_{TT} = 3.3V; V_M = 1.15V; V_{CCA} = 2.3V; R_L = 300Ω	C_L = 15pF	0	0.50	ns
			C_L = 30pF	0	1.00	
			C_L = 50pF	0	1.75	
t_{PHL}	High-to-Low Propagation Delay, from (Input) A0 or A1 to (Output) B0 or B1		C_L = 15pF	0	0.80	ns
			C_L = 30pF	0	1.65	
			C_L = 50pF	0	2.75	
t_{PLH}	Low-to-High Propagation Delay, from (Input) A0 or A1 to (Output) B0 or B1	$V_{I(OE)}$ = 2.5V; V_{IH} = 1.5V; V_{IL} = 0V; V_{TT} = 2.5V; V_M = 0.75V; V_{CCA} = 1.5V; R_L = 300Ω	C_L = 15pF	0	0.50	ns
			C_L = 30pF	0	1.00	
			C_L = 50pF	0	1.75	
t_{PHL}	High-to-Low Propagation Delay, from (Input) A0 or A1 to (Output) B0 or B1		C_L = 15pF	0	1.00	ns
			C_L = 30pF	0	2.00	
			C_L = 50pF	0	3.30	

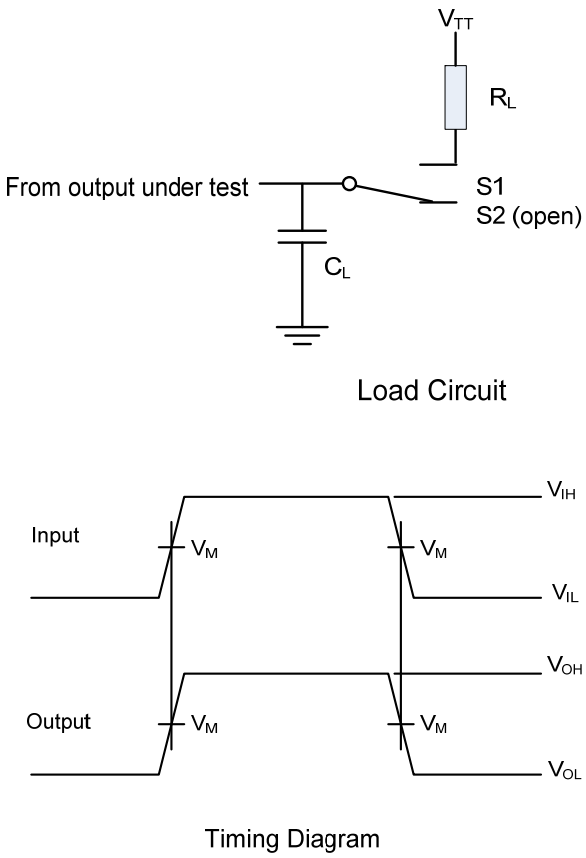


Figure 4. Load Circuit

Notes:

8. S1 = translating up (A-to-B direction), S2 = translating down (B-to-A direction).
9. C_L includes probe and jig capacitance.
10. All input pulses are supplied by generators having the following characteristics: PRR $\leq$ 10MHz; Z_O = 50Ω; $t_r \leq$ 2ns; $t_f \leq$ 2ns.
11. The outputs are measured one at a time, with one transmission per measurement.

Application Information

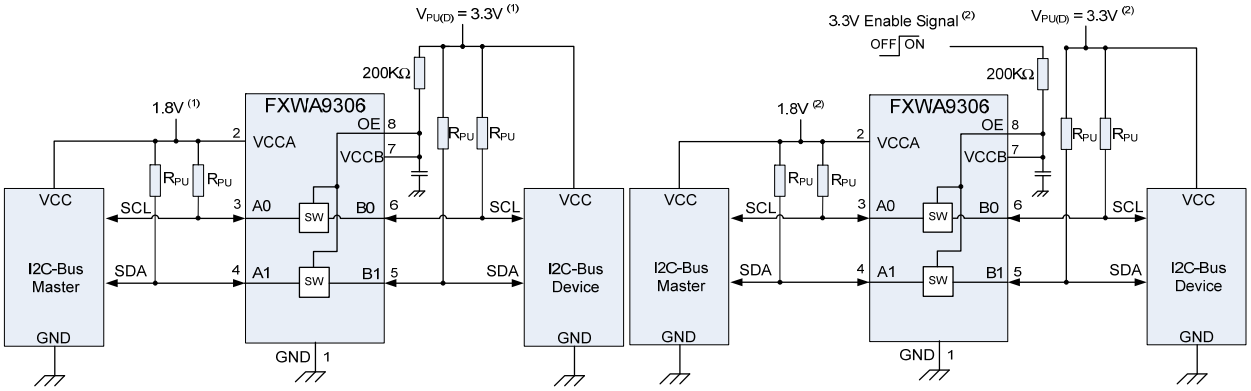


Figure 5. Application (Switch Always Enabled) **Figure 6. Application (Switch Enable Control)**

Note:

12. The applied voltages at V_{CCA} and $V_{PU(D)}$ should be such that V_{CCB} is at least 1V higher than V_{CCA} for best translator operation.

Bi-directional Translation

For the bi-directional clamping configuration (higher voltage to lower voltage or lower voltage to higher voltage), the OE input must be connected to V_{CCB} and both pins pulled to HIGH side $V_{PU(D)}$ through a pull-up resistor (typically 200kΩ). This allows V_{CCB} to regulate the OE input. A filter capacitor on V_{CCB} is recommended. The I²C-bus master output can be totem-pole or open-drain (pull-up resistors may be required) and the I²C-bus device output can be totem-pole or open-drain (pull-up resistors are required to pull the B0 and B1 outputs to $V_{PU(D)}$). However, if either output is totem-pole, data must be uni-directional or the outputs must be 3-stateable and be controlled by some direction-controlled mechanism to prevent HIGH-to-LOW contentions in either direction. If both outputs are open-drain, no direction control is needed.

The reference supply voltage (V_{CCA}) is connected to the processor core power supply voltage. When V_{CCB} is connected through a 200kΩ resistor to a 3.3V - 5.5V $V_{PU(D)}$ power supply, and V_{CCA} is set between 1.0V and ($V_{PU(D)}$ – 1V), the output of each A0 and A1 has a maximum output voltage equal to V_{CCA} and the output of each B0 and B1 has a maximum output voltage equal to $V_{PU(D)}$.

Table 1. Application Operating Conditions *(refer to Figure 6)*

All typical values are at T_A = 25°C.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$V_{BIAS}(V_{CCB})$	Reference Bias Voltage		V_{CCA} + 0.6	2.1	5.0	V
$V_{I(OE)}$	OE Pin Input Voltage		V_{CCA} + 0.6	2.1	5.0	V
V_{CCA}	Reference Voltage		0	1.5	4.4	V
$I_{SW(pass)}$	Pass Switch Current			14		mA
I_{REF}	Reference Current	Transistor		5		µA
T_A	Ambient Temperature	Operating in Free Air	-40		+85	^{0}C

Sizing Pull-Up Resistor

The pull-up resistor value needs to limit the current through the pass transistor when it is in the on state to about 15mA. This ensures a pass voltage of 260mV to 350mV. If the current through the pass transistor is higher than 15mA, the pass voltage is higher in the on state. To set the current through each pass transistor at 15mA, the pull-up resistor value is calculated as:

$$R_{PU} = \frac{V_{PU}(D) - 0.35V}{0.015A} \quad (1)$$

Table 2 summarizes the resistor reference voltages and currents at 15mA, 10mA, and 3mA. The resistor values shown in the +10% column or a larger value should be used to ensure that the pass voltage of the transistor would be 350mV or less. The external driver must be able to sink the total current from the resistors on both sides of the of the FXWA9306 device at 0.175V, although the 15mA only applies to the current flowing through the FXWA9306 device.

Table 2. Application Operating Conditions

Calculated for V_{OL} = 0.35V; assumes output driver V_{OL} = 0.175V at stated current.

$V_{PU(D)}$	Pull-Up Resistor Value (Ω)					
	15mA		10mA		3mA	
	Nominal	+10%[13]	Nominal	+10%[13]	Nominal	+10%[13]
5.0V	310	341	465	512	1550	1705
3.3V	197	217	295	325	983	1082
2.5V	143	158	215	237	717	788
1.8V	97	106	145	160	483	532
1.5V	77	85	115	127	383	422
1.2V	57	63	85	94	283	312

Note:
13. +10% to compensate for V_{CC} range and resistor tolerance.

Maximum Frequency Calculation

The maximum frequency is totally dependent upon the specifics of the application. The FXWA9306 behaves like a wire with the additional characteristics of transistor device physics and should be capable of performing at higher frequencies if used correctly.

Here are some guidelines to follow that help maximize the performance of the device:

- Keep trace lengths to a minimum by placing the FXWA9306 close to the processor.
- The trace length should be less than half the time of flight to reduce ringing and reflections.
- The faster the edge of the signal, the higher the chance of ringing.
- The greater the drive strength (up to 15mA), the higher the frequency the device can use.

In a 3.3V to 1.8V direction level shift, if the 3.3V side is being driven by a totem-pole type driver; no pull-up resistor is needed on the 3V side. The capacitance and line length of concern is on the 1.8V side because it is driven through the on resistance of the FXWA9306. If the line length on the 1.8V side is long enough, there can be a reflection at the chip / terminating end of the wire when the transition time is shorter than the time of flight of the wire. This is because the FXWA9306 looks like a high-impedance path compared to the wire. If the wire is too long and the lumped capacitance is not excessive, the signal is only slightly degraded by the series resistance added by passing through the FXWA9306. If the lumped capacitance is large, the rise time deteriorates. The fall time is much less affected and if the rise time is slowed down too much, the duty cycle of the clock is degraded and, at some point, the clock is no longer useful. So, the principle design consideration is to minimize the wire length and the capacitance on the 1.8V side for the clock path. A pull-up resistor on the 1.8V side can be used to trade a slower fall time for a faster rise time and can also reduce overshoot in some cases.

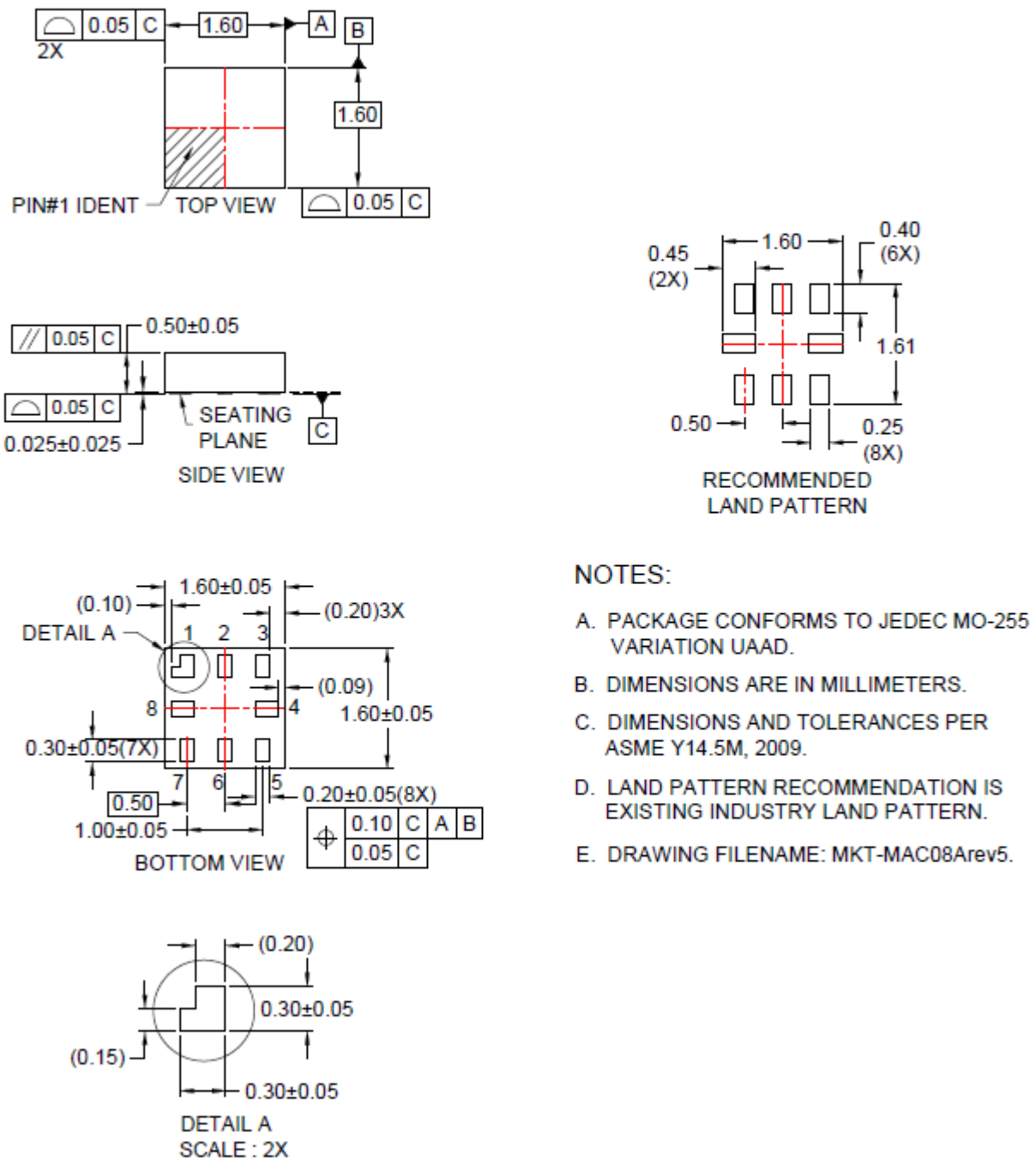
Additional Note

The FXWA9306 is not a bus buffer that provides both level translation and physical capacitance isolation to either side of the bus when both sides are connected. The FXWA9306 only isolates the sides when the device is disabled and provides level translation when active.

The FXWA9306 can be used to run two buses: one at 400kHz operating frequency and the other at 100kHz operating frequency. If the two buses are operating at different frequencies, the 100kHz bus must be isolated when the 400kHz operation of the bus is required. If the master is running at 400kHz, the maximum system operating frequency may be less than 400kHz because of the delays added to the translator.

When the A1 or B1 port is LOW, the clamp is in the ON-state and a low-resistance connection exists between the A1 and B1 ports. Assuming the higher voltage is on the B1 port, when the B1 port is HIGH, the voltage on the A1 port is limited by the voltage set by V_{CCA}. When the A1 port is HIGH, the B1 port is pulled to the drain pull-up supply voltage ($V_{PU(D)}$) by the pull-up resistors. This functionality allows a seamless translation between higher and lower voltages selected by the user without the need for directional control. The A0/B0 channel also functions as the A1/B1 channel.

Physical Dimensions



NOTES:

A. PACKAGE CONFORMS TO JEDEC MO-255 VARIATION UAAD.

B. DIMENSIONS ARE IN MILLIMETERS.

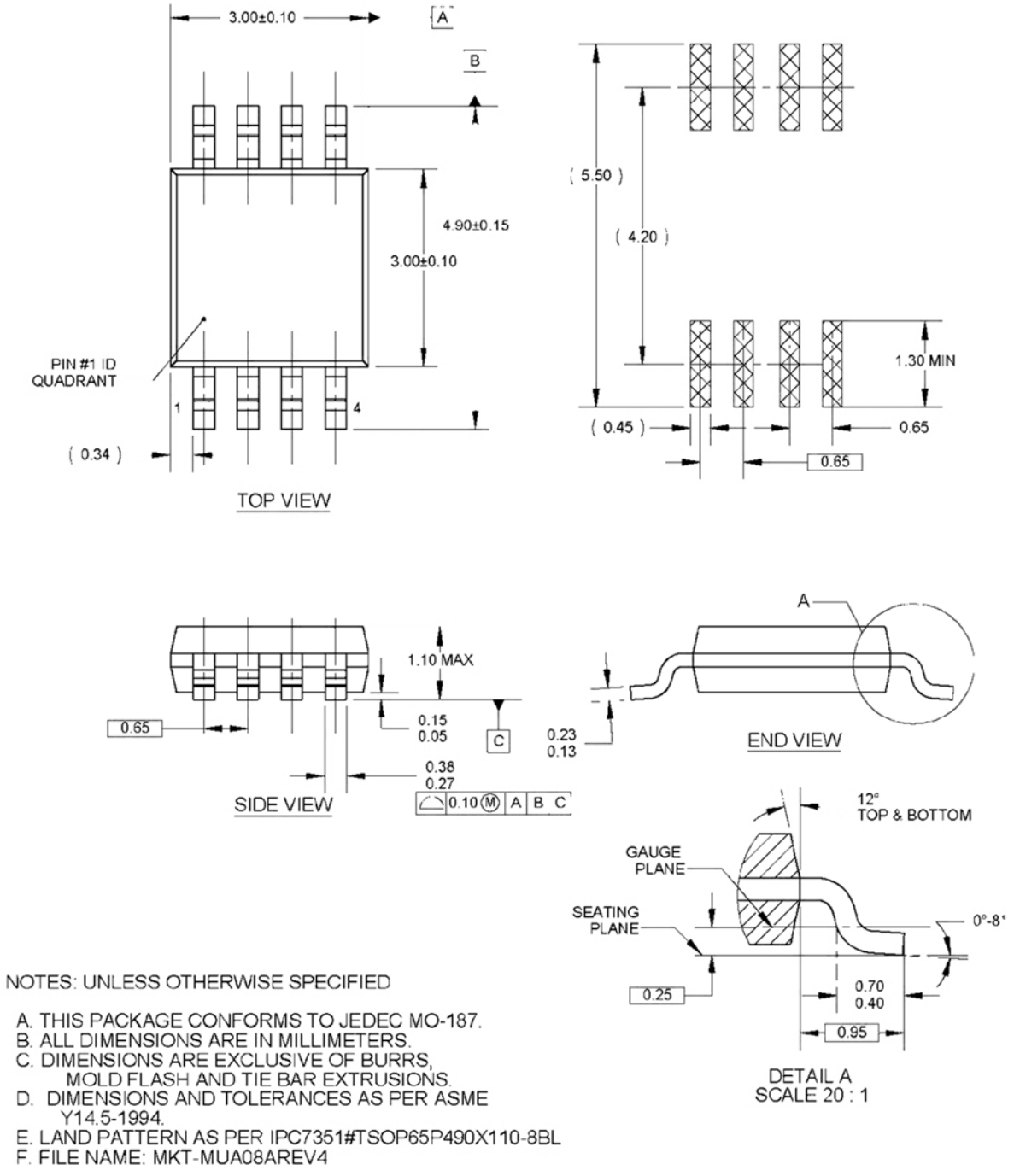
C. DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 2009.

D. LAND PATTERN RECOMMENDATION IS EXISTING INDUSTRY LAND PATTERN.

E. DRAWING FILENAME: MKT-MAC08Arev5.

Figure 7. 8-Lead MicroPak™, 1.6mm Wide

Physical Dimensions



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C. DIMENSIONS ARE EXCLUSIVE OF BURRS, MOLD FLASH AND TIE BAR EXTRUSIONS.
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E. LAND PATTERN AS PER IPC7351#TSOP65P490X110-8BL
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Figure 8. 8-Lead MSOP, 3.0mm Wide

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