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HART Modem

HT2015

DataSheet

Features

- Can be used in designs presently using the SYM20C15 or equivalent type chip
- Single-chip, half-duplex 1200 bits per second FSK modem
- Bell 202 shift frequencies of 1200 Hz and 2200 Hz
- 3.3V-5.0V power supply
- Transmit-signal wave shaping
- Receive band-pass filter
- Low power: optimal for intrinsically safe applications
- CMOS compatible
- Internal oscillator requires 460.8 kHz crystal or ceramic resonator
- Meets HART physical layer requirements
- Industrial temperature range of -40 °C to +85 °C
- Available in a 28-pin PLCC and 32-pin LQFP packages
  (LQFP pictured)

General Description

The HT2015 is a single-chip, CMOS modem for use in Highway Addressable Remote Transducer (HART) field instruments and masters. The modem and a few external passive components provide all of the functions needed to satisfy HART physical layer requirements including modulation, demodulation, receive filtering, carrier detect and transmit-signal shaping. The HT2015 is pin-compatible with the SYM20C15. See the Pin Description and Functional Description sections for details on pin compatibility with the SYM20C15.

The HT2015 uses Phase Continuous Frequency Shift Keying (FSK) at 1200 bits per second. To conserve power the receive circuits are disabled during transmit operations and vice versa. This provides the half-duplex operation used in HART communications.

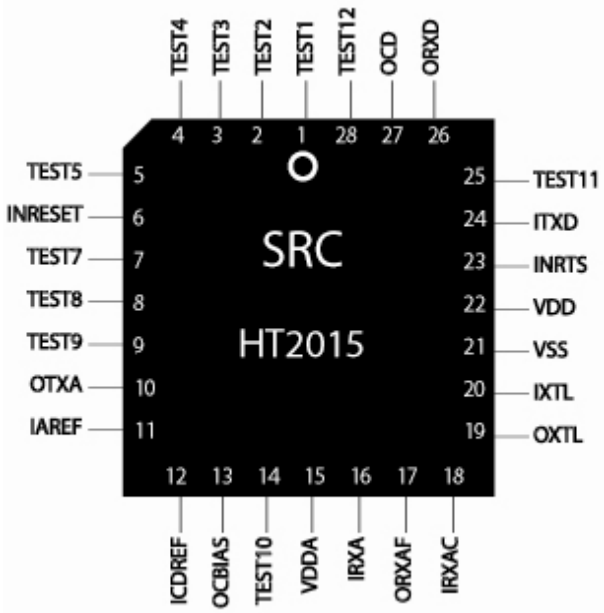

Fig. 1 - 28 pin PLCC Pinout Package

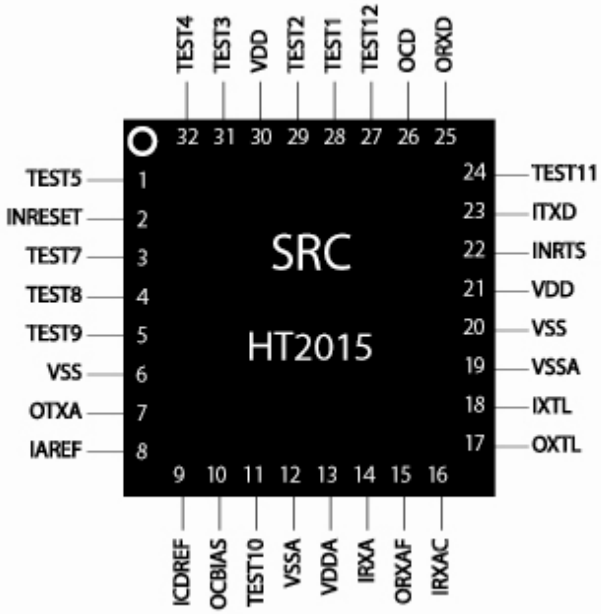

Fig. 2 - 32 pin LQFP Pinout Package

Table 1 - Pin Descriptions

Signal	Type	PLCC	LQFP	Description
TEST1	Input	1	28	Connect to Vss.
TEST2	*	2	29	No connect.
TEST3	*	3	31	No connect.
TEST4	*	4	32	No connect.
TEST5	Input	5	1	Connect to Vss.
INRESET	Input	6	2	Reset all digital logic when low.
TEST7	Input	7	3	Connect to Vss.
TEST8	Input	8	4	Connect to Vss.
TEST9	Input	9	5	Connect to Vss.
OTXA	Output	10	7	Modulated output transmit analog. FSK modulated HART transmit signal to 4-20mA loop interface circuit.
IAREF	Input	11	8	Analog reference voltage.
ICDREF	Input	12	9	Carrier detect reference voltage.
OCBIAS	Output	13	10	Comparator bias current.
TEST10	Input	14	11	Connect to Vss.
VDDA	Power	15	13	Analog supply voltage.
IRXA	Input	16	14	FSK modulated HART receive signal from 4-20mA loop interface circuit. .
ORXAF	Output	17	15	Analog receiver filter input.
IRXAC	Input	18	16	Analog receive comparator input.
OXTL	Output	19	17	Crystal oscillator output.
IXTL	Input	20	18	Crystal oscillator input.
VSS	Ground	21	6,20	Ground.
VDD	Power	22	21,30	Digital supply voltage.
INRTS	Input	23	22	Request to send.
ITXD	Input	24	23	Input transmit data. Transmitted HART data stream from UART.
TEST11	*	25	24	No connect.
ORXD	Output	26	25	Received demodulated HART data to UART.
OCD	Output	27	26	Carrier detect output.
TEST12	*	28	27	No connect.
VSSA	Ground	*	12,19	Analog ground.

Pin Descriptions:

IAREF: Analog Reference Voltage
This analog input sets the dc operating point of the operational amplifiers and comparators and is usually selected to split the dc potential between V_{DD} and V_{SS}. See IAREF in DC Characteristics on page 11.

ICDREF: Carrier Detect Reference Voltage
This analog input controls at which level the carrier detect (OCD) becomes active. This is determined by the dc voltage difference between ICDREF and IAREF. Selecting ICDREF - IAREF equal to 0.08 V_{DC} will set the carrier detect to a nominal 100 mV_{p-p}.

INRESET: Reset Digital Logic
When at logic low (V_{SS}) this input holds all the digital logic in Reset. During normal operation INRESET should be at V_{DD}. INRESET should be held low for a minimum of 10 nS after V_{DD} = 2.5 V as shown in Figure 3.

INRTS: Request To Send
This active-low input selects the operation of the modulator. OTXA is enabled when this signal is low. This signal must be held high during power-up.

IRXA*: Analog Receive Input
This input accepts the 1200/2200 Hz signals from the external filter.

IRXAC: Analog Receive Comparator Input
This is the positive input of the carrier detect comparator and the receiver filter comparator.

ITXD: Digital Transmit Input (CMOS)
This input to the modulator accepts digital data in NRZ form. When ITXD is low, the modulator output frequency is 2200 Hz. When ITXD is high, the modulator output frequency is 1200 Hz.

IXTL: Oscillator Input
This input to the internal oscillator must be connected to a parallel mode 460.8 kHz ceramic resonator when using the internal oscillator or grounded when using an external 460.8 kHz clock signal.

OCBIAS: Comparator Bias Current
The current through this output controls the operating parameters of the internal operational amplifiers and comparators. For normal operation, OCBIAS current is set to 2.5 4A.

OCD: Carrier Detect Output
This output goes high when a valid input is recognized on IRXA. If the received signal is greater than the threshold specified on ICDREF for four cycles of the IRXA signal, the valid input is recognized.

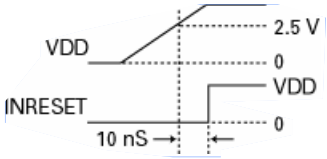

Figure 3 - Reset Timing

ORXAF*: Analog Receive Filter Output
This signal is the square wave output of the receiver high-pass filter.

ORXD: Digital Receive Output (CMOS)
This signal outputs the digital receive data. When the received signal (IRXA) is 1200 Hz, ORXD outputs logic high. When the received signal (IRXA) is 2200 Hz, ORXD outputs logic low. ORXD is qualified internally with OCD and is logic high when OCD is low.

OTXA: Analog Transmit Output
This output provides the trapezoidal signal controlled by ITXD. When ITXD is low, the output frequency is 2200 Hz. When ITXD is high, the output frequency is 1200 Hz. This output is active when INRTS is low and 0.5 V_{DC} when INRTS is high.

OXTL: Oscillator Output
This output from the internal oscillator must be connected to an external 460.8 kHz clock signal or to a parallel mode 460.8 kHz ceramic resonator when using the internal oscillator.

TEST(12:1): Factory Test
These are factory test pins. For normal operation, tie these signals as per Table 1.

VDD: Digital Power
This is the power for the digital modem circuitry.

VDDA: Analog Supply Voltage
This is the power for the analog modem circuitry.

VSS: Ground
This is the analog and digital ground.

VSSA: Analog Ground

Functional Description

The HT2015 is a functional equivalent of the SYM20C15 HART Modem. It contains a transmit data modulator and signal shaper, carrier detect circuitry, analog receiver and demodulator circuitry and an oscillator, as shown in Figure 4.

The internal HART modem modulates the transmit-signal and demodulates the receive signal. The transmit-signal shaper enables the HT2015 to transmit a HART compliant signal. The carrier is detected by comparing the receiver filter output with the difference between two external voltage references. The analog receive circuitry band-pass filters the received signal for input to the modem and the carrier detect circuitry. The oscillator provides the modem with a stable time base using either a simple external resonator or an external clock source.

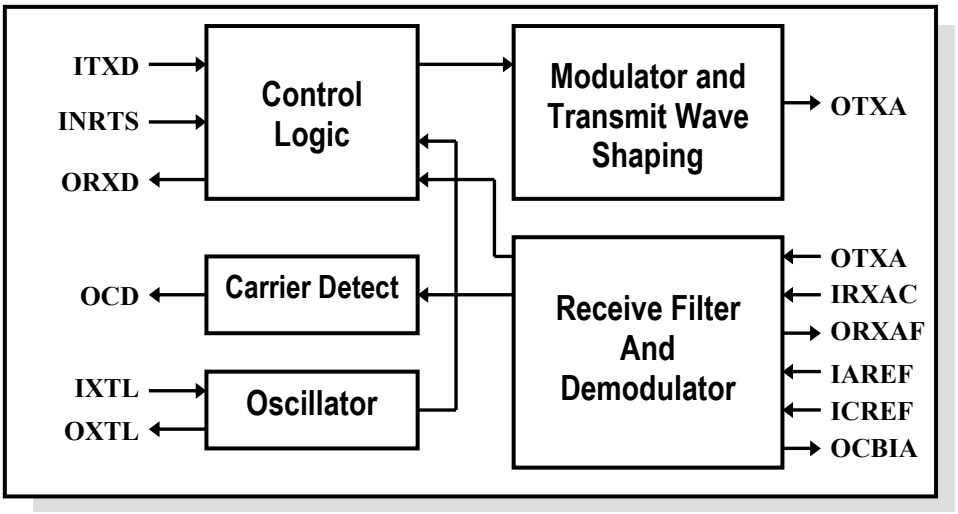

Figure 4 - HT2015 Block Diagram

HT2015 LOGIC

The modem consists of a modulator and demodulator. The modem uses shift frequencies of nominally 1200 Hz (for a 1) and 2200 Hz (for a 0). The bit rate is 1200 bits/second.

Modulator

The modulator accepts digital data in NRZ form at the ITXD input and generates the FSK modulated signal at the OTXA output. INRTS must be a logic low for the modulator to be active.

Demodulator

The demodulator accepts an FSK signal at the IRXA input and reproduces the original modulating signal at the ORXD output. The nominal bit rate is 1200 bits per second. Figure 5 illustrates the demodulation process.

The output of the demodulator is qualified with the carrier detect signal (OCD), therefore, only IRXA signals large enough to be detected (100 mVp-p typically) by the carrier detect circuit produce received serial data at ORXD.

Maximum demodulator jitter is 12 percent of one bit given input frequencies within HART specifications, a clock frequency of 460.8 kHz (±1.0 percent) and zero input (IRXA) asymmetry.

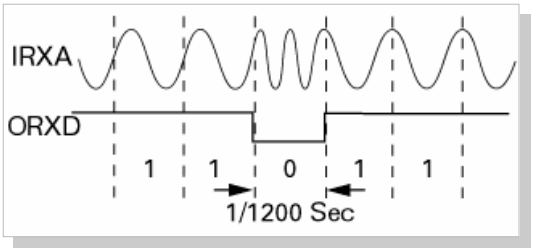

Figure 5: *Demodulator Signal Timing*

TRANSMIT–SIGNAL SHAPER

The transmit-signal shaper generates a HART compliant FSK modulated signal at OTXA. Figure 6 and Figure 7 show the transmit-signal forms of the HT2015.

For IAREF = 1.235 V_{DC}, OTXA will have a voltage swing from approximately 0.25 to 0.75 V_{DC}.

CARRIER DETECT CIRCUITRY

The Carrier Detect Comparator shown in Figure 8 below generates logic low output if the IRXAC voltage is below ICDREF. The comparator output is fed into a carrier detect block (see Figure 4 on page 5). The carrier detect block drives the carrier detect output pin OCD high if INRTS is high and four consecutive pulses out of the comparator have arrived. OCD stays high as long as INRTS is high and the next comparator pulse is received in less than 2.5 ms. Once OCD goes inactive, it takes four consecutive pulses out of the comparator to assert OCD again. Four consecutive pulses amount to 3.33 ms when the received signal is 1200 Hz and to 1.82 ms when the received signal is 2200 HZ.

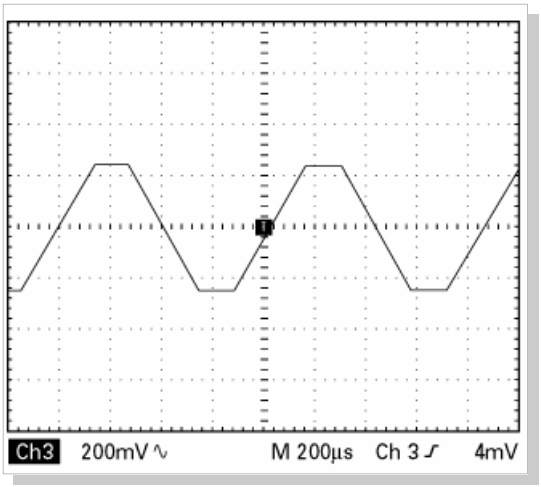

Figure 6 - *OTXA Waveform (1200 Hz)*

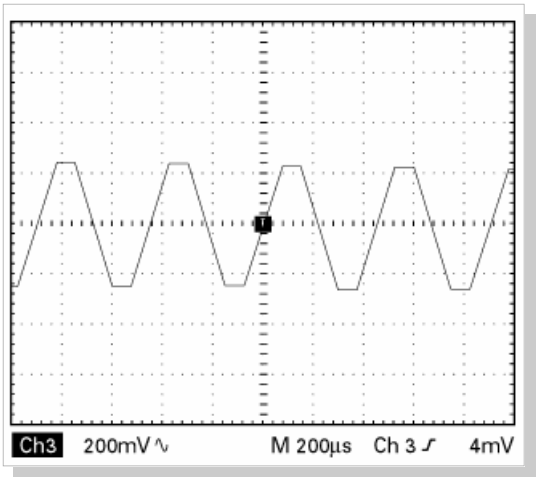

Figure 7 - *OTXA Waveform (2200 Hz)*

ANALOG RECEIVER CIRCUITRY

Voltage References

The HT2015 requires two voltage references, IAREF and ICDREF.

IAREF sets the dc operating point of the internal operational amplifiers and comparators. A 1.235 V_{DC} reference (Analog Devices AD589) is suitable as IAREF.

The level at which OCD (carrier detect) becomes active is determined by the dc voltage difference (ICDREF - IAREF). Selecting a voltage difference of 0.08 V_{DC} will set the carrier detect to a nominal 100 mV_{p-p}.

Bias Current Resistor

The HT2015 requires a bias current resistor to be connected between OCBIAS and V_{SS}. The bias current controls the operating parameters of the internal operational amplifiers and comparators.

The value of the bias current resistor is determined by the reference voltage IAREF and the following formula:

$$R_{BIAS} = \left(\frac{IAREF}{2.5\,\mu A} \right)$$

The recommended bias current resistor is 500 ohm; when IAREF is equal to 1.235 V_{DC}.

In Figure 8 all external capacitor values have a tolerance of ±5 percent and the resistors have a tolerance of ±1 percent, except the 3 ohm; which has a tolerance of ±5 percent. External to the HT2015, the filter exhibits a three-pole, high-pass filter at 624 Hz and a one-pole, low-pass filter at 2500 Hz. Internally, the HT2015 has a high-pass pole at 35 Hz and a low-pass pole at 90 kHz. The low-pass pole can vary as much as ±30 percent. The input impedance of the entire filter is greater than 150 ohm; at frequencies below 50 kHz.

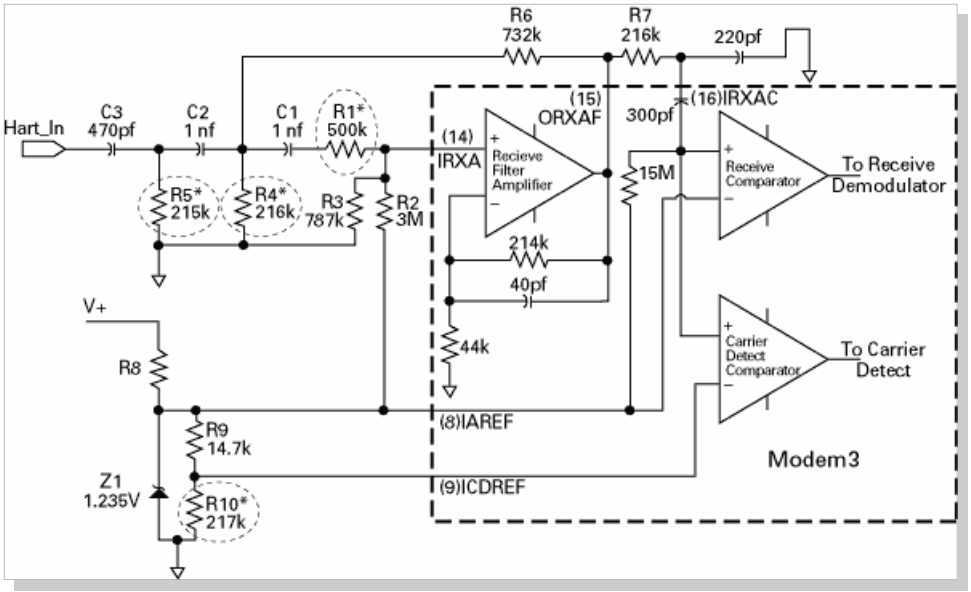

Figure 8 - *Receive Filter Schematic*

OSCILLATOR

The HT2015 requires a 460.8 kHz clock signal on OXTL. This can be provided by an external clock or external components may be connected to the HT2015 internal oscillator.

Internal Oscillator Option

The oscillator cell will function with either a 460.8 kHz crystal or ceramic resonator. A parallel resonant ceramic resonator can be connected between OXTL and IXTL. Figure 9 illustrates the crystal option for clock generation using a 460.8 kHz (±l percent tolerance) parallel resonant crystal and two tuning capacitors. The actual values of the capacitors may depend on the recommendations of the manufacturer of the resonator. Typically, capacitors in the range of 100 pF to 470 pF are used.

External Clock Option

It may be desirable to use an external 460.8 kHz clock as shown in Figure 10 rather than the internal oscillator because of the high cost and low availability of ceramic resonators. In addition, the HT2015 consumes less current when an external clock is used. Minimum current consumption occurs with the clock connected to OXTL and IXTL connected to V_{SS}.

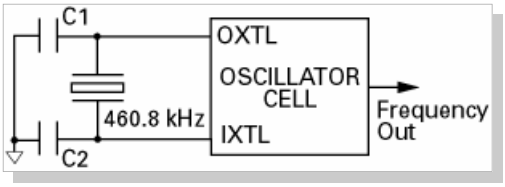

Figure 9 - *Crystal Oscillator*

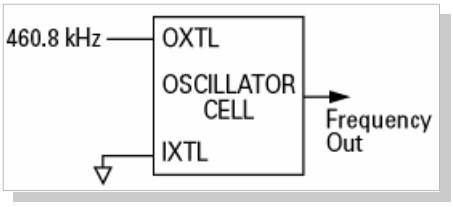

Figure 10 - *Oscillator with External Clock*

Electrical Characteristics

ABSOLUTE MAXIMUMS				
Symbol	**Parameter**	**Min.**	**Max.**	**Units**
T_A	Ambient	-40	+85	C
T_S	Storage Temperature	-55	150	C
V_{DD}	Supply Voltage	- .3	6.0	V
V_{IN}, V_{OUT}	DC Input, Output	- .3	V_{DD} + .3	V
T_L	Lead Temperature (soldering)		250	C

Cautions:
1. CMOS devices are damaged by high-energy electrostatic discharge. Devices must be stored in conductive foam or with all pins shunted. Precautions should be taken to avoid application of voltages higher than the maximum rating. Stresses above absolute maximum ratings may result in damage to the device.
2. Remove power before insertion or removal of this device.

DC CHARACTERISTICS (V_{DD} = 3.0V to 5.5V, V_{SS} = 0V, T_A = -40C to +85C)						
Symbol	**Parameter**	**V_{DD}**	**Min.**	**Typical**	**Max.**	**Units**
V_{IL}	Input Voltage, Low	3.0 - 5.5			.3 * V_{DD}	V
V_{IH}	Input Voltage	3.0 - 5.5	.7 * V_{DD}			V
V_{OL}	Output Voltage, Low (IOL = .67mA)	3.0 - 5.5			.4	V
V_{OH}	Output Voltage, High (IOH = .67mA)	3.0 - 5.5	2.4			V
C_{IN}	Input Capacitance Analog Input IRXA Digital Input			2.9 25 3.5		pF
$I_{IL/IH}$	Input Leakage Current				+/-500	nA
I_{OLL}	Output Leakage Current				+/-10	µA
I_{DD}	Power Supply Current (RBIAS = 500kΩ, IAREF = 1.235V)	3.3 5.0		150 170	180 200	µA
IAREF	Analog Reference	3.3 5.0	1.2	1.235 2.5	2.6	V
ICDREF *	Carrier Detect Reference (IAREF = .08V)			1.15		V
OCBIAS	Comparator Bias Current (RBIAS = 500kΩ, IAREF = 1.235V)			2.5		µA

* The HART specification requires Carrier Detect (OCD) to be active between 80 and 120 mV p-p. Setting ICDREF at IAREF—.08V_{DC} will set the carrier detect to a nominal 100 mV p-p.

AC CHARACTERISTICS
(V_{DD} = 3.0V to 5.5V, V_{SS} = 0V, T_A = -40C to +85C)

Pin Name	Description	Min.	Typical	Max.	Units
IRXA	Receive Analog Input Leakage Current Frequency - Mark (Logic 1) Frequency - Space (Logic 0)	 1190 2180	 1200 2200	 +/-150 1210 2220	 nA Hz Hz
ORXAF	Output of the High-pass Filter Slew Rate Gain Bandwidth (GBW) Voltage Range	 150 .15	 .025 	 V_{DD} - .15	 V/µs kHz V/µs
IRXAC	Carrier Detect & Receive Filter Input Leakage Current			 +/-500	 nA
OTXA	Modulator Output Frequency * - Mark (Logic 1) Frequency - Space (Logic 0) Amplitude (IAREF 1.235 V) Slope Loading (IAREF = 1.235 V)	 30	 1196.9 2194.3 500 2.79 	 	 Hz Hz mV p-p mV/µs kΩ
ORXD	Receive Digital Output Rise/Fall Time	 20			ns
OCD	Carrier Detect Output Rise/Fall Time	 20			ns

* The modular output frequencies are proportional to the input clock frequency (460.8 kHz)

MODEM CHARACTERISTIC
(V_{DD} = 3.0V to 5.5V, V_{SS} = OV, T_A = -40 C to +85 C)

Parameter	Min.	Typical	Max	Units
Demodulator Jitter Conditions 1. Input frequencies at 1200 Hz +/-10 Hz, 2200 Hz +/-20 Hz 2. Clock frequency of 460.8 kHz +/-0.1% 3. Input (HLXA) asymmetry, 0			12	% of 1 bit

CERAMIC RESONATOR - EXTERNAL CLOCK SPECIFICATIONS
(V_{DD} = 3.0V to 5.5V, V_{SS} = OV, T_A = -40 C to +85 C)

Parameter	Min.	Typical	Max	Units
Resonator Tolerance Frequency	 460.8	 	 1.0	 % kHz
External Clock Frequency Duty Cycle Amplitude	 456.2 40	 460.8 50 V_{OH} - V_{OL}	 465.4 60	 kHz % V

Symbol	Min	Nom	Max
A	.165	.172	.180
A1	.099	.101	.110
D	.485	.490	.495
D1	.450	.452	.455
D2	.390	.420	.430
D3		.300 REF	
E	.485	.490	.495
E1	.450	.452	.455
E2	.390	.420	.430
E3		.300 REF	
e		.050 BSC	

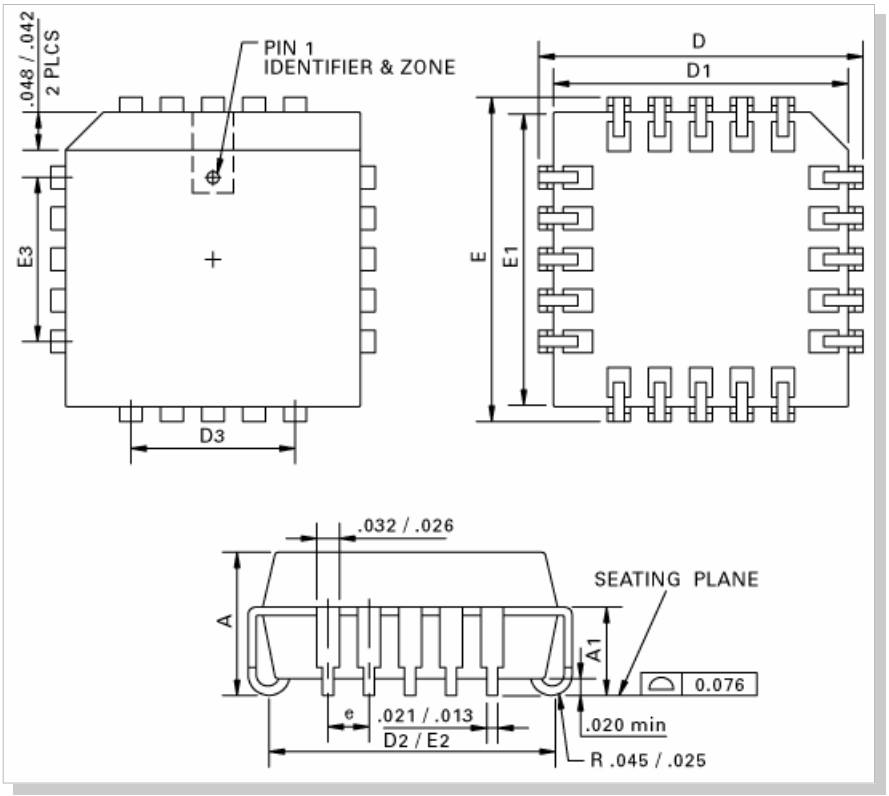

Figure 11 - 28-pin PLCC Mechanical Specification

Symbol	Min	Nom	Max
A	-	-	1.60
A1	.05	.01	.15
A2	1.35	1.40	1.45
D		9.00 BSC	
D/2		4.50 BSC	
D1		7.00 BSC	
E		9.00 BSC	
E/2		4.50 BSC	
E1		7.00 BSC	
L	.45	.60	.75
e		.80 BSC	
b	.30	.37	.45
c	.09	-	.20
ccc	-	-	.10
ddd	-	-	.20

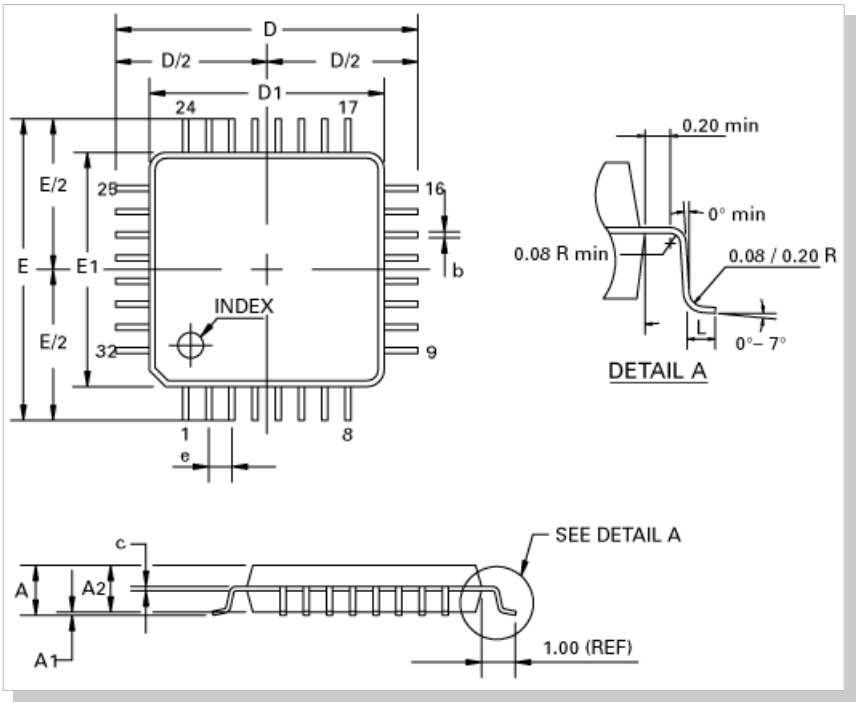

Figure 12 - 32-pin LQFP Mechanical Specification

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