Electrical Hardware Overview

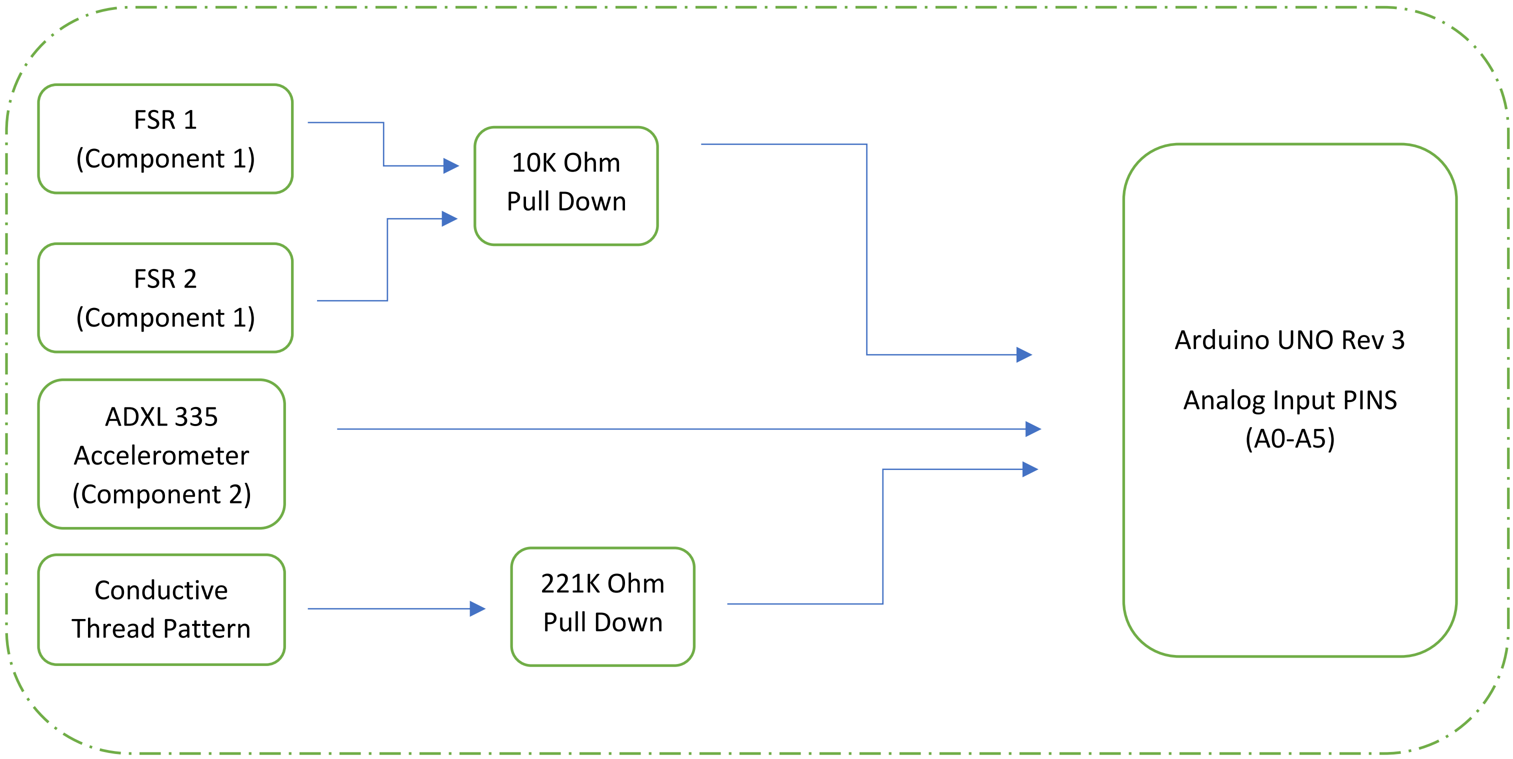
Smart Sleep Tracking Mattress for Children

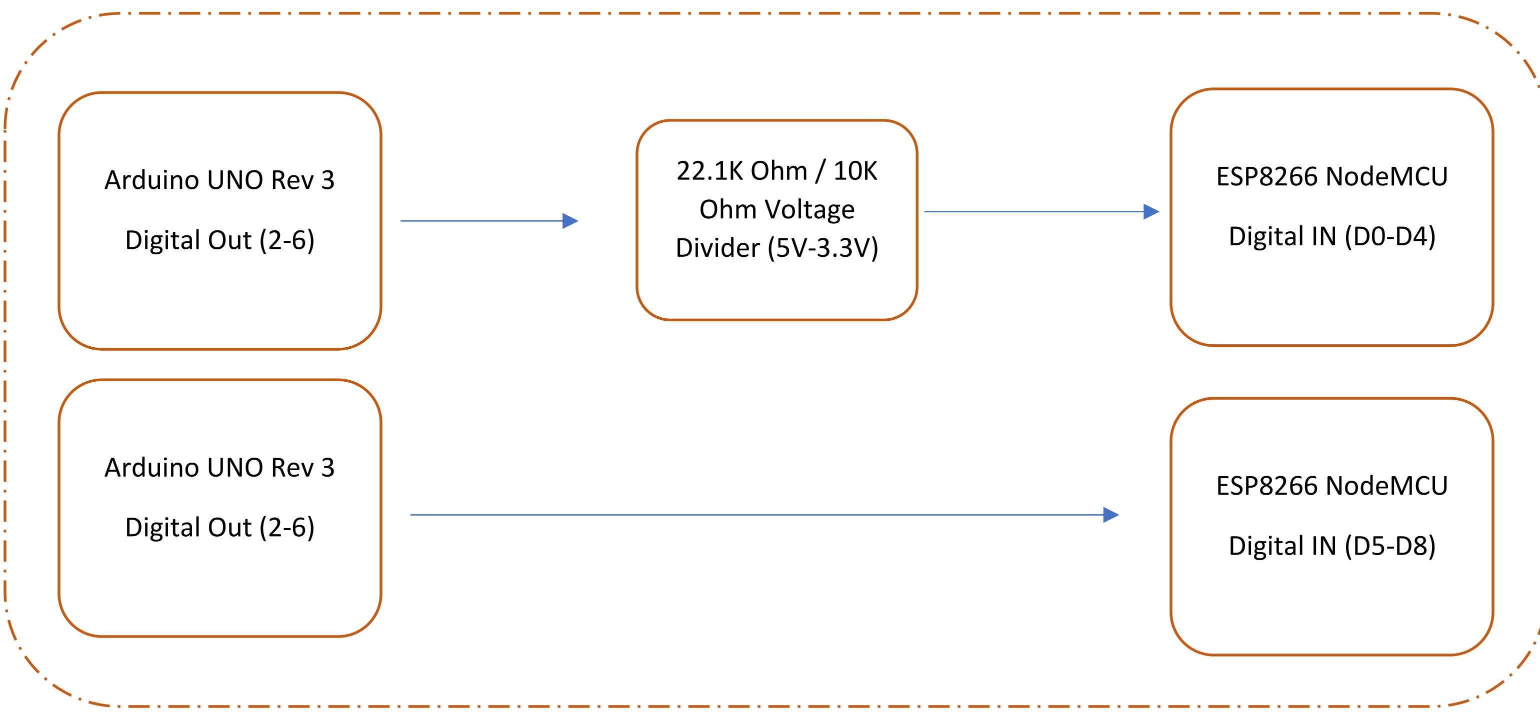
Dartmouth College Engs 90: Team 14

Last Modified: 2/25/2019

1. System Block Diagram

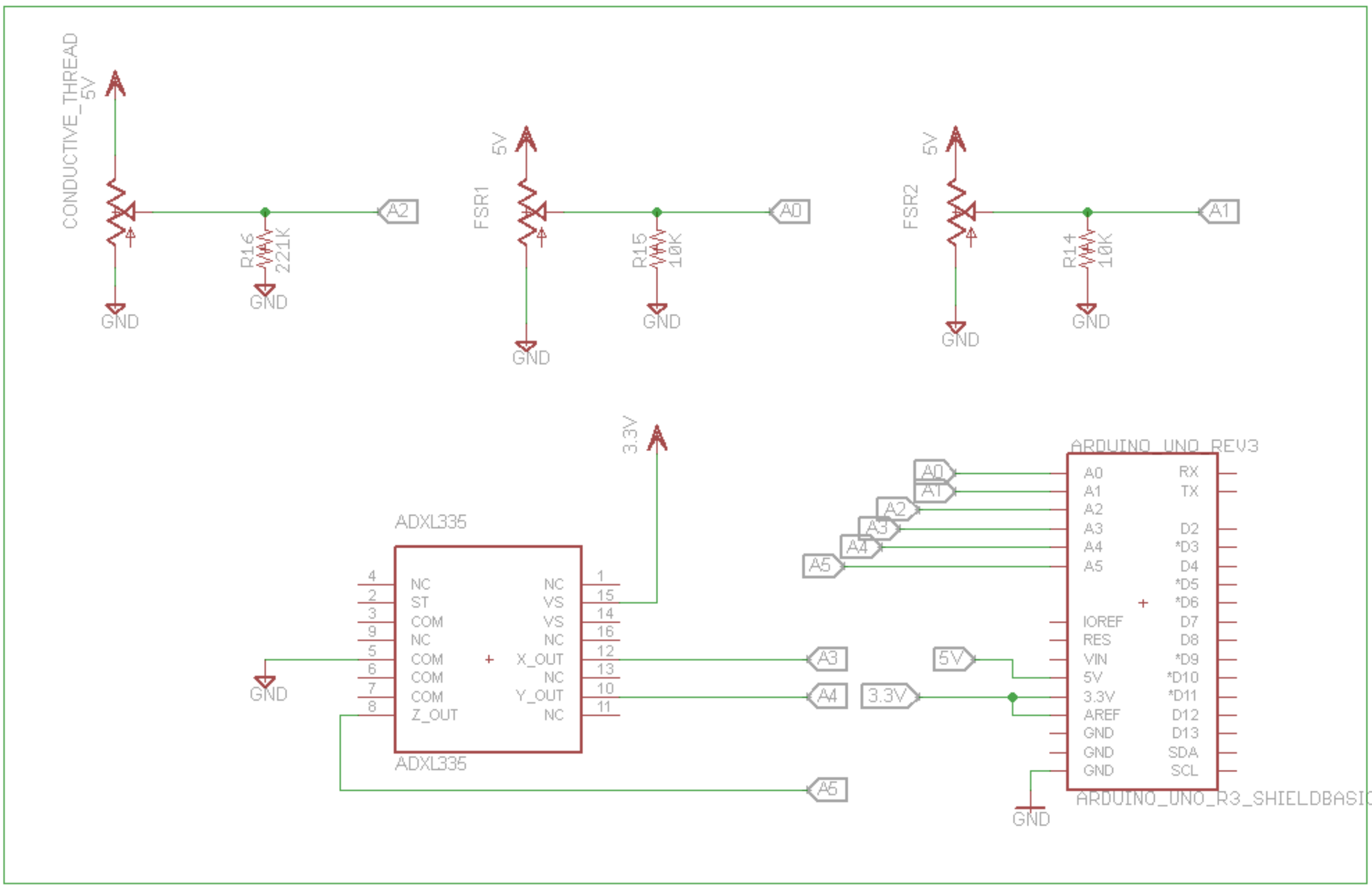
Data Acquisition





Data Processing/ Serial Communication

1.1 Data Acquisition Block

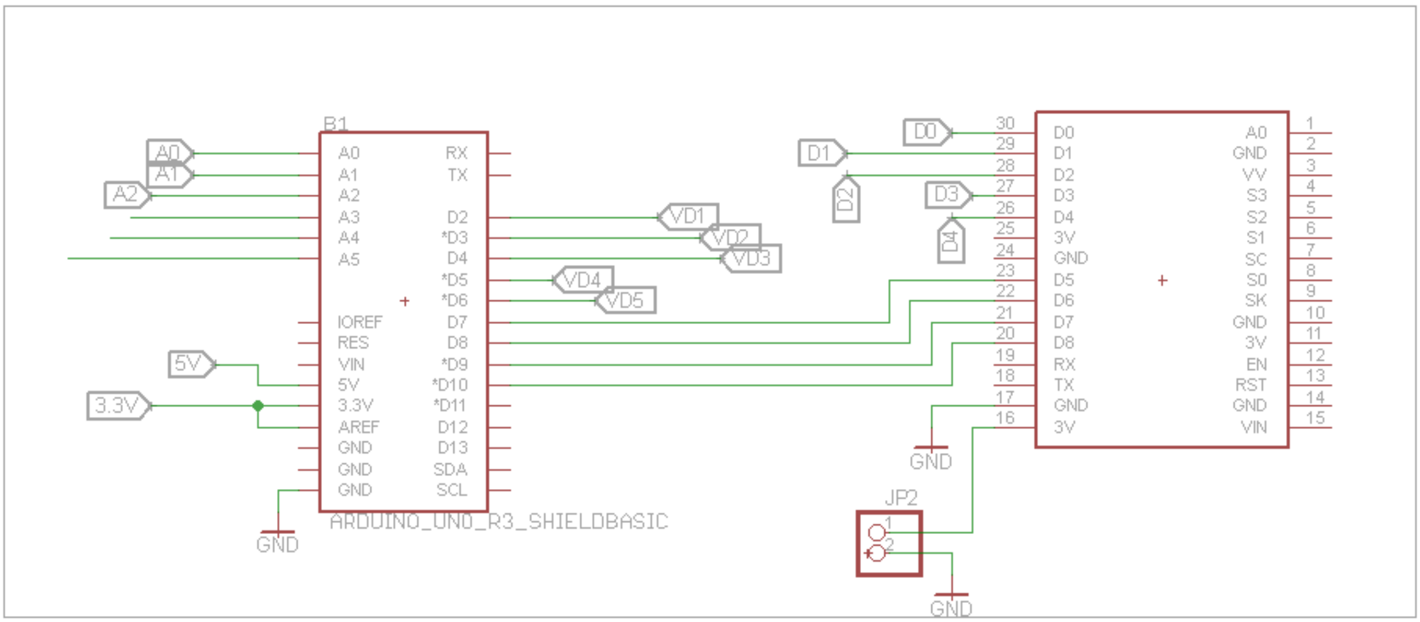


Functions / Components:

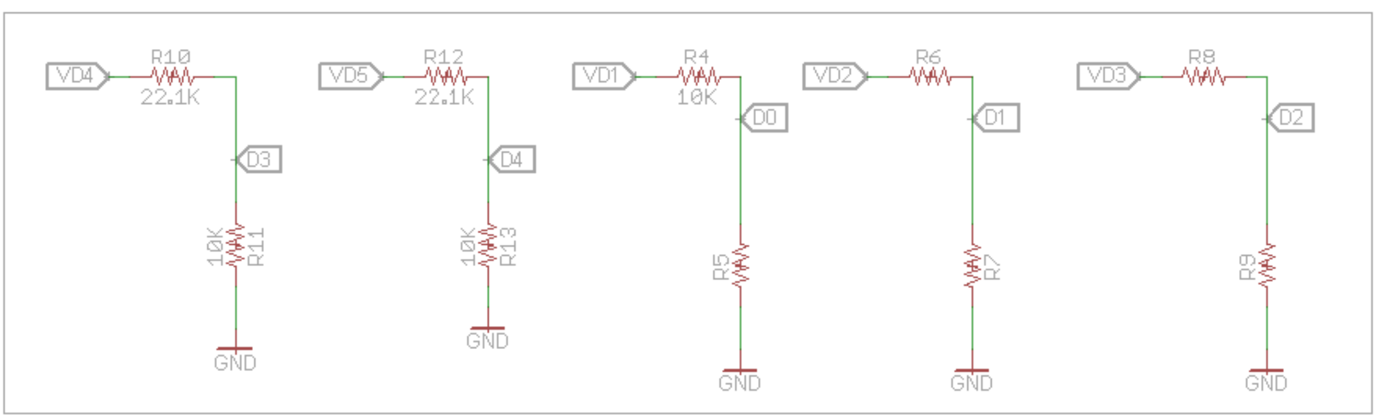
1. **2x Force Sensitive Resistors:** The two FSRs are modeled as a potentiometer. The 10K pulldown to the ground is to voltage divide the 5V supply across the FSR. Connected to A0 and A1 pins of Arduino, the embedded code measures the resistance of the FSR and map it to a load on the mattress.
2. **Conductive Thread Pattern:** The conductive thread pattern is modeled as a pot. The resistance of two ends of the thread pattern changes as a function of wetness across the pattern. When dry, the pattern is an open circuit and moisture on the surface of the pattern closes the circuit hence pulling the resistance down. Connected to A2 pin of Arduino, the embedded code measures the resistance between the two ends of the thread pattern to detect wetness.
3. **ADXL 335 Accelerometer:** ADXL 335 is an accelerometer with an analog output format (0-3.3V). Each X,Y,Z outputs a voltage between 0-3.3V which then is mapped in the embedded code to acceleration between -3G to +3G.

1.2 Data Processing / Serial Communication Block

Foot Prints for Arduino UNO and NODEMCU (ESP8266)



5V to 3.3V Voltage Dividers (Serial Communication)

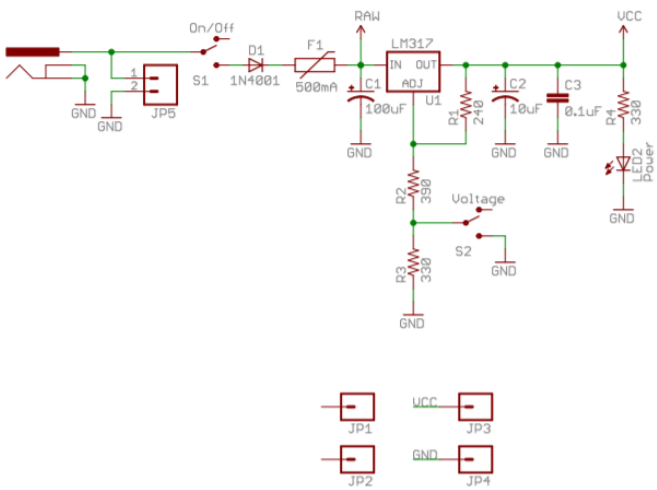


Functions / Components:

1. **Arduino UNO Rev3:** The Arduino rev 3 is the main microcontroller for the embedded system. It serves as the platform for data acquisition and front-end processing
2. **Node MCU ESP8266:** The ESP8266 serves as the WIFI communication block. It takes the output from the microcontroller and uploads data real time via WIFI.
3. **5x Voltage Dividers:** The 22.1K / 10K voltage dividers pulls down the 5V output of the Arduino to 3.3V input for the Node MCU in serial communication.

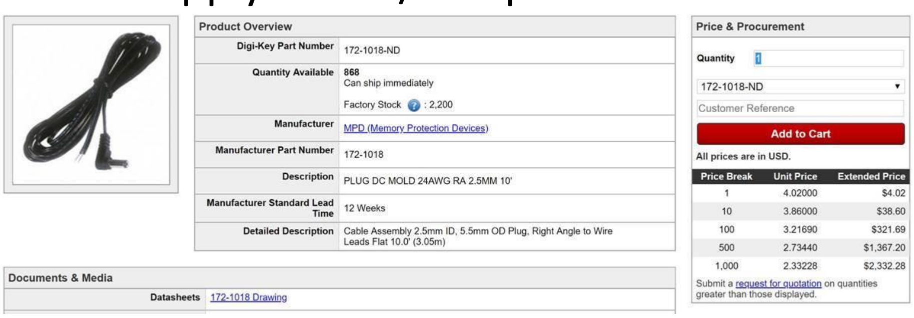
2. Misc. Blocks / Components

2.1 Regulated Power Supply



- The power regulator circuit above is built into the Arduino UNO board for nominal operating Voltage of 5V.

2.2 Power Supply Wires / Adapters



Product Overview

Digi-Key Part Number	172-1018-ND
Quantity Available	868 Can ship immediately Factory Stock : 2,200
Manufacturer	MPD (Memory Protection Devices)
Manufacturer Part Number	172-1018
Description	PLUG DC MOLD 24AWG RA 2.5MM 10'
Manufacturer Standard Lead Time	12 Weeks
Detailed Description	Cable Assembly 2.5mm ID, 5.5mm OD Plug, Right Angle to Wire Leads Flat 10.0' (3.05m)

Price & Procurement

Quantity 1

172-1018-ND

Customer Reference

Add to Cart

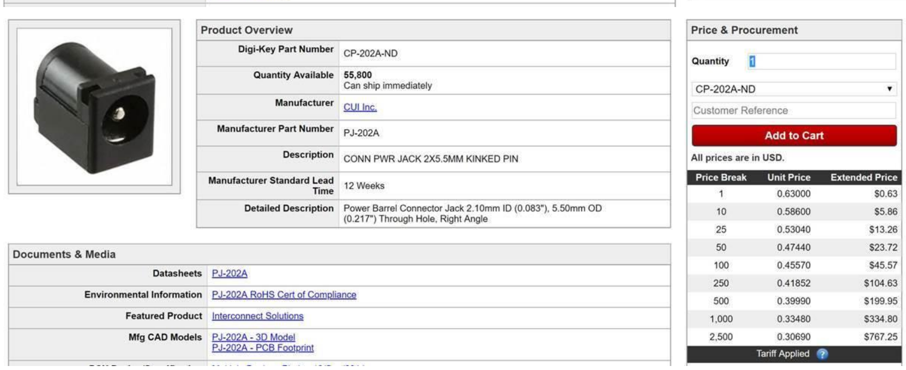
All prices are in USD.

Price Break	Unit Price	Extended Price
1	4.02000	$4.02
10	3.86000	$38.60
100	3.21690	$321.69
500	2.73440	$1,367.20
1,000	2.33228	$2,332.28

Submit a request for quotation on quantities greater than those displayed.

Documents & Media

Datasheets	172-1018 Drawing



Product Overview

Digi-Key Part Number	CP-202A-ND
Quantity Available	55,800 Can ship immediately
Manufacturer	CUI Inc.
Manufacturer Part Number	PJ-202A
Description	CONN PWR JACK 2X5.5MM KINKED PIN
Manufacturer Standard Lead Time	12 Weeks
Detailed Description	Power Barrel Connector Jack 2.10mm ID (0.083"), 5.50mm OD (0.217") Through Hole, Right Angle

Price & Procurement

Quantity 1

CP-202A-ND

Customer Reference

Add to Cart

All prices are in USD.

Price Break	Unit Price	Extended Price
1	0.63000	$0.63
10	0.58600	$5.86
25	0.53040	$13.26
50	0.47440	$23.72
100	0.45570	$45.57
250	0.41852	$104.63
500	0.39990	$199.95
1,000	0.33480	$334.80
2,500	0.30690	$767.25

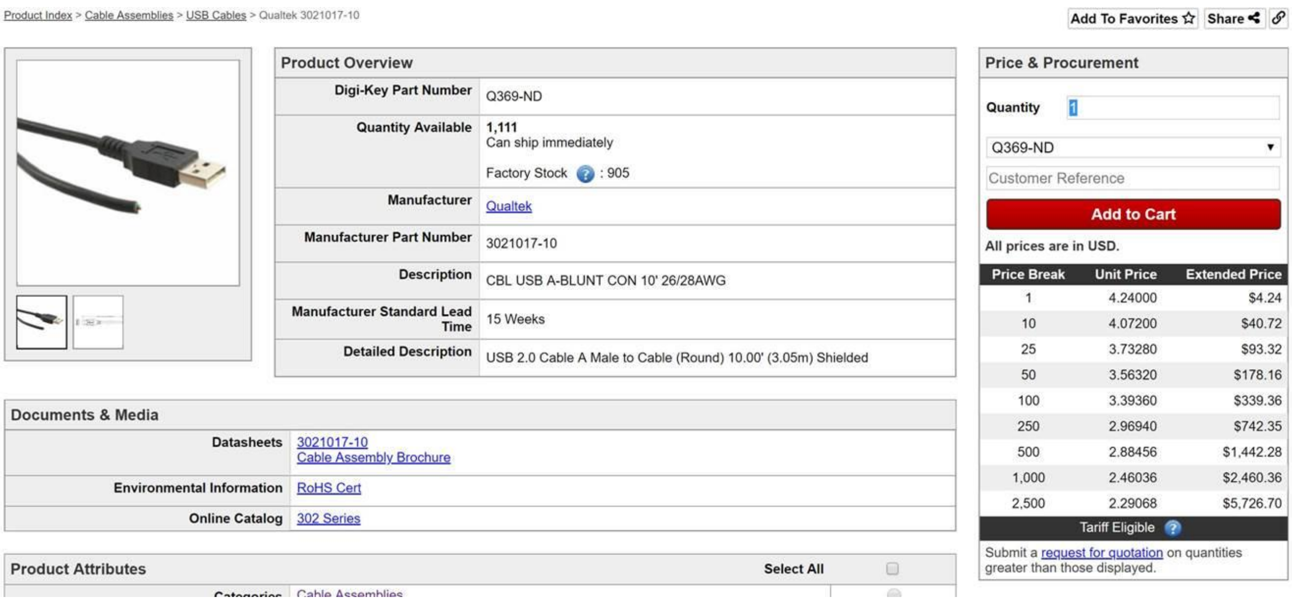
Tariff Applied

Documents & Media

Datasheets	PJ-202A
Environmental Information	PJ-202A RoHS Cert of Compliance
Featured Product	Interconnect Solutions
Mfg CAD Models	PJ-202A - 3D Model PJ-202A - PCB Footprint

- Power Supply Cables and Jack for the system operation

2.3 Interfacing Cables


Product Index > Cable Assemblies > USB Cables > Qualtek 3021017-10

Add To Favorites | Share

Product Overview

Digi-Key Part Number	Q369-ND
Quantity Available	1,111 Can ship immediately Factory Stock : 905
Manufacturer	Qualtek
Manufacturer Part Number	3021017-10
Description	CBL USB A-BLUNT CON 10' 26/28AWG
Manufacturer Standard Lead Time	15 Weeks
Detailed Description	USB 2.0 Cable A Male to Cable (Round) 10.00' (3.05m) Shielded

Documents & Media

Datasheets	3021017-10 Cable Assembly Brochure
Environmental Information	RoHS Cert
Online Catalog	302 Series

Product Attributes Select All

Categories Cable Assemblies

Price & Procurement

Quantity 1

Q369-ND

Customer Reference

Add to Cart

All prices are in USD.

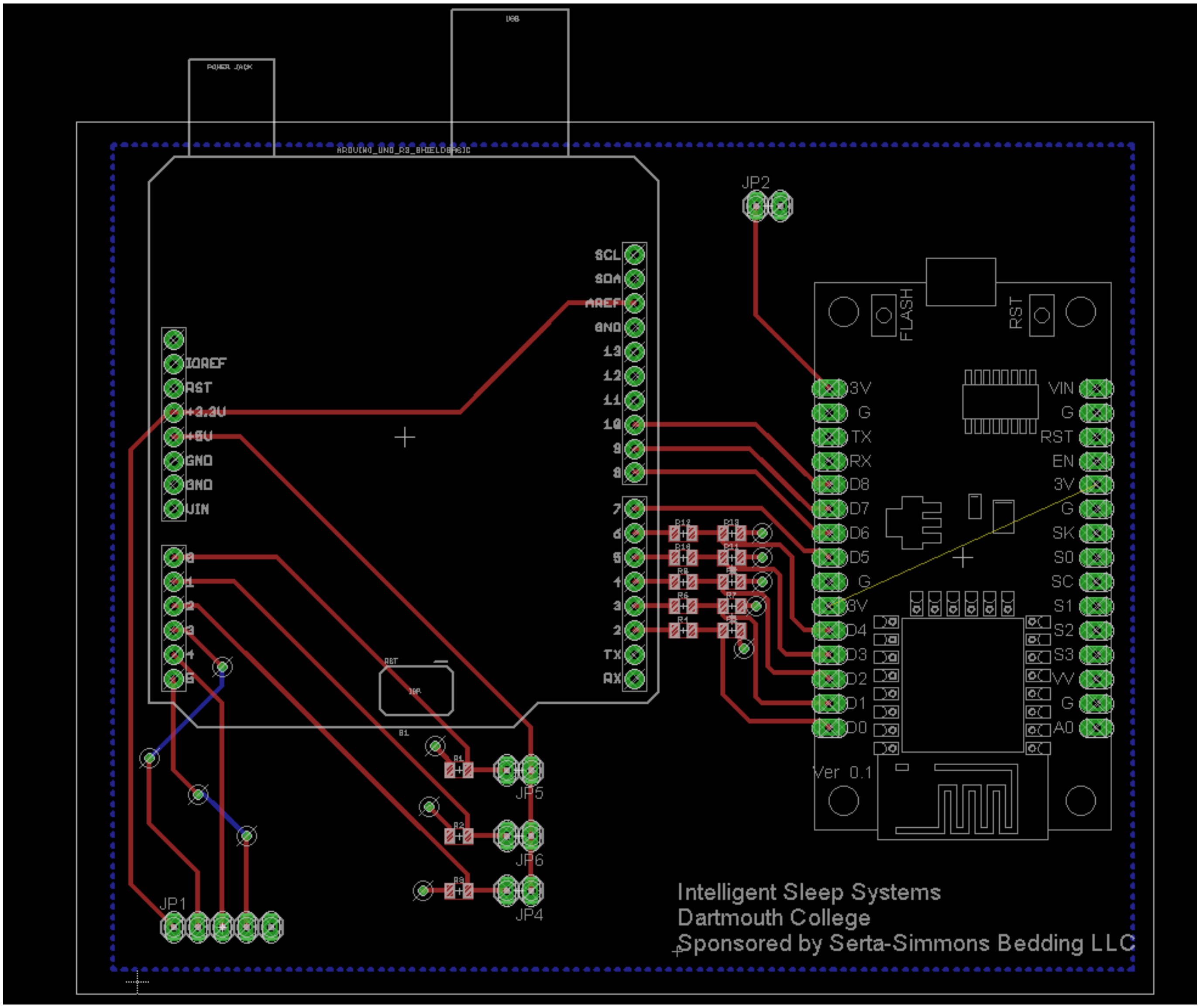
Price Break	Unit Price	Extended Price
1	4.24000	$4.24
10	4.07200	$40.72
25	3.73280	$93.32
50	3.56320	$178.16
100	3.39360	$339.36
250	2.96940	$742.35
500	2.88456	$1,442.28
1,000	2.46036	$2,460.36
2,500	2.29068	$5,726.70

Tariff Eligible

Submit a request for quotation on quantities greater than those displayed.

- Interfacing Cable (USB A): Serves as the interfacing link for data transfer from the sensors to the PCB unit. Also capable of delivering power to the sensors

3. Eagle PCB Layout



Functions / Components:

1. **Board Feature:** A 2-Layer board with copper traces. The bottom layer is reserved as the ground plane. It serves as the secure connection mechanism for the two microcontrollers and misc. electronics.
2. **Headers on the Board:** Multiple Through-Hole headers to take inputs from the sensor units and test points.

4. Bill of Materials

Electrical Hardware Bill of Materials				
Name	**Manufacturer**	**Function**	**Cost ($)**	**Notes**
Square Force Sensitive Resistor	Interlink Electronics	Load on the Bed	$6.95	
ADXL 335 Accelerometer	Analog Devices	Movement on the Bed	$3.78	LilyPad Variation
Stainless Steel Thin Thread	AdaFruit	Wetting of the Bed	$0.51	
Arduino Uno	Arduino	Main Board	$6.95	
NodeMCU ESP8266	Various	WiFi Communication	$3.78	Open Source based
2 Layer PCB	PCB Way	PCB	$0.10	
USB A Data Cable	Qualtek	I2C Data Link / Interfacing Cable	$2.00	10ft length
Power Through Hole Connector	Tensility	Power connection to PCB	$0.25	
5V Power Cable	Tensility	Power Supply	$0.85	6ft length
Misc. Electrical Hardware	Various	Pull Down Resistors, Bypass Caps etc…	$1.00	
		Total BOM:	$26.17	

Appendix: Datasheets

(In Order of Appearances)

1. FSR (Interlink Technologies)
2. ADXL 335 (Analog Devices)
3. Arduino UNO Rev3 (Arduino)
4. NodeMCU ESP 8266
5. 0805 Resistors (Vishay)

INTERLINK ELECTRONICS

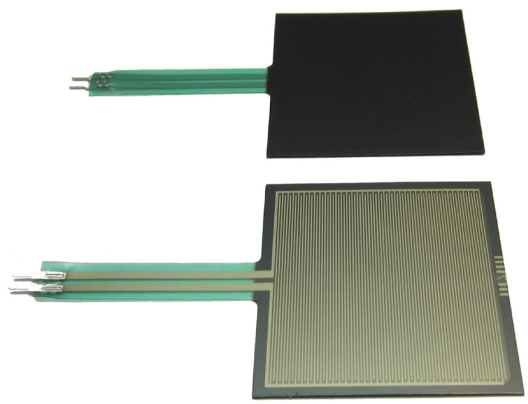
Sensor Technologies

FSR 406 Data Sheet

FSR 400 Series Square Force Sensing Resistor

Description

Interlink Electronics FSR™ 400 series is part of the single zone Force Sensing Resistor™ family. Force Sensing Resistors, or FSRs, are robust polymer thick film (PTF) devices that exhibit a decrease in resistance with increase in force applied to the surface of the sensor. This force sensitivity is optimized for use in human touch control of electronic devices such as automotive electronics, medical systems, and in industrial and robotics applications.



The standard 406 sensor is a square sensor 43.69mm in size. Custom sensors can be manufactured in sizes ranging from 5mm to over 600mm.

Features and Benefits

- Actuation Force as low as 0.1N and sensitivity range to 10N.
- Easily customizable to a wide range of sizes
- Highly Repeatable Force Reading; As low as 2% of initial reading with repeatable actuation system
- Cost effective
- Ultra thin; 0.45mm
- Robust; up to 10M actuations
- Simple and easy to integrate

Industry Segments

- Game controllers
- Musical instruments
- Medical device controls
- Remote controls
- Navigation Electronics
- Industrial HMI
- Automotive Panels
- Consumer Electronics

Figure 1 - Typical Force Curve

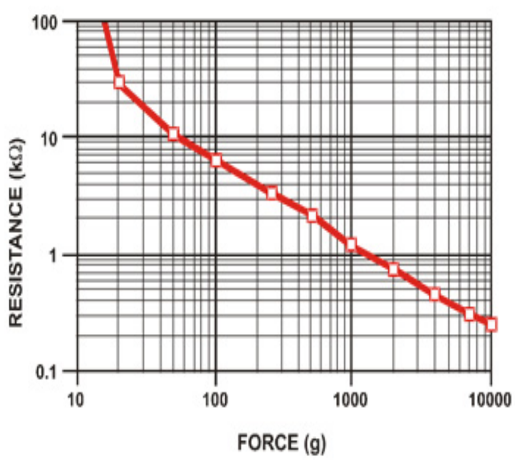
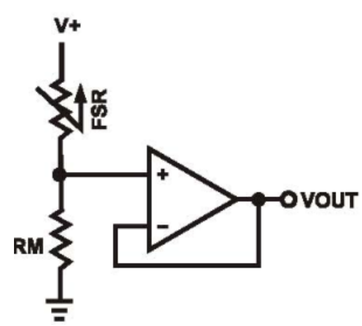


Figure 2 - Typical Schematic



Interlink Electronics - Sensor Technologies

INTERLINK ELECTRONICS
Sensor Technologies

FSR 406
P/N: 30-73258

Applications

Detect & qualify press
Sense whether a touch is accidental or intended by reading force

Use force for UI feedback
Detect more or less user force to make a more intuitive interface

Enhance tool safety
Differentiate a grip from a touch as a safety lock

Find centroid of force
Use multiple sensors to determine centroid of force

Detect presence, position, or motion
Of a person or patient in a bed, chair, or medical device

Detect liquid blockage
Detect tube or pump occlusion or blockage by measuring back pressure

Detect tube positioning

Many other force measurement applications

Device Characteristics

Feature	Condition	Value*	Notes
Actuation Force		0.1 Newtons	
Force Sensitivity Range		0.1 - 10.0[2] Newtons	
Force Repeatability[3]	(Single part)	± 2%	
Force Resolution[3]		continuous	
Force Repeatability[3]	(Part to Part)	±6%	
Non-Actuated Resistance		10M W	
Size		43.69 x 43.69mm	
Thickness Range		0.2 - 1.25 mm	
Stand-Off Resistance		>10M ohms	Unloaded, unbent
Switch Travel	(Typical)	0.05 mm	Depends on design
Hysteresis[3]		+10%	$(R_{F+} - R_{F-})/R_{F+}$.
Device Rise Time		<3 microseconds	measured w/steel ball
Long Term Drift		<5% per $\log_{10}$(time)	35 days test, 1kg load
Temp Operating Range	(Recommended)	-30 - +70 °C	
Number of Actuations	(Life time)	10 Million tested	Without failure

* Specifications are derived from measurements taken at 1000 grams, and are given as one standard deviation / mean, unless otherwise noted.

1. Max Actuation force can be modified in custom sensors.
2. Force Range can be increased in custom sensors. Interlink Electronics have designed and manufactured sensors with operating force larger than 50Kg.
3. Force sensitivity dependent on mechanics, and resolution depends on measurement electronics.

INTERLINK ELECTRONICS®
Sensor Technologies

FSR 406
P/N: 30-73258

Contact Us

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Korea Sales Office
Phone: +82 10 8776 1972

Application Information

FSRs are two-wire devices with a resistance that depends on applied force.

For specific application needs please contact Interlink Electronics support team. An integration guide is also available.

For a simple force-to-voltage conversion, the FSR device is tied to a measuring resistor in a voltage divider configuration (see Figure 3). The output is described by the equation:

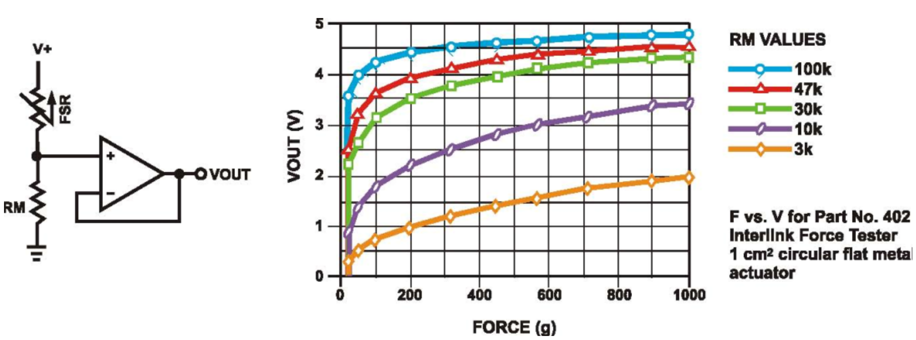
$$V_{OUT} = \frac{R_M V+}{(R_M + R_{FSR})}$$

In the shown configuration, the output voltage increases with increasing force. If R_{FSR} and R_M are swapped, the output swing will decrease with increasing force.

The measuring resistor, R_M, is chosen to maximize the desired force sensitivity range and to limit current. Depending on the impedance requirements of the measuring circuit, the voltage divider could be followed by an op-amp.

A family of force vs. V_{OUT} curves is shown on the graph below for a standard FSR in a voltage divider configuration with various R_M resistors. A (V+) of +5V was used for these examples.

Figure 3

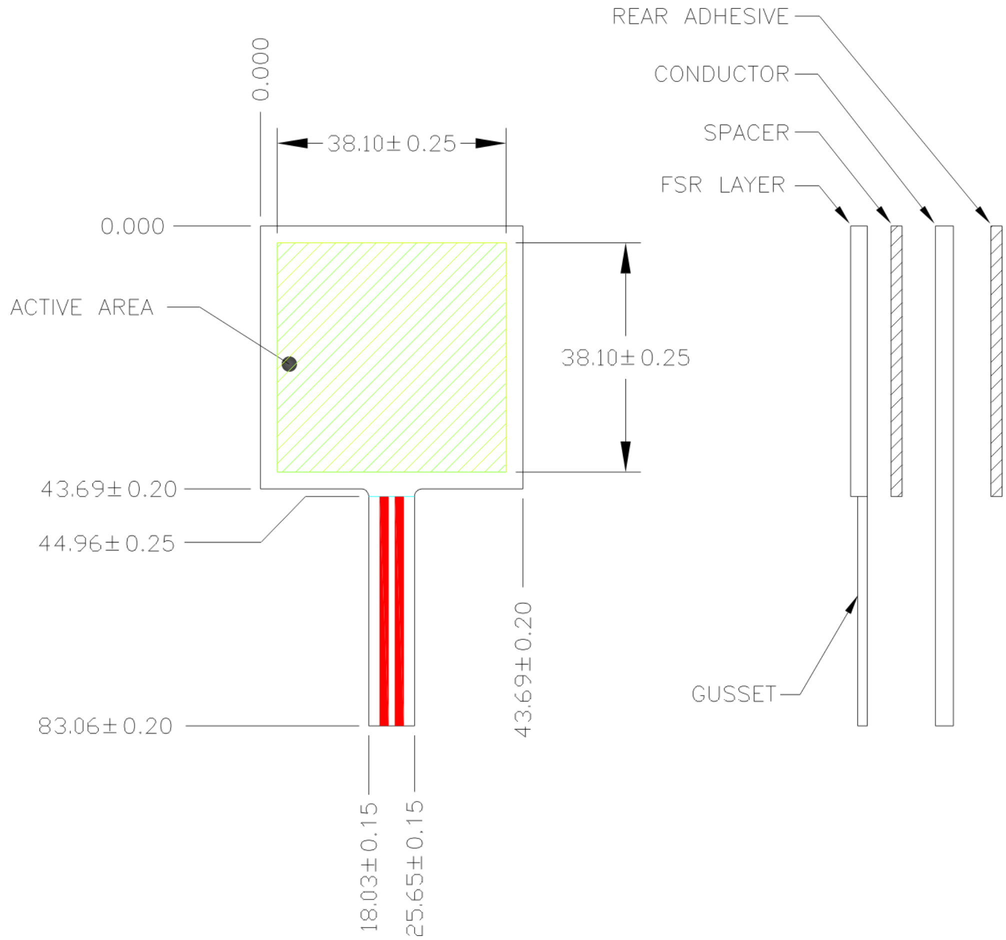


FSR 406
P/N: 30-73258

Part No. 406

- Active Area: 38.1mm x 38.1mm
- Nominal thickness: 0.54 mm

Mechanical Data



Small, Low Power, 3-Axis ±3 *g* Accelerometer

ADXL335

FEATURES

3-axis sensing
Small, low profile package
4 mm × 4 mm × 1.45 mm LFCSP
Low power : 350 µA (typical)
Single-supply operation: 1.8 V to 3.6 V
10,000 *g* shock survival
Excellent temperature stability
BW adjustment with a single capacitor per axis
RoHS/WEEE lead-free compliant

APPLICATIONS

Cost sensitive, low power, motion- and tilt-sensing applications
Mobile devices
Gaming systems
Disk drive protection
Image stabilization
Sports and health devices

GENERAL DESCRIPTION

The ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum full-scale range of ±3 *g*. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration.

The user selects the bandwidth of the accelerometer using the C_X, C_Y, and C_Z capacitors at the X_{OUT}, Y_{OUT}, and Z_{OUT} pins. Bandwidths can be selected to suit the application, with a range of 0.5 Hz to 1600 Hz for the X and Y axes, and a range of 0.5 Hz to 550 Hz for the Z axis.

The ADXL335 is available in a small, low profile, 4 mm × 4 mm × 1.45 mm, 16-lead, plastic lead frame chip scale package (LFCSP_LQ).

FUNCTIONAL BLOCK DIAGRAM

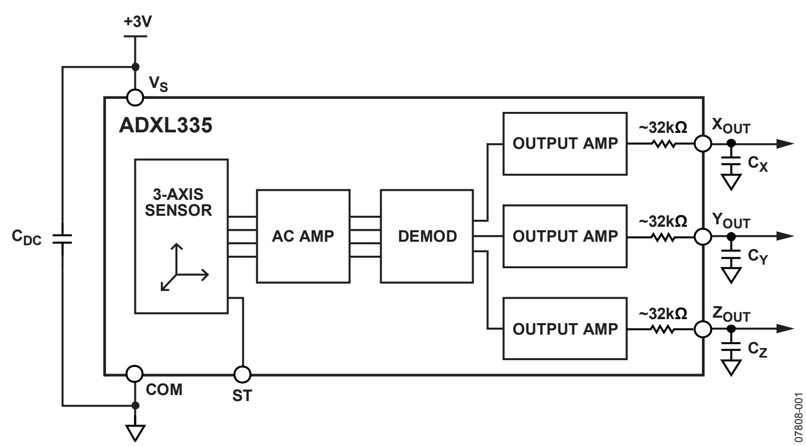


Figure 1.

Rev. 0

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700 **www.analog.com**
Fax: 781.461.3113

TABLE OF CONTENTS

REVISION HISTORY

1/09—Revision 0: Initial Version

SPECIFICATIONS

T_A = 25°C, V_S = 3 V, C_X = C_Y = C_Z = 0.1 µF, acceleration = 0 *g*, unless otherwise noted. All minimum and maximum specifications are guaranteed. Typical specifications are not guaranteed.

Table 1.

Parameter	Conditions	Min	Typ	Max	Unit
SENSOR INPUT	Each axis				
Measurement Range		±3	±3.6		*g*
Nonlinearity	% of full scale		±0.3		%
Package Alignment Error			±1		Degrees
Interaxis Alignment Error			±0.1		Degrees
Cross-Axis Sensitivity[1]			±1		%
SENSITIVITY (RATIOMETRIC)[2]	Each axis				
Sensitivity at X_{OUT}, Y_{OUT}, Z_{OUT}	V_S = 3 V	270	300	330	mV/*g*
Sensitivity Change Due to Temperature[3]	V_S = 3 V		±0.01		%/°C
ZERO *g* BIAS LEVEL (RATIOMETRIC)					
0 *g* Voltage at X_{OUT}, Y_{OUT}	V_S = 3 V	1.35	1.5	1.65	V
0 *g* Voltage at Z_{OUT}	V_S = 3 V	1.2	1.5	1.8	V
0 *g* Offset vs. Temperature			±1		m*g*/°C
NOISE PERFORMANCE					
Noise Density X_{OUT}, Y_{OUT}			150		µ*g*/√Hz rms
Noise Density Z_{OUT}			300		µ*g*/√Hz rms
FREQUENCY RESPONSE[4]					
Bandwidth X_{OUT}, Y_{OUT}[5]	No external filter		1600		Hz
Bandwidth Z_{OUT}[5]	No external filter		550		Hz
R_{FILT} Tolerance			32 ± 15%		kΩ
Sensor Resonant Frequency			5.5		kHz
SELF-TEST[6]					
Logic Input Low			+0.6		V
Logic Input High			+2.4		V
ST Actuation Current			+60		µA
Output Change at X_{OUT}	Self-Test 0 to Self-Test 1	−150	−325	−600	mV
Output Change at Y_{OUT}	Self-Test 0 to Self-Test 1	+150	+325	+600	mV
Output Change at Z_{OUT}	Self-Test 0 to Self-Test 1	+150	+550	+1000	mV
OUTPUT AMPLIFIER					
Output Swing Low	No load		0.1		V
Output Swing High	No load		2.8		V
POWER SUPPLY					
Operating Voltage Range		1.8		3.6	V
Supply Current	V_S = 3 V		350		µA
Turn-On Time[7]	No external filter		1		ms
TEMPERATURE					
Operating Temperature Range		−40		+85	°C

[1] Defined as coupling between any two axes.
[2] Sensitivity is essentially ratiometric to V_S.
[3] Defined as the output change from ambient-to-maximum temperature or ambient-to-minimum temperature.
[4] Actual frequency response controlled by user-supplied external filter capacitors (C_X, C_Y, C_Z).
[5] Bandwidth with external capacitors = 1/(2 × π × 32 kΩ × C). For C_X, C_Y = 0.003 µF, bandwidth = 1.6 kHz. For C_Z = 0.01 µF, bandwidth = 500 Hz. For C_X, C_Y, C_Z = 10 µF, bandwidth = 0.5 Hz.
[6] Self-test response changes cubically with V_S.
[7] Turn-on time is dependent on C_X, C_Y, C_Z and is approximately 160 × C_X or C_Y or C_Z + 1 ms, where C_X, C_Y, C_Z are in microfarads (µF).

ABSOLUTE MAXIMUM RATINGS

Table 2.

Parameter	Rating
Acceleration (Any Axis, Unpowered)	10,000 *g*
Acceleration (Any Axis, Powered)	10,000 *g*
V_S	−0.3 V to +3.6 V
All Other Pins	(COM − 0.3 V) to (V_S + 0.3 V)
Output Short-Circuit Duration (Any Pin to Common)	Indefinite
Temperature Range (Powered)	−55°C to +125°C
Temperature Range (Storage)	−65°C to +150°C

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

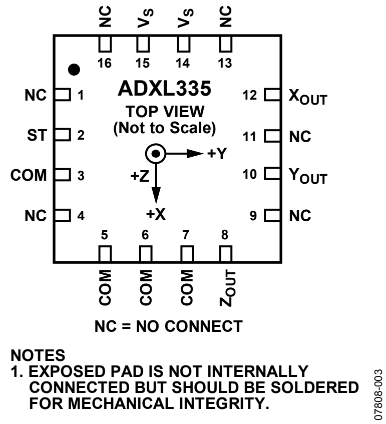


Figure 2. Pin Configuration

Table 3. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	NC	No Connect[1].
2	ST	Self-Test.
3	COM	Common.
4	NC	No Connect[1].
5	COM	Common.
6	COM	Common.
7	COM	Common.
8	Z_{OUT}	Z Channel Output.
9	NC	No Connect[1].
10	Y_{OUT}	Y Channel Output.
11	NC	No Connect[1].
12	X_{OUT}	X Channel Output.
13	NC	No Connect[1].
14	V_S	Supply Voltage (1.8 V to 3.6 V).
15	V_S	Supply Voltage (1.8 V to 3.6 V).
16	NC	No Connect[1].
EP	Exposed Pad	Not internally connected. Solder for mechanical integrity.

[1]NC pins are not internally connected and can be tied to COM pins, unless otherwise noted.

TYPICAL PERFORMANCE CHARACTERISTICS

N > 1000 for all typical performance plots, unless otherwise noted.

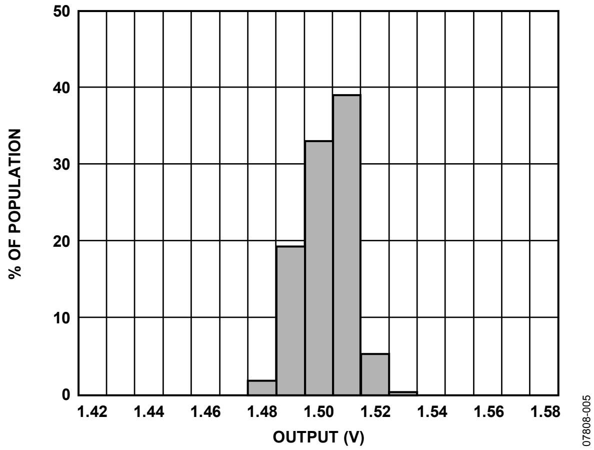


Figure 3. X-Axis Zero g Bias at 25°C, V_S = 3 V

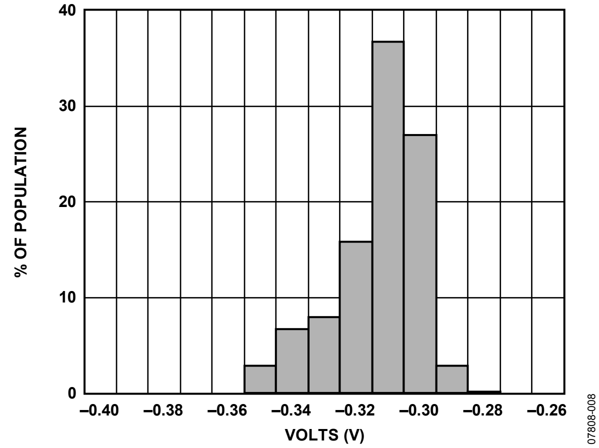


Figure 6. X-Axis Self-Test Response at 25°C, V_S = 3 V

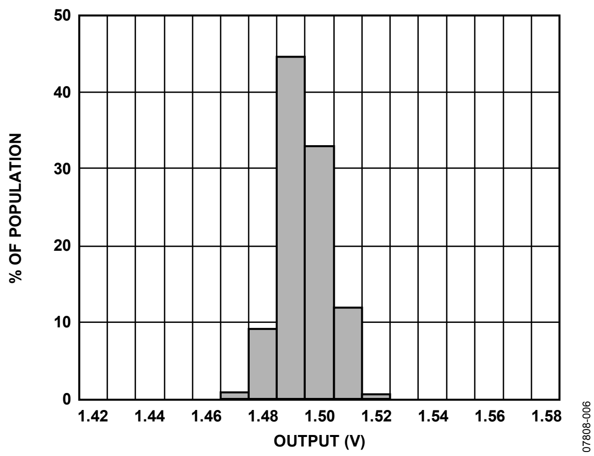


Figure 4. Y-Axis Zero g Bias at 25°C, V_S = 3 V

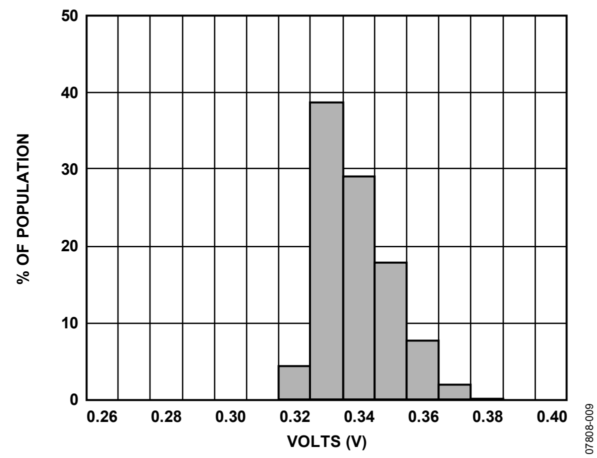


Figure 7. Y-Axis Self-Test Response at 25°C, V_S = 3 V

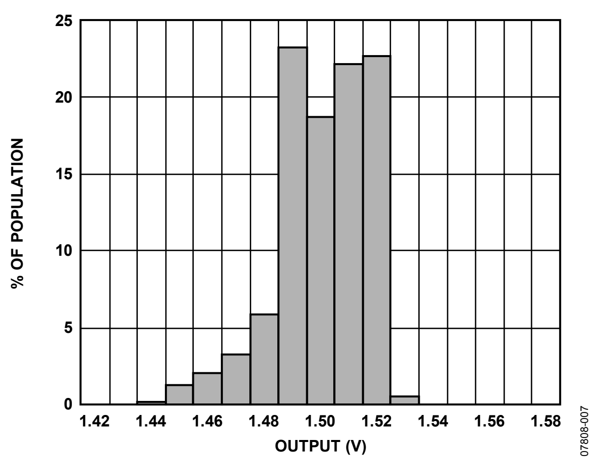


Figure 5. Z-Axis Zero g Bias at 25°C, V_S = 3 V

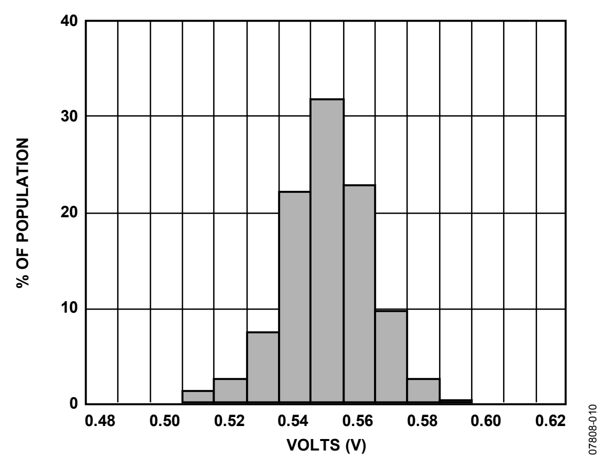


Figure 8. Z-Axis Self-Test Response at 25°C, V_S = 3 V

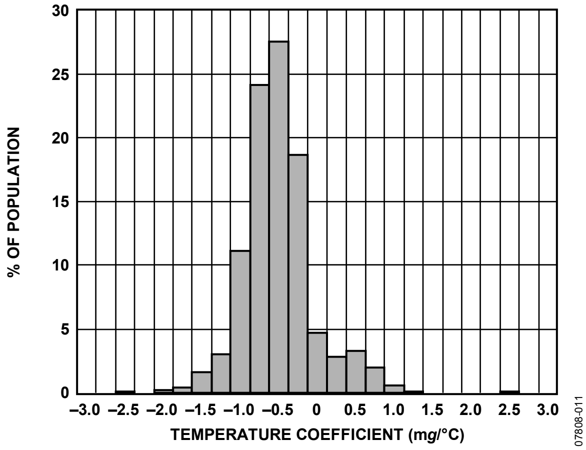


Figure 9. X-Axis Zero g *Bias Temperature Coefficient,* $V_S = 3$ *V*

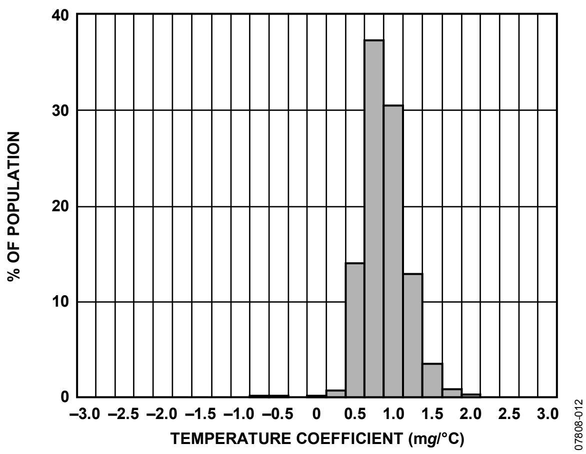


Figure 10. Y-Axis Zero g *Bias Temperature Coefficient,* $V_S = 3$ *V*

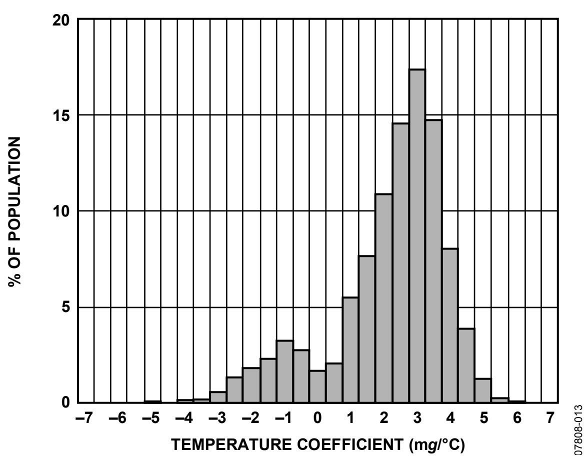


Figure 11. Z-Axis Zero g *Bias Temperature Coefficient,* $V_S = 3$ *V*

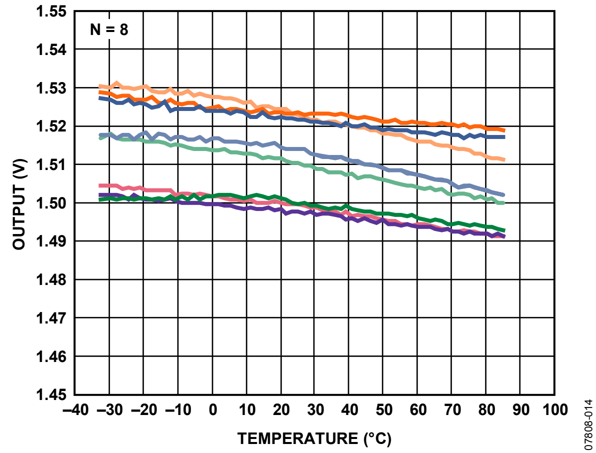


Figure 12. X-Axis Zero g *Bias vs. Temperature—*
Eight Parts Soldered to PCB

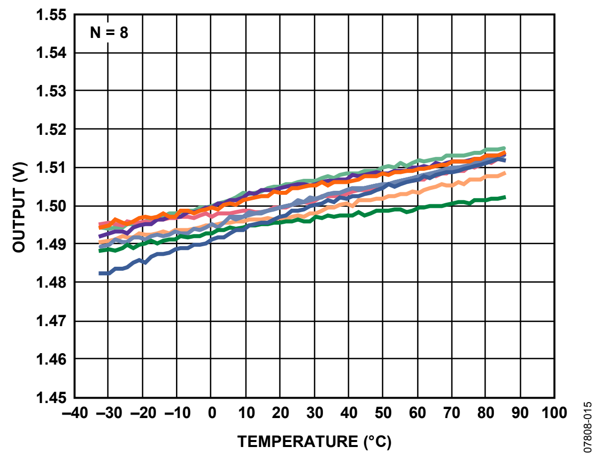


Figure 13. Y-Axis Zero g *Bias vs. Temperature—*
Eight Parts Soldered to PCB

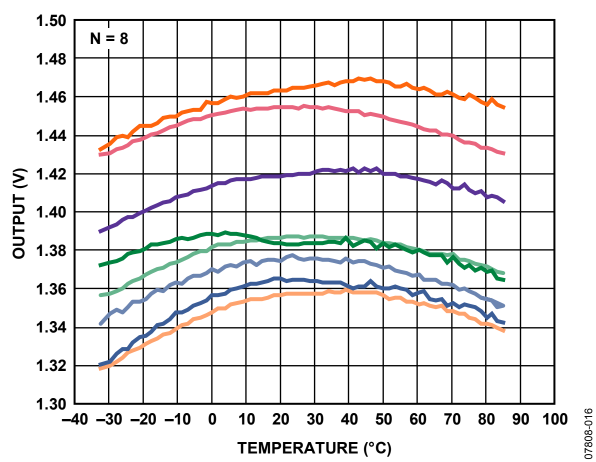


Figure 14. Z-Axis Zero g *Bias vs. Temperature—*
Eight Parts Soldered to PCB

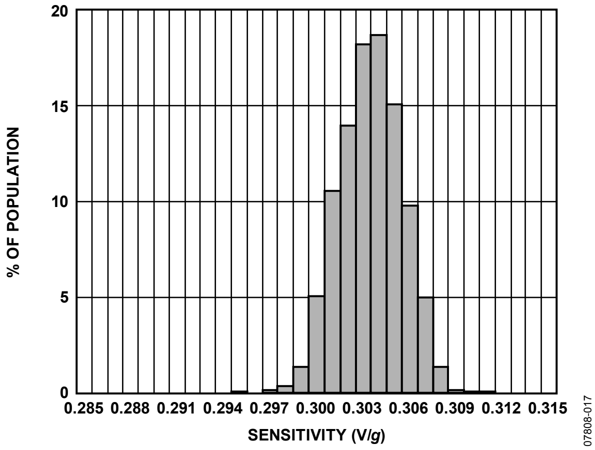


Figure 15. X-Axis Sensitivity at 25°C, V_S = 3 V

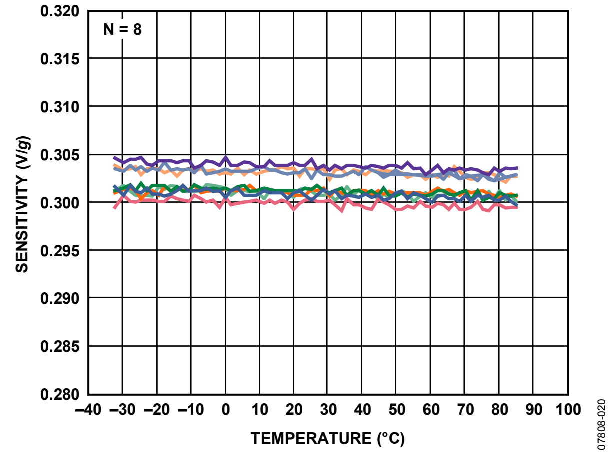


Figure 18. X-Axis Sensitivity vs. Temperature—Eight Parts Soldered to PCB, V_S = 3 V

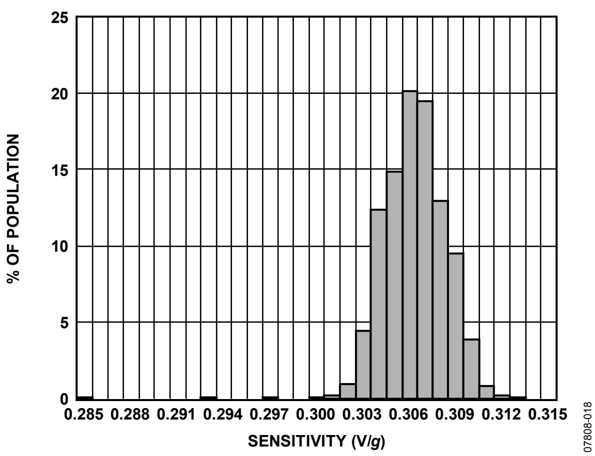


Figure 16. Y-Axis Sensitivity at 25°C, V_S = 3 V

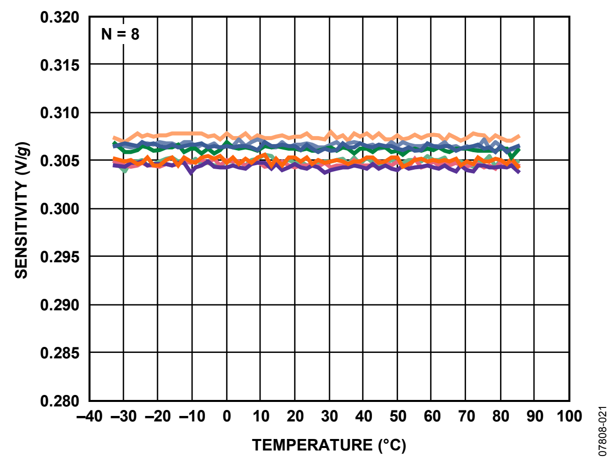


Figure 19. Y-Axis Sensitivity vs. Temperature—Eight Parts Soldered to PCB, V_S = 3 V

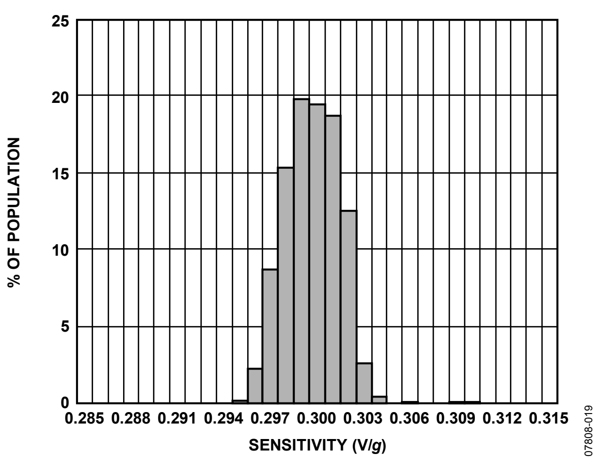


Figure 17. Z-Axis Sensitivity at 25°C, V_S = 3 V

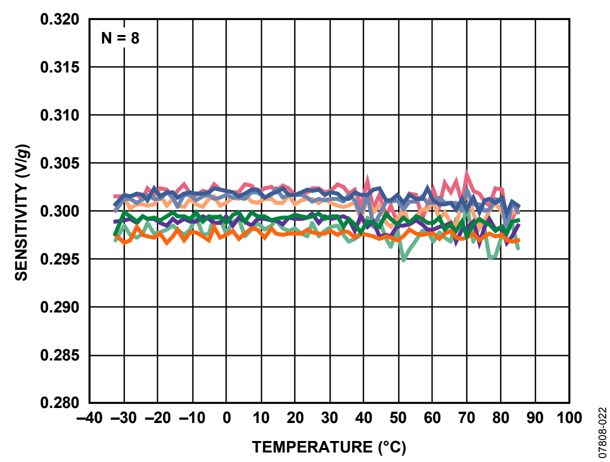


Figure 20. Z-Axis Sensitivity vs. Temperature—Eight Parts Soldered to PCB, V_S = 3 V

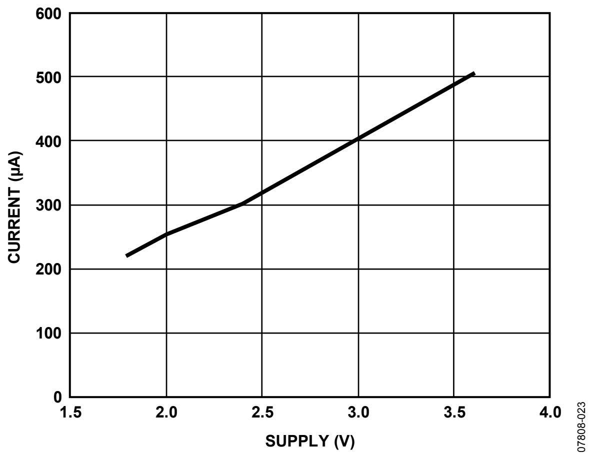


Figure 21. Typical Current Consumption vs. Supply Voltage

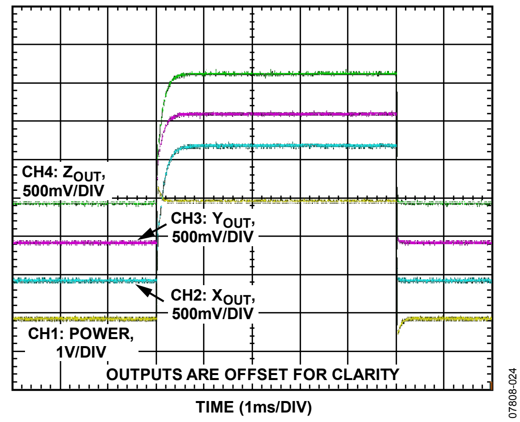


Figure 22. Typical Turn-On Time, V_S = 3 V

THEORY OF OPERATION

The ADXL335 is a complete 3-axis acceleration measurement system. The ADXL335 has a measurement range of ±3 *g* minimum. It contains a polysilicon surface-micromachined sensor and signal conditioning circuitry to implement an open-loop acceleration measurement architecture. The output signals are analog voltages that are proportional to acceleration. The accelerometer can measure the static acceleration of gravity in tilt-sensing applications as well as dynamic acceleration resulting from motion, shock, or vibration.

The sensor is a polysilicon surface-micromachined structure built on top of a silicon wafer. Polysilicon springs suspend the structure over the surface of the wafer and provide a resistance against acceleration forces. Deflection of the structure is measured using a differential capacitor that consists of independent fixed plates and plates attached to the moving mass. The fixed plates are driven by 180° out-of-phase square waves. Acceleration deflects the moving mass and unbalances the differential capacitor resulting in a sensor output whose amplitude is proportional to acceleration. Phase-sensitive demodulation techniques are then used to determine the magnitude and direction of the acceleration.

The demodulator output is amplified and brought off-chip through a 32 kΩ resistor. The user then sets the signal bandwidth of the device by adding a capacitor. This filtering improves measurement resolution and helps prevent aliasing.

MECHANICAL SENSOR

The ADXL335 uses a single structure for sensing the X, Y, and Z axes. As a result, the three axes' sense directions are highly orthogonal and have little cross-axis sensitivity. Mechanical misalignment of the sensor die to the package is the chief source of cross-axis sensitivity. Mechanical misalignment can, of course, be calibrated out at the system level.

PERFORMANCE

Rather than using additional temperature compensation circuitry, innovative design techniques ensure that high performance is built in to the ADXL335. As a result, there is no quantization error or nonmonotonic behavior, and temperature hysteresis is very low (typically less than 3 m*g* over the −25°C to +70°C temperature range).

APPLICATIONS INFORMATION

POWER SUPPLY DECOUPLING

For most applications, a single 0.1 µF capacitor, C_{DC}, placed close to the ADXL335 supply pins adequately decouples the accelerometer from noise on the power supply. However, in applications where noise is present at the 50 kHz internal clock frequency (or any harmonic thereof), additional care in power supply bypassing is required because this noise can cause errors in acceleration measurement.

If additional decoupling is needed, a 100 Ω (or smaller) resistor or ferrite bead can be inserted in the supply line. Additionally, a larger bulk bypass capacitor (1 µF or greater) can be added in parallel to C_{DC}. Ensure that the connection from the ADXL335 ground to the power supply ground is low impedance because noise transmitted through ground has a similar effect to noise transmitted through V_S.

SETTING THE BANDWIDTH USING C_X, C_Y, AND C_Z

The ADXL335 has provisions for band limiting the X_{OUT}, Y_{OUT}, and Z_{OUT} pins. Capacitors must be added at these pins to implement low-pass filtering for antialiasing and noise reduction. The equation for the 3 dB bandwidth is

$$F_{-3\,dB} = 1/(2\pi(32\ k\Omega) \times C_{(X,\,Y,\,Z)})$$

or more simply

$$F_{-3\,dB} = 5\ \mu F/C_{(X,\,Y,\,Z)}$$

The tolerance of the internal resistor (R_{FILT}) typically varies as much as ±15% of its nominal value (32 kΩ), and the bandwidth varies accordingly. A minimum capacitance of 0.0047 µF for C_X, C_Y, and C_Z is recommended in all cases.

Table 4. Filter Capacitor Selection, C_X, C_Y, and C_Z

Bandwidth (Hz)	Capacitor (µF)
1	4.7
10	0.47
50	0.10
100	0.05
200	0.027
500	0.01

SELF-TEST

The ST pin controls the self-test feature. When this pin is set to V_S, an electrostatic force is exerted on the accelerometer beam. The resulting movement of the beam allows the user to test if the accelerometer is functional. The typical change in output is −1.08 *g* (corresponding to −325 mV) in the X-axis, +1.08 *g* (or +325 mV) on the Y-axis, and +1.83 *g* (or +550 mV) on the Z-axis. This ST pin can be left open-circuit or connected to common (COM) in normal use.

Never expose the ST pin to voltages greater than V_S + 0.3 V. If this cannot be guaranteed due to the system design (for instance, if there are multiple supply voltages), then a low V_F clamping diode between ST and V_S is recommended.

DESIGN TRADE-OFFS FOR SELECTING FILTER CHARACTERISTICS: THE NOISE/BW TRADE-OFF

The selected accelerometer bandwidth ultimately determines the measurement resolution (smallest detectable acceleration). Filtering can be used to lower the noise floor to improve the resolution of the accelerometer. Resolution is dependent on the analog filter bandwidth at X_{OUT}, Y_{OUT}, and Z_{OUT}.

The output of the ADXL335 has a typical bandwidth of greater than 500 Hz. The user must filter the signal at this point to limit aliasing errors. The analog bandwidth must be no more than half the analog-to-digital sampling frequency to minimize aliasing. The analog bandwidth can be further decreased to reduce noise and improve resolution.

The ADXL335 noise has the characteristics of white Gaussian noise, which contributes equally at all frequencies and is described in terms of µg/√Hz (the noise is proportional to the square root of the accelerometer bandwidth). The user should limit bandwidth to the lowest frequency needed by the application to maximize the resolution and dynamic range of the accelerometer.

With the single-pole, roll-off characteristic, the typical noise of the ADXL335 is determined by

$$rms\ Noise = Noise\ Density \times (\sqrt{BW \times 1.6})$$

It is often useful to know the peak value of the noise. Peak-to-peak noise can only be estimated by statistical methods. Table 5 is useful for estimating the probabilities of exceeding various peak values, given the rms value.

Table 5. Estimation of Peak-to-Peak Noise

Peak-to-Peak Value	% of Time That Noise Exceeds Nominal Peak-to-Peak Value
2 × rms	32
4 × rms	4.6
6 × rms	0.27
8 × rms	0.006

USE WITH OPERATING VOLTAGES OTHER THAN 3 V

The ADXL335 is tested and specified at V_S = 3 V; however, it can be powered with V_S as low as 1.8 V or as high as 3.6 V. Note that some performance parameters change as the supply voltage is varied.

The ADXL335 output is ratiometric, therefore, the output sensitivity (or scale factor) varies proportionally to the supply voltage. At V_S = 3.6 V, the output sensitivity is typically 360 mV/*g*. At V_S = 2 V, the output sensitivity is typically 195 mV/*g*.

The zero *g* bias output is also ratiometric, thus the zero *g* output is nominally equal to $V_S/2$ at all supply voltages.

The output noise is not ratiometric but is absolute in volts; therefore, the noise density decreases as the supply voltage increases. This is because the scale factor (mV/*g*) increases while the noise voltage remains constant. At V_S = 3.6 V, the X-axis and Y-axis noise density is typically 120 μ*g*/√Hz, whereas at V_S = 2 V, the X-axis and Y-axis noise density is typically 270 μ*g*/√Hz.

Self-test response in *g* is roughly proportional to the square of the supply voltage. However, when ratiometricity of sensitivity is factored in with supply voltage, the self-test response in volts is roughly proportional to the cube of the supply voltage. For example, at V_S = 3.6 V, the self-test response for the ADXL335 is approximately −560 mV for the X-axis, +560 mV for the Y-axis, and +950 mV for the Z-axis.

At V_S = 2 V, the self-test response is approximately −96 mV for the X-axis, +96 mV for the Y-axis, and −163 mV for the Z-axis.

The supply current decreases as the supply voltage decreases. Typical current consumption at V_S = 3.6 V is 375 μA, and typical current consumption at V_S = 2 V is 200 μA.

AXES OF ACCELERATION SENSITIVITY

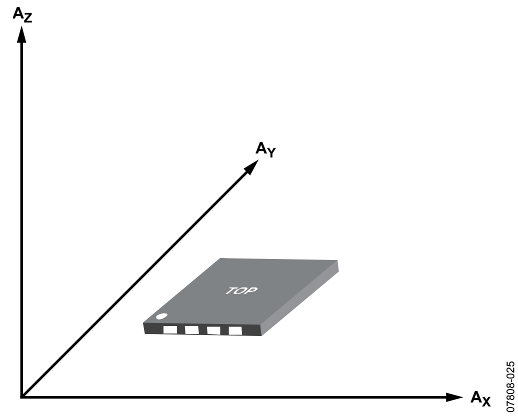


Figure 23. Axes of Acceleration Sensitivity; Corresponding Output Voltage Increases When Accelerated Along the Sensitive Axis.

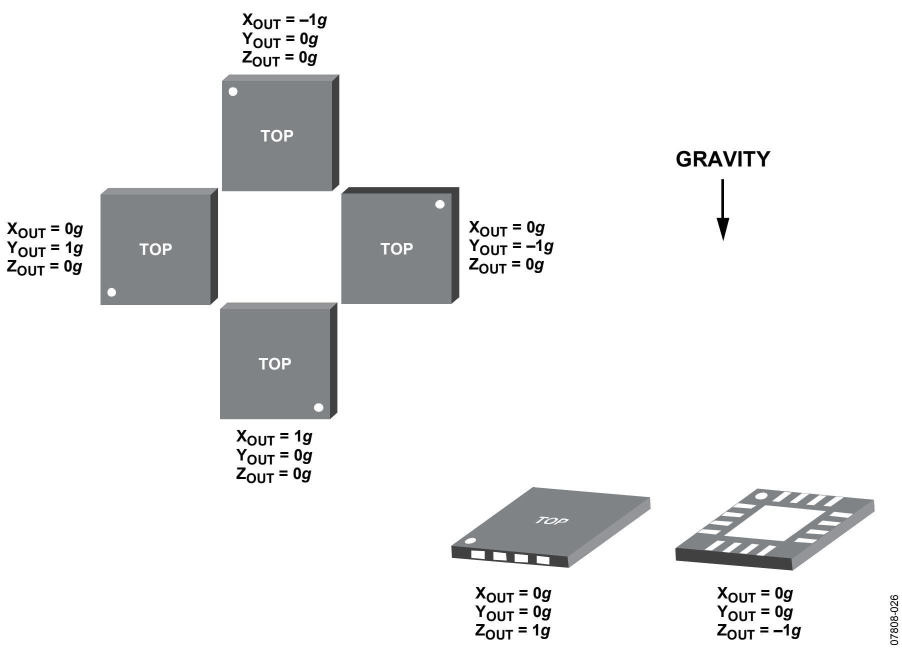


Figure 24. Output Response vs. Orientation to Gravity

LAYOUT AND DESIGN RECOMMENDATIONS

The recommended soldering profile is shown in Figure 25 followed by a description of the profile features in Table 6. The recommended PCB layout or solder land drawing is shown in Figure 26.

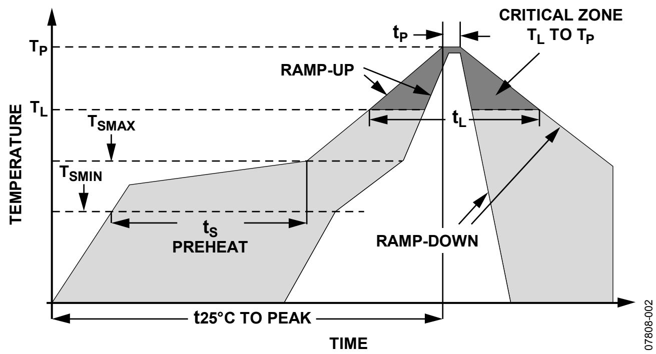


Figure 25. Recommended Soldering Profile

Table 6. Recommended Soldering Profile

Profile Feature	Sn63/Pb37	Pb-Free
Average Ramp Rate (T_L to T_P)	3°C/sec max	3°C/sec max
Preheat		
Minimum Temperature (T_{SMIN})	100°C	150°C
Maximum Temperature (T_{SMAX})	150°C	200°C
Time (T_{SMIN} to T_{SMAX})(t_S)	60 sec to 120 sec	60 sec to 180 sec
T_{SMAX} to T_L		
Ramp-Up Rate	3°C/sec max	3°C/sec max
Time Maintained Above Liquidous (T_L)		
Liquidous Temperature (T_L)	183°C	217°C
Time (t_L)	60 sec to 150 sec	60 sec to 150 sec
Peak Temperature (T_P)	240°C + 0°C/−5°C	260°C + 0°C/−5°C
Time Within 5°C of Actual Peak Temperature (t_P)	10 sec to 30 sec	20 sec to 40 sec
Ramp-Down Rate	6°C/sec max	6°C/sec max
Time 25°C to Peak Temperature	6 minutes max	8 minutes max

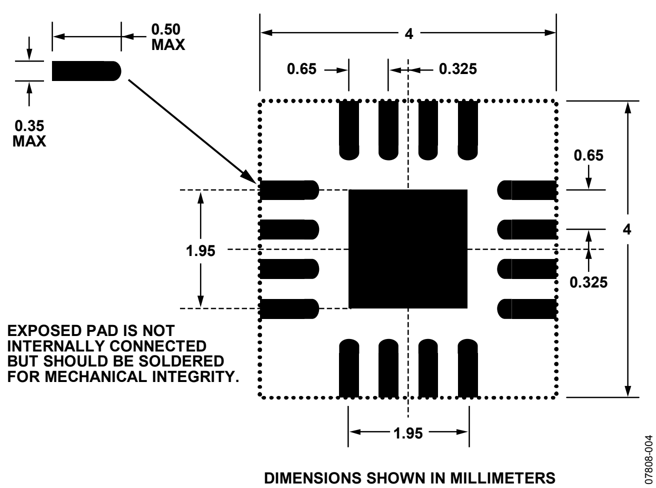


Figure 26. Recommended PCB Layout

OUTLINE DIMENSIONS

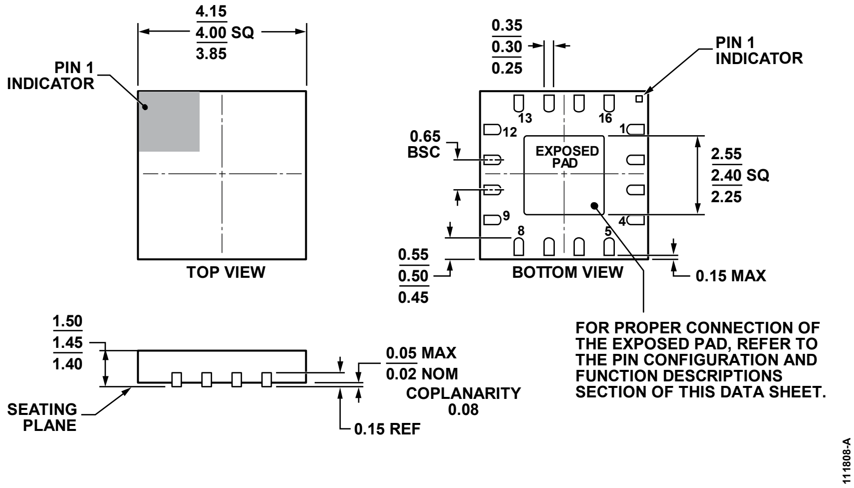


Figure 27. 16-Lead Lead Frame Chip Scale Package [LFCSP_LQ]
4 mm × 4 mm Body, 1.45 mm Thick Quad
(CP-16-14)
Dimensions shown in millimeters

ORDERING GUIDE

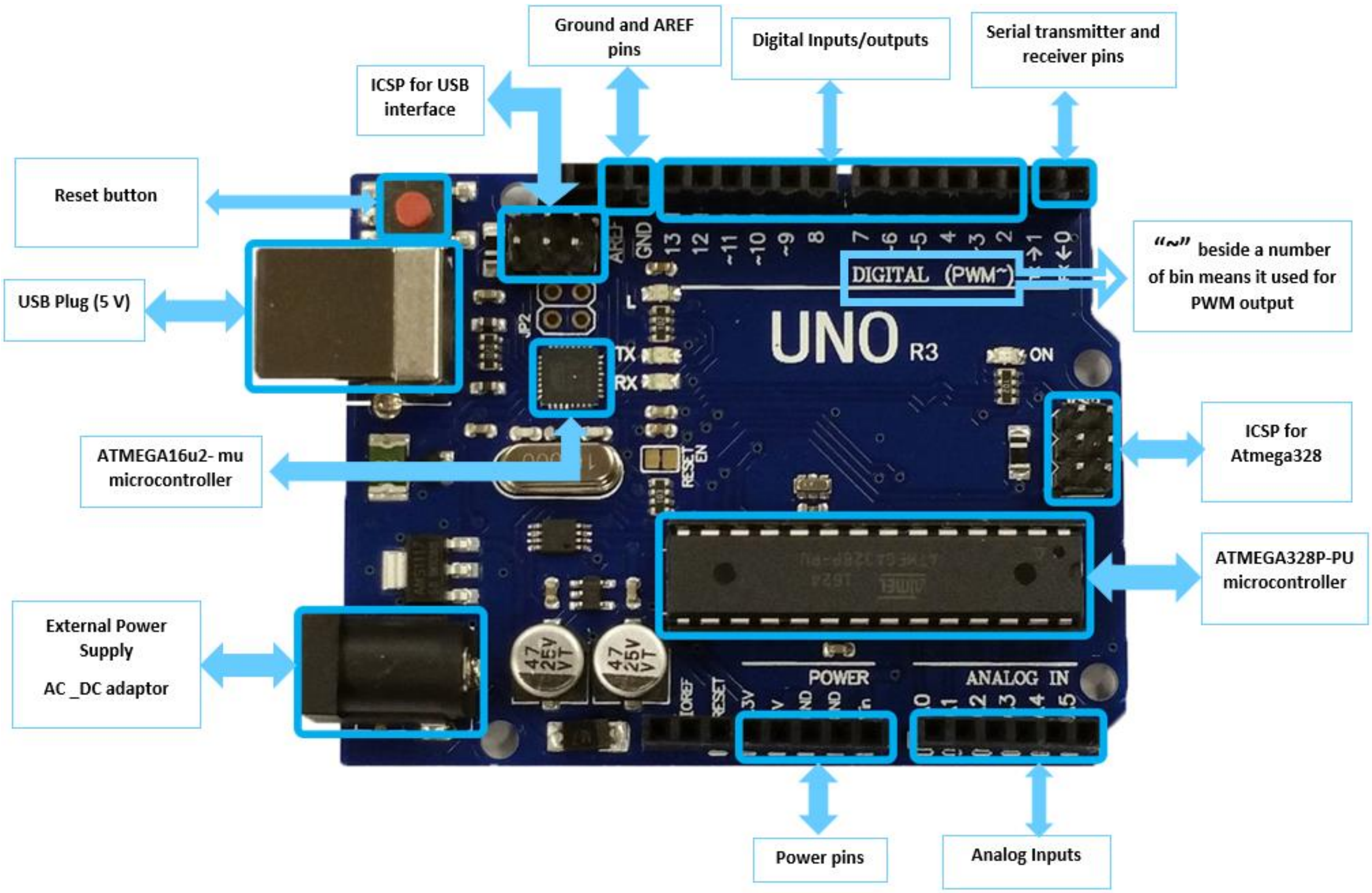
Model	Measurement Range	Specified Voltage	Temperature Range	Package Description	Package Option
ADXL335BCPZ[1]	±3 *g*	3 V	−40°C to +85°C	16-Lead LFCSP_LQ	CP-16-14
ADXL335BCPZ–RL[1]	±3 *g*	3 V	−40°C to +85°C	16-Lead LFCSP_LQ	CP-16-14
ADXL335BCPZ–RL7[1]	±3 *g*	3 V	−40°C to +85°C	16-Lead LFCSP_LQ	CP-16-14
EVAL-ADXL335Z[1]				Evaluation Board	

[1] Z = RoHS Compliant Part.

NOTES

NOTES

Arduino Uno R3



INTRODUCTION

Arduino is used for building different types of electronic circuits easily using of both a physical programmable circuit board usually microcontroller and piece of code running on computer with USB connection between the computer and Arduino.

Programming language used in Arduino is just a simplified version of C++ that can easily replace thousands of wires with words.

ARDUINO UNO-R3 PHYSICAL COMPONENTS

ATMEGA328P-PU microcontroller

The most important element in Arduino Uno R3 is ATMEGA328P-PU is an 8-bit Microcontroller with flash memory reach to 32k bytes. It's features as follow:

- High Performance, Low Power AVR
- Advanced RISC Architecture
  - 131 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Up to 20 MIPS Throughput at 20 MHz
  - On-chip 2-cycle Multiplier
- High Endurance Non-volatile Memory Segments
  - 4/8/16/32K Bytes of In-System Self-Programmable Flash program memory
  - 256/512/512/1K Bytes EEPROM
  - 512/1K/1K/2K Bytes Internal SRAM
  - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/100 years at 25°C
  - Optional Boot Code Section with Independent Lock Bits
  - In-System Programming by On-chip Boot Program
  - True Read-While-Write Operation
  - Programming Lock for Software Security
- Peripheral Features
  - Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
  - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  - Real Time Counter with Separate Oscillator
  - Six PWM Channels
  - 8-channel 10-bit ADC in TQFP and QFN/MLF package
  - Temperature Measurement
  - 6-channel 10-bit ADC in PDIP Package
  - Temperature Measurement
  - Programmable Serial USART

- Master/Slave SPI Serial Interface
- Byte-oriented 2-wire Serial Interface (Philips I2 C compatible)
- Programmable Watchdog Timer with Separate On-chip Oscillator
- On-chip Analog Comparator
- Interrupt and Wake-up on Pin Change

• Special Microcontroller Features

- Power-on Reset and Programmable Brown-out Detection
- Internal Calibrated Oscillator
- External and Internal Interrupt Sources
- Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby

• I/O and Packages

- 23 Programmable I/O Lines
- 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF

• Operating Voltage:

- 1.8 - 5.5V

• Temperature Range:

- -40°C to 85°C

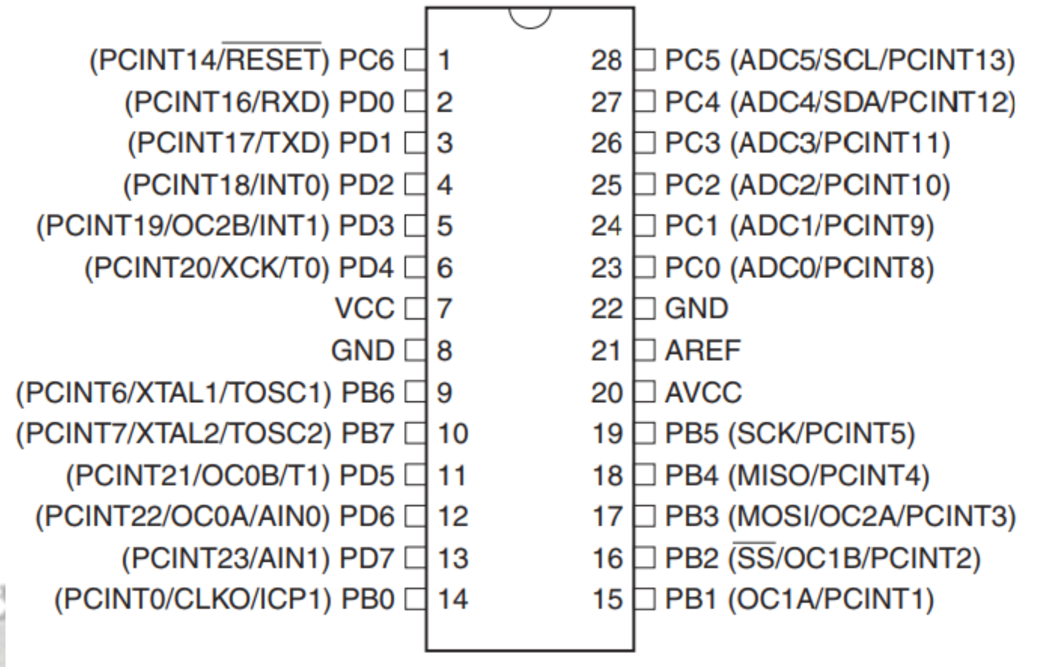
• Speed Grade:

- 0 - 4 MHz@1.8 - 5.5V, 0 - 10 MHz@2.7 - 5.5.V, 0 - 20 MHz @ 4.5 - 5.5V

• Power Consumption at 1 MHz, 1.8V, 25°C

- Active Mode: 0.2 mA
- Power-down Mode: 0.1 µA
- Power-save Mode: 0.75 µA (Including 32 kHz RTC)

- Pin configuration



ATMEGA16u2- mu microcontroller

Is a 8-bit microcontroller used as USB driver in Arduino uno R3 it's features as follow:

- High Performance, Low Power AVR

- Advanced RISC Architecture
  - 125 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 16 MIPS Throughput at 16 MHz

- Non-volatile Program and Data Memories
  - 8K/16K/32K Bytes of In-System Self-Programmable Flash
  - 512/512/1024 EEPROM
  - 512/512/1024 Internal SRAM
  - Write/Erase Cycles: 10,000 Flash/ 100,000 EEPROM
  - Data retention: 20 years at 85˚C/ 100 years at 25˚C

- Optional Boot Code Section with Independent Lock Bits
- In-System Programming by on-chip Boot Program hardware-activated after reset
- Programming Lock for Software Security

- **USB 2.0 Full-speed Device Module with Interrupt on Transfer Completion**
  - Complies fully with Universal Serial Bus Specification REV 2.0
  - 48 MHz PLL for Full-speed Bus Operation: data transfer rates at 12 Mbit/s
  - Fully independent 176 bytes USB DPRAM for endpoint memory allocation
  - Endpoint 0 for Control Transfers: from 8 up to 64-bytes
  - 4 Programmable Endpoints:
    - IN or Out Directions
    - Bulk, Interrupt and Isochronous Transfers
    - Programmable maximum packet size from 8 to 64 bytes
    - Programmable single or double buffer
  - Suspend/Resume Interrupts
  - Microcontroller reset on USB Bus Reset without detach
  - USB Bus Disconnection on Microcontroller Request

- **Peripheral Features**
  - One 8-bit Timer/Counters with Separate Prescaler and Compare Mode (two 8-bit PWM channels)
  - One 16-bit Timer/Counter with Separate Prescaler, Compare and Capture Mode(three 8-bit PWM channels)
  - USART with SPI master only mode and hardware flow control (RTS/CTS)
  - Master/Slave SPI Serial Interface
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
  - Interrupt and Wake-up on Pin Change

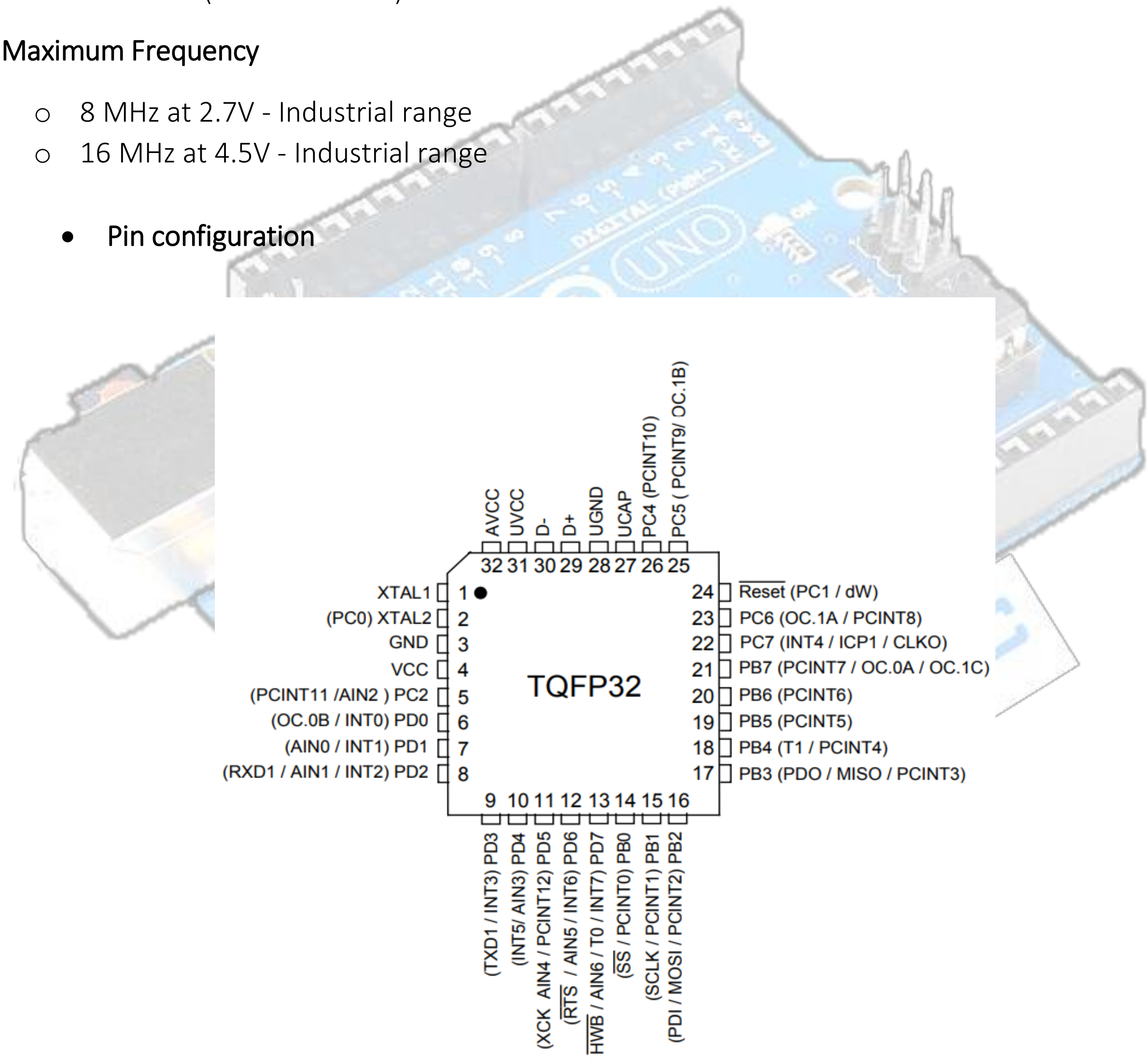
- **On Chip Debug Interface (debug WIRE)**

- **Special Microcontroller Features**
  - Power-On Reset and Programmable Brown-out Detection
  - Internal Calibrated Oscillator
  - External and Internal Interrupt Sources
  - Five Sleep Modes: Idle, Power-save, Power-down, Standby, and Extended Standby

- **I/O and Packages**
  - 22 Programmable I/O Lines
  - QFN32 (5x5mm) / TQFP32 packages

- Operating Voltages
  - 2.7 - 5.5V
- Operating temperature
  - Industrial (-40°C to +85°C)
- Maximum Frequency
  - 8 MHz at 2.7V - Industrial range
  - 16 MHz at 4.5V - Industrial range

- Pin configuration



OTHER ARDUINO UNO R3 PARTS

Input and Output

Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode (), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 k Ohms. In addition, some pins have specialized functions:

- Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.
- PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analogWrite() function.
- SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication using the SPI library.
- LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

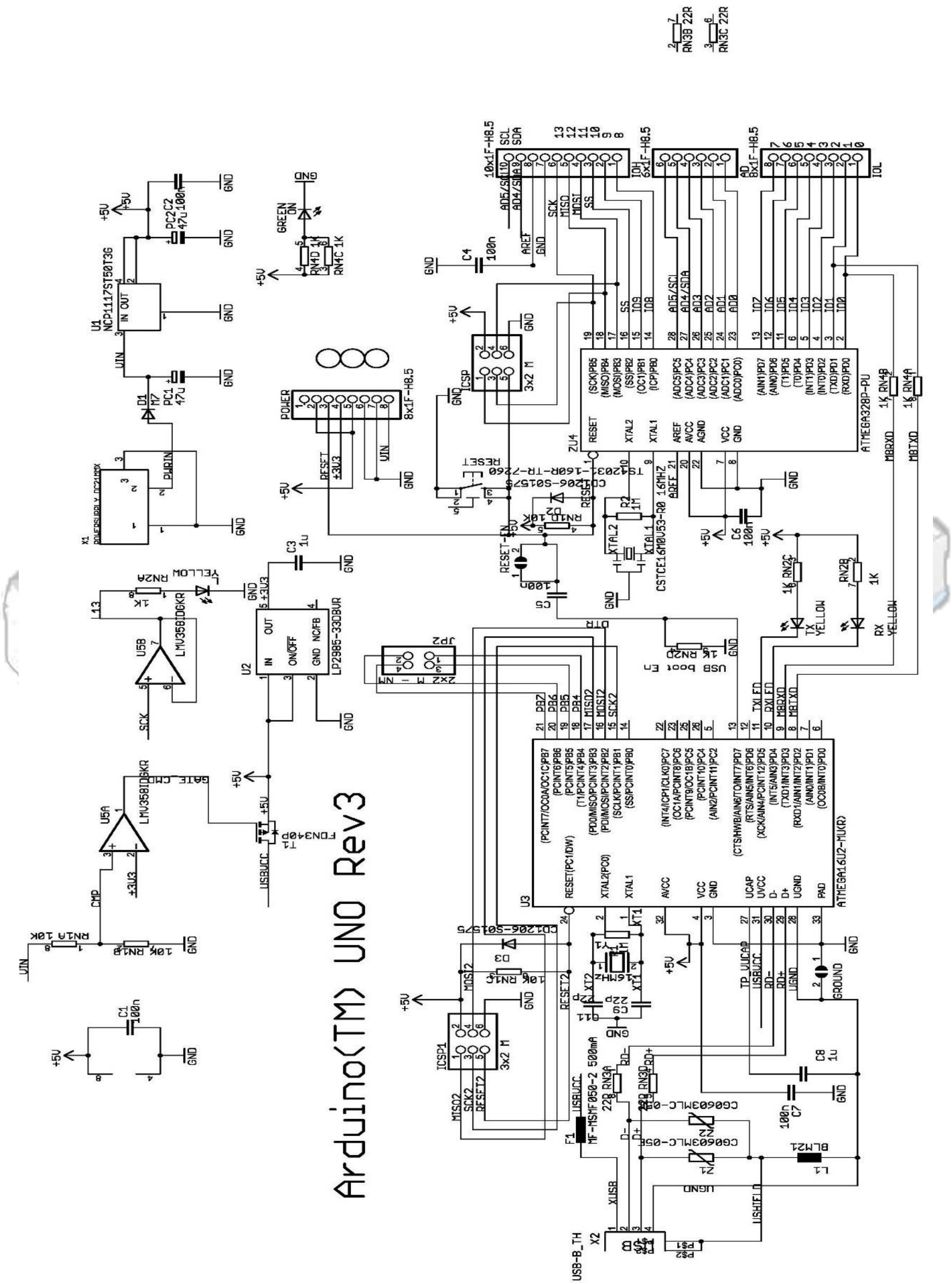
The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e.1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogReference() function. Additionally, some pins have specialized functionality:

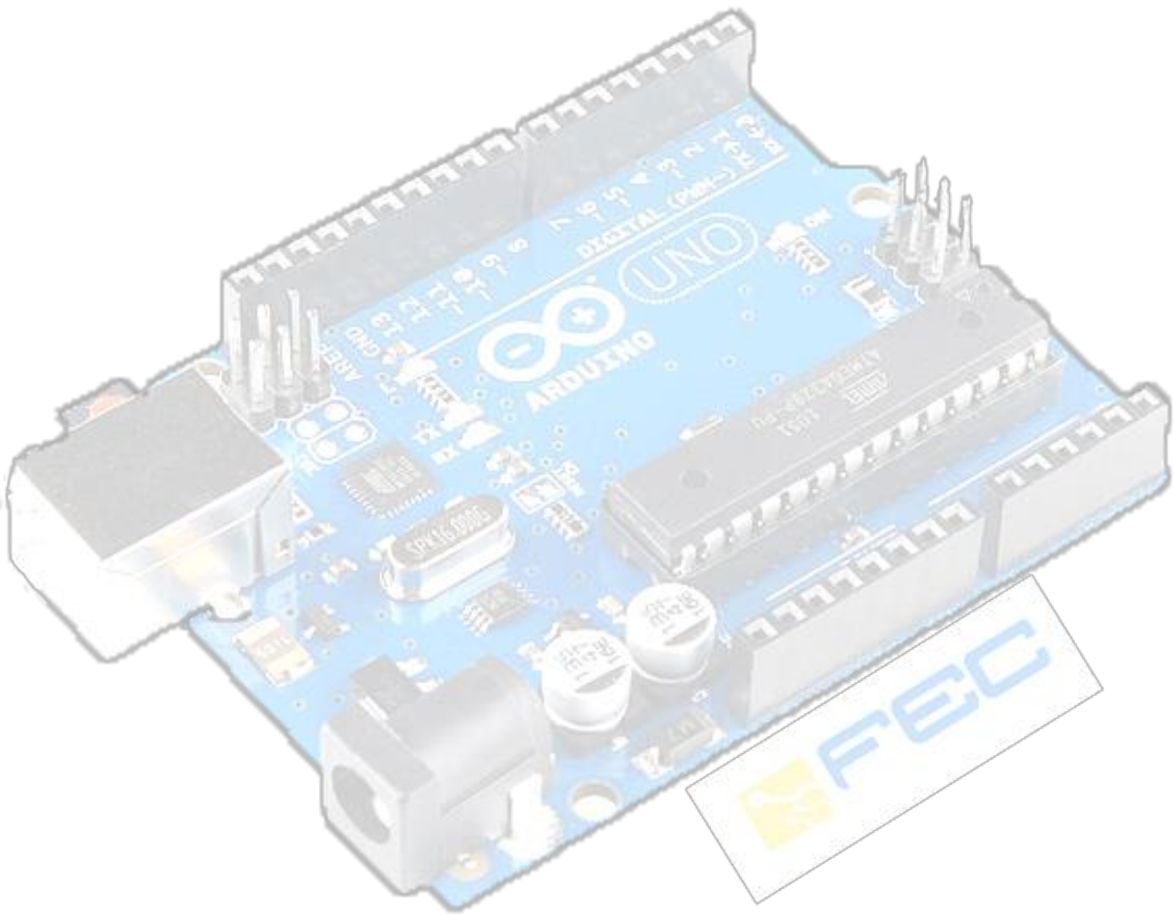
- TWI: A4 or SDA pin and A5 or SCL pin. Support TWI communication using the Wire library.

There are a couple of other pins on the board:

- AREF: Reference voltage for the analog inputs. Used with analogReference().
- Reset: Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

ARDUINO UNO R3 SCHEMATIC DIAGRAM




UNO
ARDUINO
FEC

ESP8266EX Datasheet

Version 4.3

Espressif Systems IOT Team

http://bbs.espressif.com/

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Table of Contents

1. General Overview

1.1. Introduction

Espressif Systems' Smart Connectivity Platform (ESCP) is a set of high performance, high integration wireless SOCs, designed for space and power constrained mobile platform designers. It provides unsurpassed ability to embed WiFi capabilities within other systems, or to function as a standalone application, with the lowest cost, and minimal space requirement.

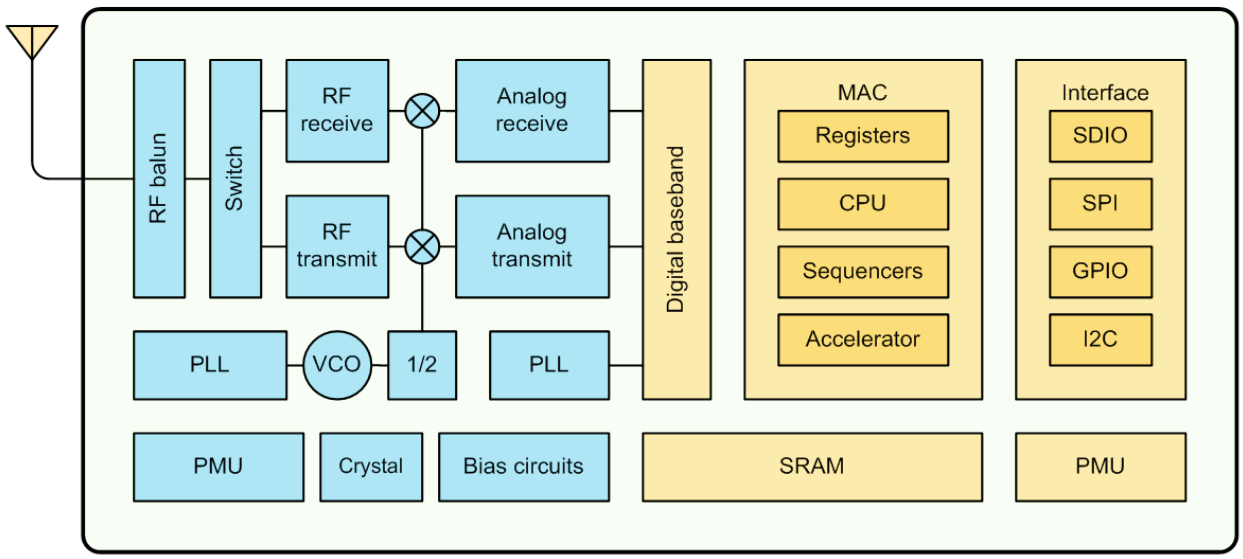


Figure 1 ESP8266EX Block Diagram

ESP8266EX offers a complete and self-contained WiFi networking solution; it can be used to host the application or to offload WiFi networking functions from another application processor.

When ESP8266EX hosts the application, it boots up directly from an external flash. In has integrated cache to improve the performance of the system in such applications.

Alternately, serving as a WiFi adapter, wireless internet access can be added to any micro controller-based design with simple connectivity (SPI/SDIO or I2C/UART interface).

ESP8266EX is among the most integrated WiFi chip in the industry; it integrates the antenna switches, RF balun, power amplifier, low noise receive amplifier, filters, power management modules, it requires minimal external circuitry, and the entire solution, including front-end module, is designed to occupy minimal PCB area.

ESP8266EX also integrates an enhanced version of Tensilica's L106 Diamond series 32-bit processor, with on-chip SRAM, besides the WiFi functionalities. ESP8266EX is often integrated with external sensors and other application specific devices through its GPIOs; sample codes for such applications are provided in the software development kit (SDK).

Espressif Systems' Smart Connectivity Platform (ESCP) demonstrates sophisticated system-level features include fast sleep/wake context switching for energy-efficient VoIP, adaptive radio biasing for low-power operation, advance signal processing, and spur cancellation and radio co-existence features for common cellular, Bluetooth, DDR, LVDS, LCD interference mitigation.

1.2. Features

- 802.11 b/g/n
- Integrated low power 32-bit MCU
- Integrated 10-bit ADC
- Integrated TCP/IP protocol stack
- Integrated TR switch, balun, LNA, power amplifier and matching network
- Integrated PLL, regulators, and power management units
- Supports antenna diversity
- WiFi 2.4 GHz, support WPA/WPA2
- Support STA/AP/STA+AP operation modes
- Support Smart Link Function for both Android and iOS devices
- SDIO 2.0, (H) SPI, UART, I2C, I2S, IR Remote Control, PWM, GPIO
- STBC, 1x1 MIMO, 2x1 MIMO
- A-MPDU & A-MSDU aggregation & 0.4s guard interval
- Deep sleep power <10uA, Power down leakage current < 5uA
- Wake up and transmit packets in < 2ms
- Standby power consumption of < 1.0mW (DTIM3)
- +20 dBm output power in 802.11b mode
- Operating temperature range -40C ~ 125C
- FCC, CE, TELEC, WiFi Alliance, and SRRC certified

1.3. Parameters

Table 1 Parameters

Categories	Items	Values
WiFi Paramters	Certificates	FCC/CE/TELEC/SRRC
	WiFi Protocles	802.11 b/g/n
	Frequency Range	2.4G-2.5G (2400M-2483.5M)
	Tx Power	802.11 b: +20 dBm
		802.11 g: +17 dBm
		802.11 n: +14 dBm
	Rx Sensitivity	802.11 b: -91 dbm (11 Mbps)
		802.11 g: -75 dbm (54 Mbps)
		802.11 n: -72 dbm (MCS7)
	Types of Antenna	PCB Trace, External, IPEX Connector, Ceramic Chip
Hardware Paramaters	Peripheral Bus	UART/SDIO/SPI/I2C/I2S/IR Remote Control
		GPIO/PWM
	Operating Voltage	3.0~3.6V
	Operating Current	Average value: 80mA
	Operating Temperature Range	-40°~125°
	Ambient Temperature Range	Normal temperature
	Package Size	5x5mm
	External Interface	N/A
Software Parameters	WiFi mode	station/softAP/SoftAP+station
	Security	WPA/WPA2
	Encryption	WEP/TKIP/AES
	Firmware Upgrade	UART Download / OTA (via network)
	Ssoftware Development	Supports Cloud Server Development / SDK for custom firmware development
	Network Protocols	IPv4, TCP/UDP/HTTP/FTP

	User Configuration	AT Instruction Set, Cloud Server, Android/ iOS App

1.4. Ultra Low Power Technology

ESP8266EX has been designed for mobile, wearable electronics and Internet of Things applications with the aim of achieving the lowest power consumption with a combination of several proprietary techniques. The power saving architecture operates mainly in 3 modes: active mode, sleep mode and deep sleep mode.

By using advance power management techniques and logic to power-down functions not required and to control switching between sleep and active modes, ESP8266EX consumes about than 60uA in deep sleep mode (with RTC clock still running) and less than 1.0mA (DTIM=3) or less than 0.5mA (DTIM=10) to stay connected to the access point.

When in sleep mode, only the calibrated real-time clock and watchdog remains active. The real-time clock can be programmed to wake up the ESP8266EX at any required interval.

The ESP8266EX can be programmed to wake up when a specified condition is detected. This minimal wake-up time feature of the ESP8266EX can be utilized by mobile device SOCs, allowing them to remain in the low-power standby mode until WiFi is needed.

In order to satisfy the power demand of mobile and wearable electronics, ESP8266EX can be programmed to reduce the output power of the PA to fit various application profiles, by trading off range for power consumption.

1.5. Major Applications

Major fields of ESP8266EX applications to Internet-of-Things include:

- Home Appliances
- Home Automation
- Smart Plug and lights
- Mesh Network
- Industrial Wireless Control
- Baby Monitors
- IP Cameras
- Sensor Networks
- Wearable Electronics

- WiFi Location-aware Devices
- Security ID Tags
- WiFi Position System Beacons

2. Hardware Overview

2.1. Pin Definitions

The pin assignments for 32-pin QFN package is illustrated in Fig.2.

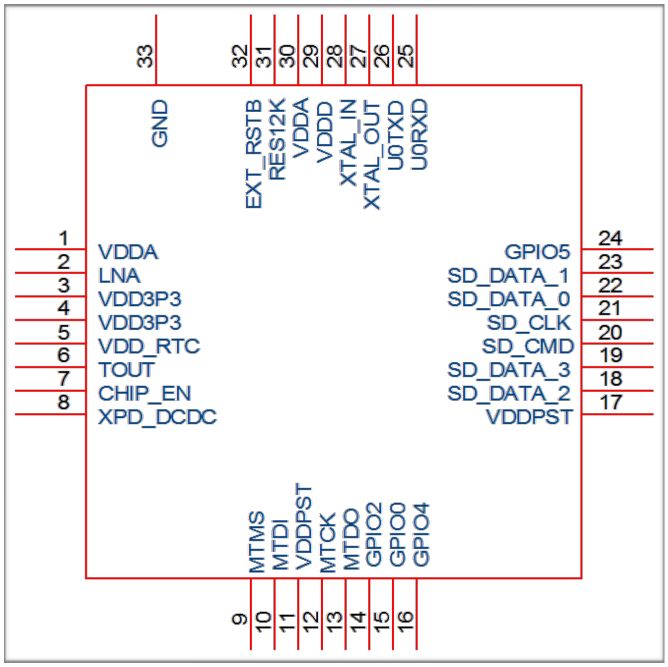


Figure 2 Pin Assignments

Table 2 below presents an overview on the general pin attributes and the functions of each pin.

Table 2 Pin Definitions

Pin	Name	Type	Function
1	VDDA	P	Analog Power 3.0 ~3.6V
2	LNA	I/O	RF Antenna Interface. Chip Output Impedance=50Ω No matching required but we recommend that the π-type matching network is retained.
3	VDD3P3	P	Amplifier Power 3.0~3.6V
4	VDD3P3	P	Amplifier Power 3.0~3.6V
5	VDD_RTC	P	NC (1.1V)

6	TOUT	I	ADC Pin (note: an internal pin of the chip) can be used to check the power voltage of VDD3P3 (Pin 3 and Pin4) or the input voltage of TOUT (Pin 6). These two functions cannot be used simultaneously.
7	CHIP_EN	I	Chip Enable. High: On, chip works properly; Low: Off, small current
8	XPD_DCDC	I/O	Deep-Sleep Wakeup； GPIO16
9	MTMS	I/O	GPIO14; HSPI_CLK
10	MTDI	I/O	GPIO12; HSPI_MISO
11	VDDPST	P	Digital/IO Power Supply (1.8V~3.3V)
12	MTCK	I/O	GPIO13; HSPI_MOSI; UART0_CTS
13	MTDO	I/O	GPIO15; HSPI_CS; UART0_RTS
14	GPIO2	I/O	UART Tx during flash programming; GPIO2
15	GPIO0	I/O	GPIO0; SPI_CS2
16	GPIO4	I/O	GPIO4
17	VDDPST	P	Digital/IO Power Supply (1.8V~3.3V)
18	SDIO_DATA_2	I/O	Connect to SD_D2 (Series R: 200Ω); SPIHD; HSPIHD; GPIO9
19	SDIO_DATA_3	I/O	Connect to SD_D3 (Series R: 200Ω); SPIWP; HSPIWP; GPIO10
20	SDIO_CMD	I/O	Connect to SD_CMD (Series R: 200Ω); SPI_CS0; GPIO11
21	SDIO_CLK	I/O	Connect to SD_CLK (Series R: 200Ω); SPI_CLK; GPIO6
22	SDIO_DATA_0	I/O	Connect to SD_D0 (Series R: 200Ω); SPI_MSIO; GPIO7
23	SDIO_DATA_1	I/O	Connect to SD_D1 (Series R: 200Ω); SPI_MOSI; GPIO8
24	GPIO5	I/O	GPIO5
25	U0RXD	I/O	UART Rx during flash programming; GPIO3
26	U0TXD	I/O	UART Tx during flash progamming; GPIO1; SPI_CS1
27	XTAL_OUT	I/O	Connect to crystal oscillator output, can be used to provide BT clock input
28	XTAL_IN	I/O	Connect to crystal oscillator input
29	VDDD	P	Analog Power 3.0V~3.6V
30	VDDA	P	Analog Power 3.0V~3.6V
31	RES12K	I	Serial connection with a 12 kΩ resistor and connect to the ground
32	EXT_RSTB	I	External reset signal (Low voltage level: Active)

Note: GPIO2, GPIO0, MTDO can be configurable as 3-bit SDIO mode.

2.2. Electrical Characteristics

Table 3 ESP8266EX Electrical Characteristics

Parameters		Conditions	Min	Typical	Max	Unit
Storage Temperature Range			-40	Normal	125	°C
Maximum Soldering Temperature		IPC/JEDEC J-STD-020			260	°C
Working Voltage Value			3.0	3.3	3.6	V
I/O	V_{IL}/V_{IH}		-0.3/0.75V_{IO}		0.25V_{IO}/3.6	V
I/O	V_{OL}/V_{OH}		N/0.8V_{IO}		0.1V_{IO}/N	V
I/O	I_{MAX}				12	mA
Electrostatic Discharge (HBM)		TAMB=25°C			2	KV
Electrostatic Discharge (CDM)		TAMB=25°C			0.5	KV

2.3. Power Consumption

The following current consumption is based on 3.3V supply, and 25°C ambient, using internal regulators. Measurements are done at antenna port without SAW filter. All the transmitter's measurements are based on 90% duty cycle, continuous transmit mode.

Table 4 Description on Power Consumption

Parameters	Min	Typical	Max	Unit
Tx802.11b, CCK 11Mbps, P OUT=+17dBm		170		mA
Tx 802.11g, OFDM 54Mbps, P OUT =+15dBm		140		mA
Tx 802.11n, MCS7, P OUT =+13dBm		120		mA
Rx 802.11b, 1024 bytes packet length , -80dBm		50		mA
Rx 802.11g, 1024 bytes packet length, -70dBm		56		mA
Rx 802.11n, 1024 bytes packet length, -65dBm		56		mA
Modem-Sleep①		15		mA
Light-Sleep②		0.9		mA
Deep-Sleep③		10		uA
Power Off		0.5		uA

①: Modem-Sleep requires the CPU to be working, as in PWM or I2S applications. According to 802.11 standards (like U-APSD), it saves power to shut down the WiFi Modem circuit while maintaining a WiFi connection with no data transmission. E.g. in DTIM3, to maintain a sleep 300ms-wake 3ms cycle to receive AP's Beacon packages, the current is about 15mA

②: During Light-Sleep, the CPU may be suspended in applications like WiFi switch. Without data transmission, the WiFi Modem circuit can be turned off and CPU suspended to save power according to the 802.11 standard (U-APSD). E.g. in DTIM3, to maintain a sleep 300ms-wake 3ms cycle to receive AP's Beacon packages, the current is about 0.9mA.

③: Deep-Sleep does not require WiFi connection to be maintained. For application with long time lags between data transmission, e.g. a temperature sensor that checks the temperature every 100s, sleep 300s and waking up to connect to the AP (taking about 0.3~1s), the overall average current is less than 1mA.

2.4. Receiver Sensitivity

The following are measured under room temperature conditions with 3.3V and 1.1V power supplies.

Table 5 Receiver Sensitivity

Parameters	Min	Typical	Max	Unit
Input frequency	2412		2484	MHz
Input impedance		50		Ω
Input reflection			-10	dB
Output power of PA for 72.2Mbps	15.5	16.5	17.5	dBm
Output power of PA for 11b mode	19.5	20.5	21.5	dBm
Sensitivity				
DSSS, 1Mbps		-98		dBm
CCK, 11Mbps		-91		dBm
6Mbps (1/2 BPSK)		-93		dBm
54Mbps (3/4 64-QAM)		-75		dBm
HT20, MCS7 (65Mbps, 72.2Mbps)		-72		dBm
Adjacent Channel Rejection				
OFDM, 6Mbps		37		dB
OFDM, 54Mbps		21		dB
HT20, MCS0		37		dB
HT20, MCS7		20		dB

2.5. MCU

ESP8266EX is embedded with Tensilica L106 32-bit micro controller (MCU), which features extra low power consumption and 16-bit RSIC. The CPU clock speed is 80MHz. It can also reach a maximum value of 160MHz. Real Time Operation System (RTOS) is enabled. Currently, only 20% of MIPS has been occupied by the WiFi stack, the rest can all be used for user application programming and development. The following interfaces can be used to connect to the MCU embedded in ESP8266EX:

- Programmable RAM/ROM interfaces (iBus), which can be connected with memory controller, and can also be used to visit external flash;
- Data RAM interface (dBus), which can connected with memory controller;
- AHB interface, can be used to visit the register.

2.6. Memory Organization

2.6.1. Internal SRAM and ROM

ESP8266EX WiFi SoC is embedded with memory controller, including SRAM and ROM. MCU can visit the memory units through iBus, dBus, and AHB interfaces. All memory units can be visited upon request, while a memory arbiter will decide the running sequence according to the time when these requests are received by the processor.

According to our current version of SDK provided, SRAM space that is available to users is assigned as below:

- **RAM size < 36kB,** that is to say, when ESP8266EX is working under the station mode and is connected to the router, programmable space accessible to user in heap and data section is around 36kB.)
- There is no programmable ROM in the SoC, therefore, user program must be stored in an external SPI flash.

2.6.2. External SPI Flash

An external SPI flash is used together with ESP8266EX to store user programs. Theoretically speaking, up to 16 Mbyte memory capacity can be supported.

Suggested SPI Flash memory capacity:

- OTA is disabled: the minimum flash memory that can be supported is 512 kByte;
- OTA is enabled: the minimum flash memory that can be supported is 1 Mbyte.

Several SPI modes can be supported, including Standard SPI, Dual SPI, DIO SPI, QIO SPI, and Quad SPI.

Therefore, please choose the correct SPI mode when you are downloading into the flash, otherwise firmwares/programs that you downloaded may not work in the right way.

2.7. AHB and AHB Blocks

The AHB blocks performs the function of an arbiter, controls the AHB interfaces from the MAC, SDIO (host) and CPU. Depending on the address, the AHB data requests can go into one of the two slaves:

APB block, or

flash controller (usually for standalone applications).

Data requests to the memory controller are usually high speed requests, and requests to the APB block are usually register access.

The APB block acts as a decoder. It is meant only for access to programmable registers within ESP8266's main blocks. Depending on the address, the APB request can go to the radio, SI/SPI, SDIO (host), GPIO, UART, real-time clock (RTC), MAC or digital baseband.

3. Pins and Definitions

The chipset encapsulates variable analog and data transmission I/Os, descriptions and definitions of which are explained below in detail.

3.1. GPIO

3.1.1. General Purpose Input/Output Interface (GPIO)

There are up to 17 GPIO pins. They can be assigned to various functions by the firmware. Each GPIO can be configured with internal pull-up (except XPD_DCDC, which is configured with internal pull-down), input available for sampling by a software register, input triggering an edge or level CPU interrupt, input triggering a level wakeup interrupt, open-drain or push-pull output driver, or output source from a software register, or a sigma-delta PWM DAC.

These pins are multiplexed with other functions such as I2C, I2S, UART, PWM, IR Remote Control, etc.

Data I/O soldering pad is bidirectional and tri-state that include data input and output controlling buffer. Besides, I/O can be set as a specific state and remains like this. For example, if you intend to lower the power consumption of the chip, all data input and output enable signals can be set as remaining low power state. You can transport some specific state into the I/O. When the I/O is not powered by external circuits, the I/O will remain to be the state that it was used the last time. Some positive feedback is generated by the state-remaining function of the pins, therefore, if the external driving power must be stronger than the positive feedback. Even so, the driving power that is needed is within 5uA.

Table 6 Pin Definitions of GPIOs

Variables	Symbol	Min	Max	Unit
Input Low Voltage	V_{IL}	-0.3	$0.25\times V_{IO}$	V
Input High Voltage	V_{IH}	$0.75\times V_{IO}$	3.3	V
Input Leakage Current	I_{IL}		50	nA
Output Low Voltage	V_{OL}		$0.1\times V_{IO}$	V
Output High Voltage	V_{OH}	$0.8\times V_{IO}$		V
Input Pin Resistance Value	C_{pad}		2	pF
VDDIO	V_{IO}	1.8	3.3	V
Maximum Driving Power	I_{MAX}		12	mA
Temerpature	T_{amb}	-40	125	°C

All digital IO pins are protected from over-voltage with a snap-back circuit connected between the pad and ground. The snap back voltage is typically about 6V, and the holding voltage is 5.8V. This

provides protection from over-voltages and ESD. The output devices are also protected from reversed voltages with diodes.

3.2. Secure Digital Input/Output Interface (SDIO)

One Slave SDIO has been defined by ESP8266EX, the definitions of which are described in Table 7 below. 4bit 25MHz SDIO v1.1 and 4bit 50MHz SDIO v2.0 are supported.

Table 7 Pin Definitions of SDIOs

Pin Name	Pin Num	IO	Function Name
SDIO_CLK	21	IO6	SDIO_CLK
SDIO_DATA0	22	IO7	SDIO_DATA0
SDIO_DATA1	23	IO8	SDIO_DATA1
SDIO_DATA_2	18	IO9	SDIO_DATA_2
SDIO_DATA_3	19	IO10	SDIO_DATA_3
SDIO_CMD	20	IO11	SDIO_CMD

3.3. Serial Peripheral Interface (SPI/HSPI)

Currently, one general Slave/Master SPI, one Slave SDID/SPI, and one general Slave/Master HSPI have been defined by ESP8266EX. Functions of all these pins can be implemented via hardware. The pin definitions are are described below:

3.3.1. General SPI (Master/Slave)

Table 8 Pin Definitions of General SPIs

Pin Name	Pin Num	IO	Function Name
SDIO_CLK	21	IO6	SPICLK
SDIO_DATA0	22	IO7	SPIQ/MISO
SDIO_DATA1	23	IO8	SPID/MOSI
SDIO_DATA_2	18	IO9	SPIHD
SDIO_DATA_3	19	IO10	SPIWP
SDIO_CMD	20	IO11	SPICS0
U0TXD	26	IO1	SPICS1
GPIO0	15	IO0	SPICS2

3.3.2. SDIO / SPI (Slave)

Table 9 Pin Definitions of SDIO / SPI (Slave)

Pin Name	Pin Num	IO	Function Name
SDIO_CLK	21	IO6	SPI_SLAVE_CLK
SDIO_DATA0	22	IO7	SPI_SLAVE_MISO
SDIO_DATA1	23	IO8	SPI_SLAVE_INT
SDIO_DATA_2	18	IO9	NC
SDIO_DATA_3	19	IO10	SPI_SLAVE_CS
SDIO_CMD	20	IO11	SPI_SLAVE_MOSI

3.3.3. HSPI (Master/Slave)

Table 10 Pin Definitions of HSPI (Master/Slave)

Pin Name	Pin Num	IO	Function Name
MTMS	9	IO14	HSPICLK
MTDI	10	IO12	HSPIQ/MISO
MTCK	12	IO13	HSPID/MOSI
MTDO	13	IO15	HPSICS

Note:

- SPI mode can be implemented via software programming. The clock frequency can reach up to a maximum value of 80MHz.
- Function of Slave SDIO/SPI interface can be implemented via hardware, and linked list DMA (Direct Memory Access) is supported, software overheads are smaller. However, there is no linked list DMA on general SPI and HSPI, and the software overheads are larger, therefore, the data transmitting speed will be restrained by software processing speed.

3.4. Inter-integrated Circuit Interface (I2C)

One I2C, which is mainly used to connect with micro controller and other peripheral equipment such as sensors, is defined by ESP8266EX. The present pin definition of I2C is as defined below:

Table 11 Pin Definitions of I2C

Pin Name	Pin Num	IO	Function Name
MTMS	9	IO14	I2C_SCL
GPIO2	14	IO2	I2C_SDA

Both I2C-Master and I2C-Slave are supported. I2C interface functionality can be realized via software programming, the clock frequency can be up to around 100KHz at most. It should be noted that I2C clock frequency should be higher than the slowest clock frequency of the slave device.

3.5. I2S

Currently one I2S data input interface and one I2S data output interface are defined. I2S interface is mainly used in applications such as data collection, processing, and transmission of audio data, as well as the input and output of serial data. For example, LED lights (WS2812 series) are supported. The pin definition of I2S is as defined below:

Table 12 Pin Definitions of I2S

I2S Data Input:			
Pin Name	**Pin Num**	**IO**	**Function Name**
MTDI	10	IO12	I2SI_DATA
MTCK	12	IO13	I2SI_BCK
MTMS	9	IO14	I2SI_WS
I2S Data Output:			
Pin Name	**Pin Num**	**IO**	**Function Name**
MTDO	13	IO15	I2SO_BCK
U0RXD	25	IO3	I2SO_DATA
GPIO2	14	IO2	I2SO_WS

I2S functionality can be realized via software programming, the GPIOs that will be used are multiplexed, and linked list DMA is supported.

3.6. Universal Asynchronous Receiver Transmitter (UART)

Two UART interfaces, UART0 and UART1, have been defined by ESP8266EX, the definitions are as below:

Table 13 Pin Definitions of UART Interfaces

Pin Type	Pin Name	Pin Num	IO	Function Name
UART0	U0RXD	25	IO3	U0RXD
	U0TXD	26	IO1	U0TXD
	MTDO	13	IO15	U0RTS
	MTCK	12	IO13	U0CTS
UART1	GPIO2	14	IO2	U1TXD
	SD_D1	23	IO8	U1RXD

Data transfers to/from UART interfaces can be implemented via hardware. The data transmission speed via UART interfaces can reach 115200*40 (4.5Mbps).

UART0 can be for communication. It supports fluid control. Since UART1 features only data transmit signal (Tx), it is usually used for printing log.

Notes: By default, UART0 will output some printed information when the device is powered on and is booting up. The baud rate of the printed information is closely related to the frequency of the external crystal oscillator. If the frequency of the crystal oscillator is 40MHz, then the baud rate for printing is 115200; if the frequency of the crystal oscillator is 26MHz, then the baud rate for printing is 74880. If the printed information exerts any influence on the functionality of your device, you'd better block the printing during the power-on period by changing (`U0TXD,U0RXD`) to (`MTDO,MTCK`).

3.7. Pulse-Width Modulation (PWM)

Four PWM output interfaces have been defined by ESP8266EX. They can be extended by users themselves. The present pin definitions of the PWM interfaces are defined as below:

Table 14 Pin Definitions of PWM Interfaces

Pin Name	Pin Num	IO	Function Name
MTDI	10	IO12	PWM0
MTDO	13	IO15	PWM1
MTMS	9	IO14	PWM2
GPIO4	16	IO4	PWM3

The functionality of PWM interfaces can be implemented via software programming. For example, in the LED smart light demo, the function of PWM is realized by interruption of the timer, the minimum resolution can reach as much as 44 ns. PWM frequency range is adjustable from 1000 us to 10000 us,

i.e., between 100Hz and 1KHz. When the PWM frequency is at 1 KHz, the duty ratio will reach 1/22727, and over 14 bit resolution will be achieved at 1KHz refresh rate.

3.8. IR Remote Control

Currently, only one Infrared remote control interface is defined, the pin definition is as below:

Table 14 Pin Definition of IR Remote Control

Pin Name	Pin Num	IO	Function Name
MTMS	9	IO12	IR Tx
GPIO5	24	IO5	IR Rx

The functionality of Infrared remote control interface can be implemented via software programming. NEC coding, modulation, and demodulation are used by this interface. The frequency of modulated carrier signal is 38KHz, while the duty ratio of the square wave is 1/3. The length of data transmission, which is around 1m, is determined by two factors: one is the maximum value of rated current, the other is internal current-limiting resistance value in the infrared receiver. The larger the resistance value, the lower the current, so is the power, and vice versa. The transmission angle is between 15° and 30°, and is mainly determined by the radiation direction of the infrared receiver.

Notes: Among the eight interfaces mentioned above, most of them can be multiplexed. Pin definitions that can be defined is not limited to the eight ones herein mentioned, customers can self customise the functions of the pins according to their specific application scenarios. Functions of these pins can be implemented via software programming and hardware.

3.9. ADC (Analog-to-digital Converter)

ESP8266EX is embedded with a 10-bit precision SARADC. Currently, TOUT (Pin6) is defined as ADC interface, the definition of which is described below:

Pin Name	Pin Num	Function Name
TOUT	6	ADC Interface

Table 16 Pin Definition of ADC

The following two applications can be implemented using ADC (Pin6). However, these two applications cannot be implemented concurrently.

- Test the power supply voltage of VDD3P3 (Pin 3 and Pin 4).

The function used to test the power supply voltage on PA_VDD pin is: `uint16 system_get_vdd33(void)`

- Test the input voltage of TOUT (Pin 6):

The function used to test the input voltage of TOUT is: `uint16 system_adc_read(void)`

`RF-init` parameter in the following passage refers to `esp_init_data_default.bin`

Application One:	Test the power supply voltage of VDD3P3 (Pin 3 and Pin 4).
Hardware Design:	TOUT must be dangled.
`RF-init` Parameter:	The 107th byte of `esp_init_data_default.bin` (0 - 127 byte), "vdd33_const", must set to be 0xFF, i.e., the value of "vdd33_const" is 255.
RF Calibration Process:	Optimize the RF circuit conditions based on the testing results of VDD3P3 (Pin 3 and Pin 4).
User Programming:	Use `system_get_vdd33` instead of `system_adc_read`.

Application Two:	Test the input voltage of TOUT (Pin 6).
Hardware Design:	The input voltage range is 0 to 1.0 V when TOUT is connected to external circuit.
`RF-init` Parameter:	The value of the 107th byte of `esp_init_data_default.bin` (0 - 127 byte), "vdd33_const", must be set to be the real power supply voltage of Pin 3 and Pin 4. The working power voltage range of ESP8266EX is between 1.8V and 3.6V, while the unit of "vdd33_const" is 0.1V, therefore, the effective value range of "vdd33_const" is 18 to 36.
RF Calibration Process:	Optimize the RF circuit conditions based on the value of "vdd33_const". The permissible error is ±0.2V.
User Programming:	Use `system_adc_read` instead of `system_get_vdd33`.

Note One:

In `RF_init` parameter `esp_init_data_default.bin` (0 - 127 byte), the 107th byte is defined as "vdd33_const". Definitions of "vdd33_const" is described below:

（1） If vdd33_const = 0xff, the power voltage of Pin 3 and Pin 4 will be tested by the internal self-calibration process of ESP8266EX chipset itself. RF circuit conditions should be optimized according to the testing results.

(2) If 18 =< vdd33_const =< 36, ESP8266EX RF Calibration and optimization process is implemented via (vdd33_const/10).

(3) If vdd33_const < 18 or 36 < vdd33_const < 255, ESP8266EX RF Calibration and optimization process is implemented via the default value 3.0V.

Note Two:

Function `system_get_vdd33` is used to test the power supply voltage of VDD3P3 (Pin 3 and Pin 4). Details on this function are described below:

(1) Pin Tout must be dangled. The 107th byte of `esp_init_data_default.bin` (0 - 127 byte), “vdd33_const“, must set to be 0xFF.

(2) If the 107th byte of `esp_init_data_default.bin` (0 - 127 byte), “vdd33_const“, is equal to `0xff`, the returned value of function `system_get_vdd33` will be an effective value, otherwise `0xffff` will be returned.

(3) The unit of the returned value is: 1/1024 V.

Note Three:

Function system_adc_read is defined to test the input voltage of Pin TOUT (Pin 6). Details on this function are described below:

(1) The value of the 107th byte of `esp_init_data_default.bin` (0 - 127 byte), “vdd33_const“, must be set to be the real power supply voltage of Pin 3 and Pin 4.

(2) If the 107th byte of `esp_init_data_default.bin` (0 - 127 byte), “vdd33_const“, is NOT equal to `0xff`, the returned value of `system_adc_read` will be an effective value of the input voltage of Pin TOUT, otherwise `0xffff` will be returned.

(3) The unit of the returned value is: 1/1024 V.

3.10. LED Light and Button

ESP8266EX features up to 17 GPIOs, all of which can be assigned to realise various functions of LED lights and buttons. Definitions of some GPIOs that are assigned with certain functions in our demo application design are shown below:

Table 17 Pin Definitions of LED and Button

Pin Name	Pin Num	IO	Function Name
MTCK	12	IO13	Button (Reset)
GPIO0	15	IO0	WiFi Light
MTDI	10	IO12	Link Light

Altogether three interfaces have been defined, one is for the button, and the other two is for LED light. Generally, **MTCK** is used to control the reset button, **GPIO0** is used as an signal to indicate the WiFi working state, **MTDI** is used as a signal light to indicate communication between the device and the server.

Note: Among the nine interfaces mentioned above, most of them can be multiplexed. Pin definitions that can be defined is not limited to the eight ones herein mentioned, customers can self customise the functions of the pins according to their specific application scenarios. Functions of these pins can be implemented via software programming and hardware.

4. Firmware & Software Development Kit

The application and firmware is executed in on-chip ROM and SRAM, which loads the instructions during wake-up, through the SDIO interface, from the external flash.

The firmware implements TCP/IP, the full 802.11 b/g/n/e/i WLAN MAC protocol and WiFi Direct specification. It supports not only basic service set (BSS) operations under the distributed control function (DCF) but also P2P group operation compliant with the latest WiFi P2P protocol. Low level protocol functions are handled automatically by ESP8266:

- RTS/CTS
- acknowledgement
- fragmentation and defragmentation
- aggregation
- frame encapsulation (802.11h/RFC 1042)
- automatic beacon monitoring / scanning, and
- P2P WiFi direct

Passive or active scanning, as well as P2P discovery procedure is performed autonomously once initiated by the appropriate command. Power management is handled with minimum host interaction to minimize active duty period.

4.1. Features

The SDK includes the following library functions:

- 802.11 b/g/n/d/e/i/k/r support;
- WiFi Direct (P2P) support:
- P2P Discovery, P2P Group Owner mode, P2P Power Management
- Infrastructure BSS Station mode / P2P mode / softAP mode support;
- Hardware accelerators for CCMP (CBC-MAC, counter mode), TKIP (MIC, RC4), WAPI (SMS4), WEP (RC4), CRC;
- WPA/WPA2 PSK, and WPS driver;
- Additional 802.11i security features such as pre-authentication, and TSN;
- Open Interface for various upper layer authentication schemes over EAP such as TLS, PEAP, LEAP, SIM, AKA, or customer specific;
- 802.11n support (2.4GHz);
- Supports MIMO 1×1 and 2×1, STBC, A-MPDU and A-MSDU aggregation and 0.4μs guard interval;

- WMM power save U-APSD;
- Multiple queue management to fully utilize traffic prioritization defined by 802.11e standard;
- UMA compliant and certified;
- 802.1h/RFC1042 frame encapsulation;
- Scattered DMA for optimal CPU off load on Zero Copy data transfer operations;
- Antenna diversity and selection (software managed hardware);
- Clock/power gating combined with 802.11-compliant power management dynamically adapted to current connection condition providing minimal power consumption;
- Adaptive rate fallback algorithm sets the optimum transmission rate and Tx power based on actual SNR and packet loss information;
- Automatic retransmission and response on MAC to avoid packet discarding on slow host environment;
- Seamless roaming support;
- Configurable packet traffic arbitration (PTA) with dedicated slave processor based design provides flexible and exact timing Bluetooth co-existence support for a wide range of Bluetooth Chip vendors;
- Dual and single antenna Bluetooth co-existence support with optional simultaneous receive (WiFi/Bluetooth) capability.

5. Power Management

The chip can be put into the following states:

- **OFF**: CHIP_PD pin is low. The RTC is disabled. All registers are cleared.
- **DEEP_SLEEP**: Only RTC is powered on – the rest of the chip is powered off. Recovery memory of RTC can keep basic WiFi connecting information.
- **SLEEP**: Only the RTC is operating. The crystal oscillator is disabled. Any wakeup events (MAC, host, RTC timer, external interrupts) will put the chip into the WAKEUP state.
- **WAKEUP**: In this state, the system goes from the sleep states to the PWR state. The crystal oscillator and PLLs are enabled.
- **ON**: the high speed clock is operational and sent to each block enabled by the clock control register. Lower level clock gating is implemented at the block level, including the CPU, which can be gated off using the WAITI instruction, while the system is on.

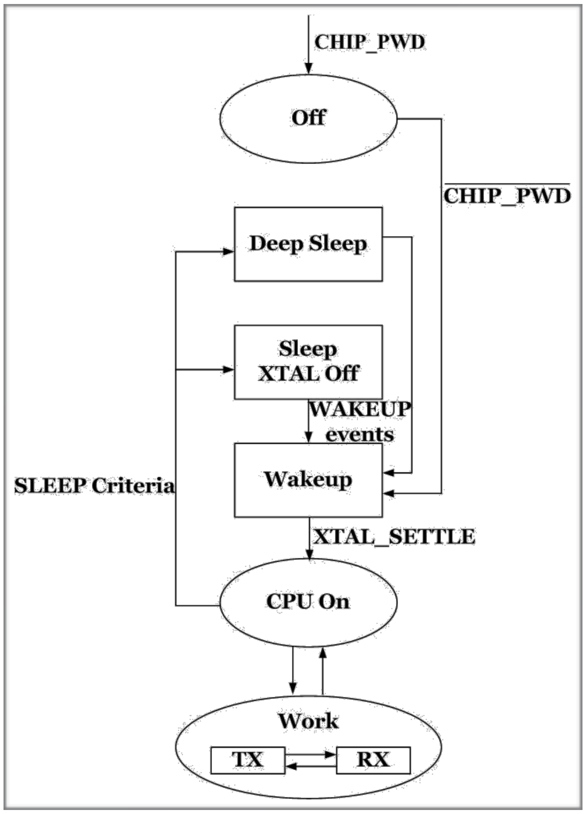


Figure 3 Illustration of Power Management

6. Clock Management

6.1. High Frequency Clock

The high frequency clock on ESP8266EX is used to drive both transmit and receive mixers. This clock is generated from the internal crystal oscillator and an external crystal. The crystal frequency can range from 26MHz to 52MHz.

While internal calibration of the crystal oscillator ensures that a wide range of crystals can be used, in general, the quality of the crystal is still a factor to consider, to have reasonable phase noise that is required for good performance. When the crystal selected is sub-optimal due to large frequency drifts or poor Q-factor, the maximum throughput and sensitivity of the WiFi system is degraded. Please refer to the application notes on how the frequency offset can be measured.

Table 18 High Frequency Clock

Parameter	Symbol	Min	Max	Unit
Frequency	FXO	26	52	MHz
Loading capacitance	CL		32	pF
Motional capacitance	CM	2	5	pF
Series resistance	RS	0	65	Ω
Frequency tolerance	ΔFXO	-15	15	ppm
Frequency vs temperature (-25°C ~ 75°C)	ΔFXO,Temp	-15	15	ppm

6.2. External Reference Requirements

For an externally generated clock, the frequency can range from 26MHz to 52MHz can be used. For good performance of the radio, the following characteristics are expected of the clock:

Table 19 External Clock Reference

Parameter	Symbol	Min	Max	Unit
Clock amplitude	VXO	0.2	1	Vpp
External clock accuracy	ΔFXO,EXT	-15	15	ppm
Phase noise @1kHz offset, 40MHz clock			-120	dBc/Hz
Phase noise @10kHz offset, 40MHz clock			-130	dBc/Hz
Phase noise @100kHz offset, 40MHz clock			-138	dBc/Hz

7. Radio

The ESP8266EX radio consists of the following main blocks:

- 2.4GHz receiver
- 2.4GHz transmitter
- High speed clock generators and crystal oscillator
- Real time clock
- Bias and regulators
- Power management

7.1. Channel Frequencies

The RF transceiver supports the following channels according to the IEEE802.11b/g/n standards.

Table 20 Frequency Channel

Channel No	Frequency (MHz)	Channel No	Frequency (MHz)
1	2412	8	2447
2	2417	9	2452
3	2422	10	2457
4	2427	11	2462
5	2432	12	2467
6	2437	13	2472
7	2442	14	2484

7.2. 2.4 GHz Receiver

The 2.4GHz receiver downconverts the RF signal to quadrature baseband signals and converts them to the digital domain with 2 high resolution high speed ADCs. To adapt to varying signal channel conditions, RF filters, automatic gain control (AGC), DC offset cancelation circuits and baseband filters are integrated within ESP8266EX.

7.3. 2.4 GHz Transmitter

The 2.4GHz transmitter up-converts the quadrature baseband signals to 2.4GHz, and drives the antenna with a high powered CMOS power amplifier. The use of digital calibration further improves the linearity of the power amplifier, enabling a state of art performance of delivering +19.5dBm average power for 802.11b transmission and +16dBm for 802.11n transmission.

Additional calibrations are integrated to cancel any imperfections of the radio, such as:

- carrier leakage,
- I/Q phase matching, and
- baseband nonlinearities

This reduces the amount of time required and test equipment required for production testing.

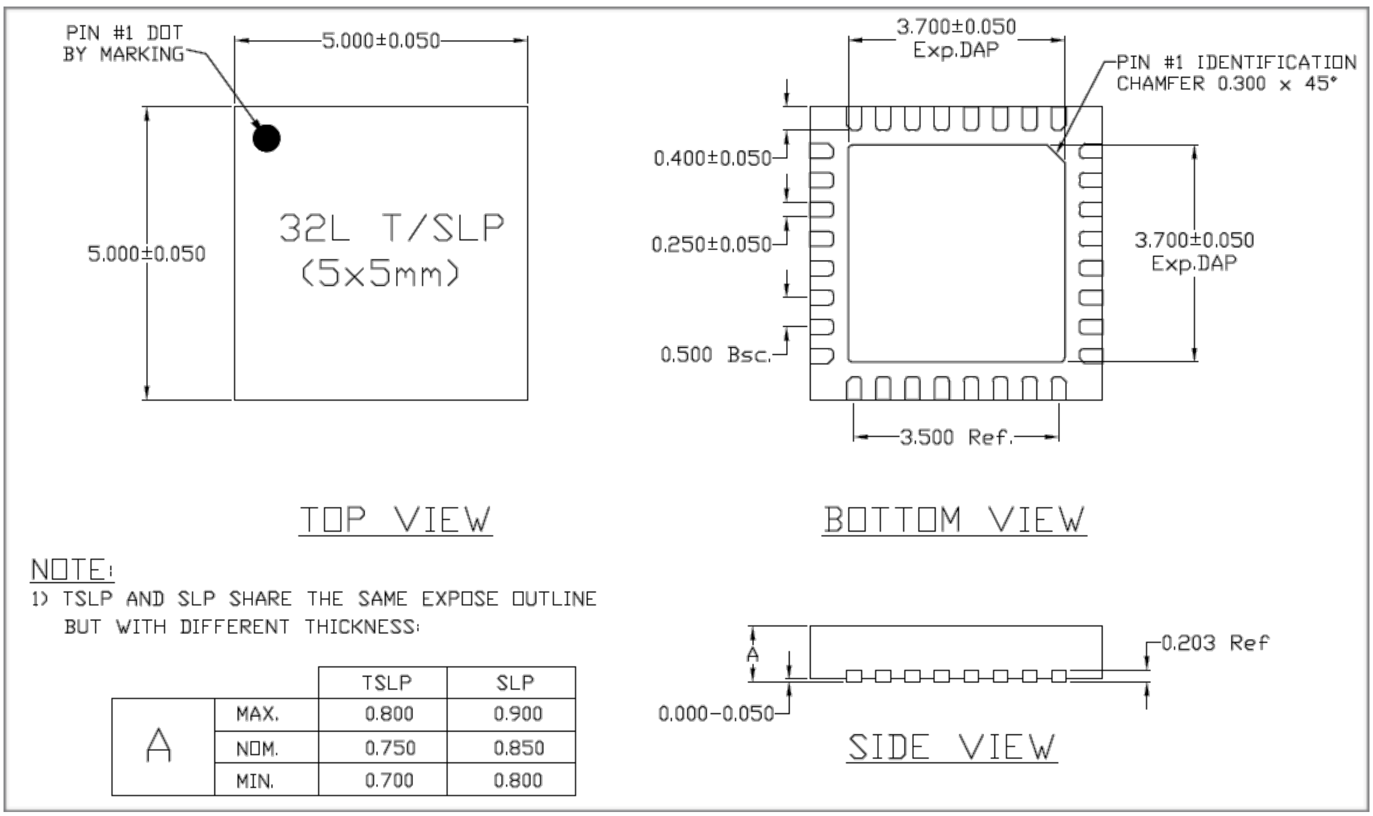
7.4. Clock Generator

The clock generator generates quadrature 2.4 GHz clock signals for the receiver and transmitter. All components of the clock generator are integrated on-chip, including:

- inductor,
- varactor, and
- loop filter

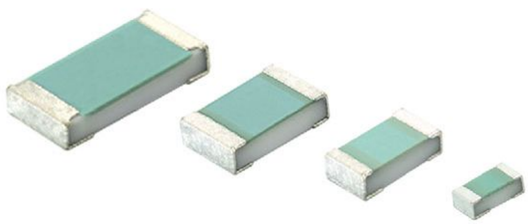
The clock generator has built-in calibration and self test circuits. Quadrature clock phases and phase noise are optimized on-chip with patented calibration algorithms to ensure the best receiver and transmitter performance.

8. Appendix: QFN32 Package Size



		TSLP	SLP
A	MAX.	0.800	0.900
	NOM.	0.750	0.850
	MIN.	0.700	0.800

Professional Thin Film Chip Resistors



MCS 0402, MCT 0603, MCU 0805, and MCA 1206 professional thin film flat chip resistors are the perfect choice for most fields of modern professional electronics where reliability and stability are of major concern. Typical applications include telecommunication, medical equipment, high-end computer and audio / video electronics.

FEATURES

- Approved to EN 140401-801
- Excellent overall stability: class 0.5
- Professional tolerance of resistance: ± 0.5 % and ± 1 %
- Rated dissipation P_{70} up to 0.4 W for size 1206
- Sulfur resistance verified according to ASTM B 809
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

RoHS COMPLIANT

APPLICATIONS

- Automotive
- Telecommunication
- Medical equipment
- Industrial equipment

TECHNICAL SPECIFICATIONS				
DESCRIPTION	**MCS 0402**	**MCT 0603**	**MCU 0805**	**MCA 1206**
Imperial size	0402	0603	0805	1206
Metric size code	RR1005M	RR1608M	RR2012M	RR3216M
Resistance range	10 Ω to 4.99 MΩ; 0 Ω	1 Ω to 10 MΩ; 0 Ω	1 Ω to 10 MΩ; 0 Ω	1 Ω to 2 MΩ; 0 Ω
Resistance tolerance	± 1 %; ± 0.5 %			
Temperature coefficient	± 50 ppm/K; ± 25 ppm/K			
Rated dissipation, P_{70} (1)	0.100 W	0.125 W	0.200 W	0.400 W
Operating voltage, $U_{max.}$ AC_{RMS}/DC	50 V	75 V	150 V	200 V
Permissible film temperature, $\vartheta_{F\ max.}$ (1)	155 °C			
Operating temperature range	-55 °C to 155 °C			
Permissible voltage against ambient (insulation): 1 min; U_{ins}	75 V	100 V	200 V	300 V
Failure rate: $FIT_{observed}$	≤ 0.1 x 10^{-9}/h			

Note

(1) Please refer to APPLICATION INFORMATION below.

APPLICATION INFORMATION

When the resistor dissipates power, a temperature rise above the ambient temperature occurs, dependent on the thermal resistance of the assembled resistor together with the printed circuit board. The rated dissipation applies only if the permitted film temperature is not exceeded.

These resistors do not feature a limited lifetime when operated within the permissible limits. However, resistance value drift increasing over operating time may result in exceeding a limit acceptable to the specific application, thereby establishing a functional lifetime.

MAXIMUM RESISTANCE CHANGE AT RATED DISSIPATION			
OPERATION MODE		**STANDARD**	**POWER**
Rated dissipation, P_{70}	**MCS 0402**	0.063 W	0.100 W
	MCT 0603	0.100 W	0.125 W
	MCU 0805	0.125 W	0.200 W
	MCA 1206	0.250 W	0.400 W
Operating temperature range		-55 °C to 125 °C	-55 °C to 155 °C
Permissible film temperature, $\vartheta_{F\ max.}$		125 °C	155 °C
Max. resistance change at P_{70} for resistance range, $\lvert\Delta R/R\rvert$ after:	**MCS 0402**	10 Ω to 4.99 MΩ	10 Ω to 4.99 MΩ
	MCT 0603	1 Ω to 10 MΩ	1 Ω to 10 MΩ
	MCU 0805	1 Ω to 10 MΩ	1 Ω to 10 MΩ
	MCA 1206	1 Ω to 2 MΩ	1 Ω to 2 MΩ
	1000 h	≤ 0.25 %	≤ 0.5 %
	8000 h	≤ 0.5 %	≤ 1.0 %
	225 000 h	≤ 1.5 %	-

Note

- The presented operation modes do not refer to different types of resistors, but actually show examples of different loads, that lead to different film temperatures and different achievable load-life stability (drift) of the resistance value. A suitable low thermal resistance of the circuit board assembly must be safeguarded in order to maintain the film temperature of the resistors within the specified limits. Please consider the application note "Thermal Management in Surface-Mounted Resistor Applications" (www.vishay.com/doc?28844) for information on the general nature of thermal resistance.

TEMPERATURE COEFFICIENT AND RESISTANCE RANGE				
TYPE / SIZE	**TCR**	**TOLERANCE**	**RESISTANCE**	**E-SERIES**
MCS 0402	± 50 ppm/K	± 1 %	**10 Ω to 4.99 MΩ**	E24; E96
		± 0.5 %	10 Ω to 221 kΩ	E24; E192
	± 25 ppm/K	± 0.5 %	**10 Ω to 221 kΩ**	E24; E192
	Jumper, $I_{max.}$ = 0.63 A	≤ 20 mΩ	0 Ω	-
MCT 0603	± 50 ppm/K	± 1 %	**1 Ω to 10 MΩ**	E24; E96
		± 0.5 %	10 Ω to 511 kΩ	E24; E192
	± 25 ppm/K	± 0.5 %	**10 Ω to 511 kΩ**	E24; E192
	Jumper, $I_{max.}$ = 1 A	≤ 20 mΩ	0 Ω	-
MCU 0805	± 50 ppm/K	± 1 %	**1 Ω to 10 MΩ**	E24; E96
		± 0.5 %	10 Ω to 1.5 MΩ	E24; E192
	± 25 ppm/K	± 0.5 %	**10 Ω to 1.5 MΩ**	E24; E192
	Jumper, $I_{max.}$ = 1.5 A	≤ 20 mΩ	0 Ω	-
MCA 1206	± 50 ppm/K	± 1 %	**1 Ω to 2 MΩ**	E24; E96
		± 0.5 %	10 Ω to 2 MΩ	E24; E192
	± 25 ppm/K	± 0.5 %	**10 Ω to 2 MΩ**	E24; E192
	Jumper, $I_{max.}$ = 2 A	≤ 20 mΩ	0 Ω	-

Note

- Resistance ranges printed in bold are preferred TCR / tolerance combinations with optimized availability.

PACKAGING						
TYPE / SIZE	**CODE**	**QUANTITY**	**PACKAGING STYLE**	**WIDTH**	**PITCH**	**PACKAGING DIMENSIONS**
MCS 0402	E5	5000	Paper tape acc. IEC 60286-3, Type 1a	8 mm	2 mm	Ø 180 mm/7"
	E0	10 000				
MCT 0603	P5	5000			4 mm	Ø 180 mm/7"
	PW	20 000				Ø 330 mm/13"
MCU 0805	P5	5000				Ø 180 mm/7"
	PW	20 000				Ø 330 mm/13"
MCA 1206	P5	5000				Ø 180 mm/7"

PART NUMBER AND PRODUCT DESCRIPTION

Part Number: MCT06030D4641DPW00
Part Number: MCT06030Z0000ZP500

M	C	T	0	6	0	3	0	D	4	6	4	1	D	P	W	0	0

TYPE / SIZE	VERSION	TCR	RESISTANCE	TOLERANCE	PACKAGING
MCS0402 **MCT0603** **MCU0805** **MCA1206**	**0** = neutral	**D** = ± 25 ppm/K **C** = ± 50 ppm/K **Z** = jumper	3 digit value 1 digit multiplier **Multiplier** **8** = $*10^{-2}$ **9** = $*10^{-1}$ **0** = $*10^{0}$ **1** = $*10^{1}$ **2** = $*10^{2}$ **3** = $*10^{3}$ **4** = $*10^{4}$ **5** = $*10^{5}$ **0000** = jumper	**D** = ± 0.5 % **F** = ± 1 % **Z** = jumper	**E5** **E0** **P5** **PW**

Product Description: MCT 0603-25 0.5 % PW 4K64
Product Description: MCT 0603 P5 0R0

MCT	0603	-25	0.5 %	PW	4K64

TYPE	SIZE	TCR	TOLERANCE	PACKAGING	RESISTANCE
MCS **MCT** **MCU** **MCA**	**0402** **0603** **0805** **1206**	± **25** ppm/K ± **50** ppm/K	± **0.5 %** ± **1 %**	**E5** **E0** **P5** **PW**	**4K64** = 4.64 kΩ **50R1** = 50.1 Ω **0R0** = jumper

Note

- Products can be ordered using either the PART NUMBER or PRODUCT DESCRIPTION.

DESCRIPTION

Production is strictly controlled and follows an extensive set of instructions established for reproducibility. A homogeneous film of metal alloy is deposited on a high grade ceramic substrate (Al_2O_3) and conditioned to achieve the desired temperature coefficient. Specially designed inner contacts are deposited on both sides. A special laser is used to achieve the target value by smoothly cutting a meander groove in the resistive layer without damaging the ceramics. For the high and low ohmic range, optimized Cermet products provide comparable properties. The resistor elements are covered by a protective coating designed for electrical, mechanical and climatic protection. The terminations receive a final pure tin on nickel plating.

The result of the determined production is verified by an extensive testing procedure and optical inspection performed on 100 % of the individual chip resistors. This includes full screening for the elimination of products with potential risk of early field failures (feasible for $R \geq 10\ \Omega$). Only accepted products are laid directly into the paper tape in accordance with **IEC 60286-3 Type 1a** [(1)].

ASSEMBLY

The resistors are suitable for processing on automatic SMD assembly systems. They are suitable for automatic soldering using wave, reflow or vapor phase as shown in **IEC 61760-1**. The encapsulation is resistant to all cleaning solvents commonly used in the electronics industry, including alcohols, esters and aqueous solutions. The suitability of conformal coatings, potting compounds and their processes, if applied, shall be qualified by appropriate means to ensure the long-term stability of the whole system.

The resistors are RoHS-compliant, the pure tin plating provides compatibility with lead (Pb)-free and lead-containing soldering processes. Solderability is specified for 2 years after production or requalification. The permitted storage time is 20 years. The immunity of the plating against tin whisker growth has been proven under extensive testing.

MATERIALS

Vishay acknowledges the following systems for the regulation of hazardous substances:

- IEC 62474, Material Declaration for Products of and for the Electrotechnical Industry, with the list of declarable substances given therein [(2)]
- The Global Automotive Declarable Substance List (GADSL) [(3)]
- The REACH regulation (1907/2006/EC) and the related list of substances with very high concern (SVHC) [(4)] for its supply chain

The products do not contain any of the banned substances as per IEC 62474, GADSL, or the SVHC list, see www.vishay.com/how/leadfree.

Hence the products fully comply with the following directives:

- 2000/53/EC End-of-Life Vehicle Directive (ELV) and Annex II (ELV II)
- 2011/65/EU Restriction of the Use of Hazardous Substances Directive (RoHS) with amendment 2015/863/EU
- 2012/19/EU Waste Electrical and Electronic Equipment Directive (WEEE)

Vishay pursues the elimination of conflict minerals from its supply chain, see the Conflict Minerals Policy at www.vishay.com/doc?49037.

APPROVALS

The resistors are approved within the IECQ-CECC Quality Assessment System for Electronic Components to the detail specification **EN 140401-801** which refers to **EN 60115-1**, **EN 60115-8** and the variety of environmental test procedures of the **IEC 60068** [(1)] series. The detail specification refers to the climatic category 55/125/56, which relates to the “standard operation mode” of this datasheet.

Conformity is attested by the use of the **CECC** logo ( ) as the mark of conformity on the package label.

Vishay Beyschlag has achieved **“Approval of Manufacturer”** in accordance with **IECQ 03-1**. The release certificate for **“Technology Approval Schedule”** in accordance with **CECC 240001** based on **IECQ 03-3-1** is granted for the Vishay BEYSCHLAG manufacturing process.

RELATED PRODUCTS

For more information about products with better TCR and tighter tolerance please refer to the Precision Thin Film Chip Resistors datasheet (www.vishay.com/doc?28700).

Resistors are available with established reliability in accordance with EN 140401-801 version E. Please refer to the special datasheet (www.vishay.com/doc?28744) for information on failure rate level, available resistance ranges and order codes.

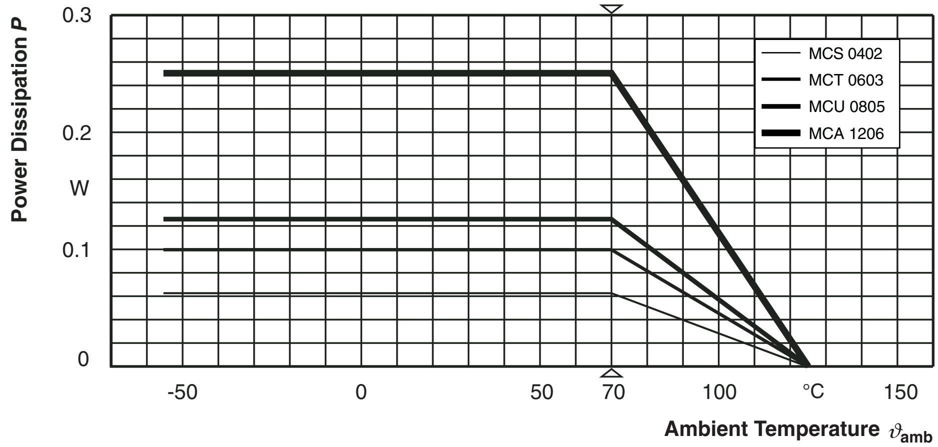
Precision chip resistor arrays may be used in voltage divider applications or precision amplifiers where close matching between multiple resistors is necessary. ACAS 0612 chip arrays are specified by the following datasheets:

- Professional type (www.vishay.com/doc?28754)
- Precision type (www.vishay.com/doc?28751)

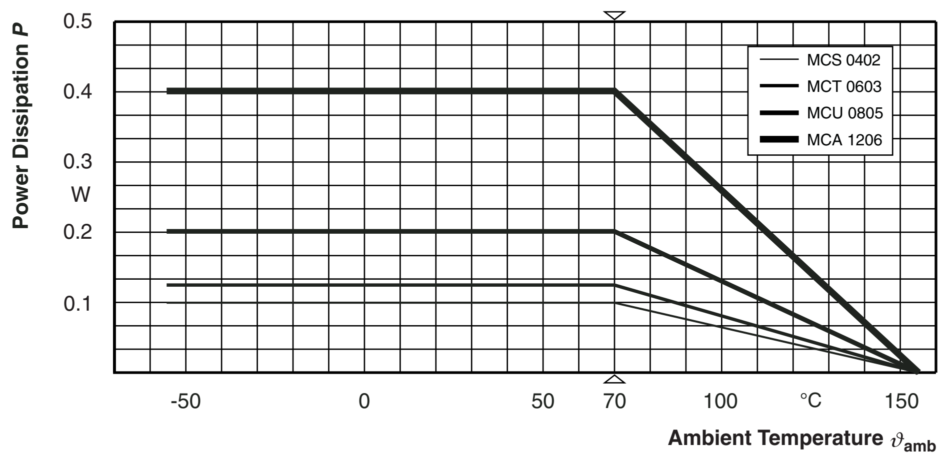
Notes

(1) The quoted IEC standards are also released as EN standards with the same number and identical contents.
(2) The IEC 62474 list of declarable substances is maintained in a dedicated database, which is available at http://std.iec.ch/iec62474.
(3) The Global Automotive Declarable Substance List (GADSL) is maintained by the American Chemistry Council and available at www.gadsl.org.
(4) The SVHC list is maintained by the European Chemical Agency (ECHA) and available at http://echa.europa.eu/candidate-list-table.

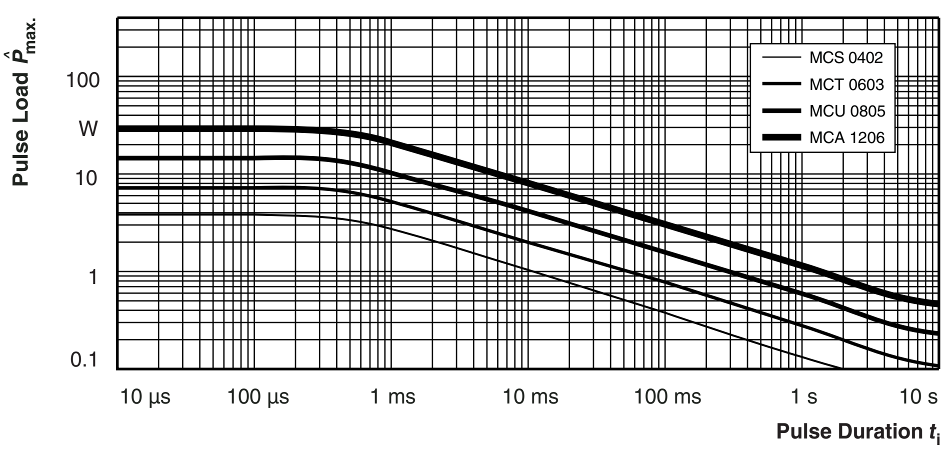
FUNCTIONAL PERFORMANCE



Derating - Standard Operation

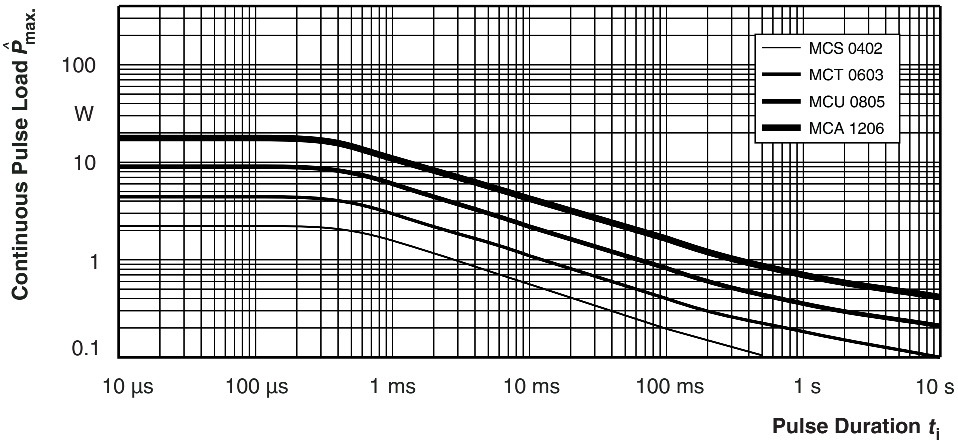


Derating - Power Operation



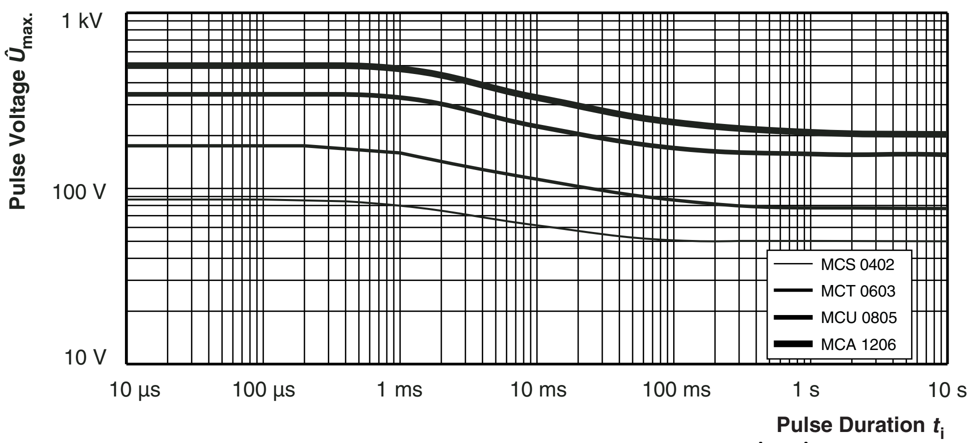
Maximum pulse load, single pulse; applicable if $\bar{P} \rightarrow 0$ and $n \leq 1000$ and $\hat{U} \leq \hat{U}_{max.}$;
for permissible resistance change equivalent to 8000 h operation in standard operation mode

Single Pulse



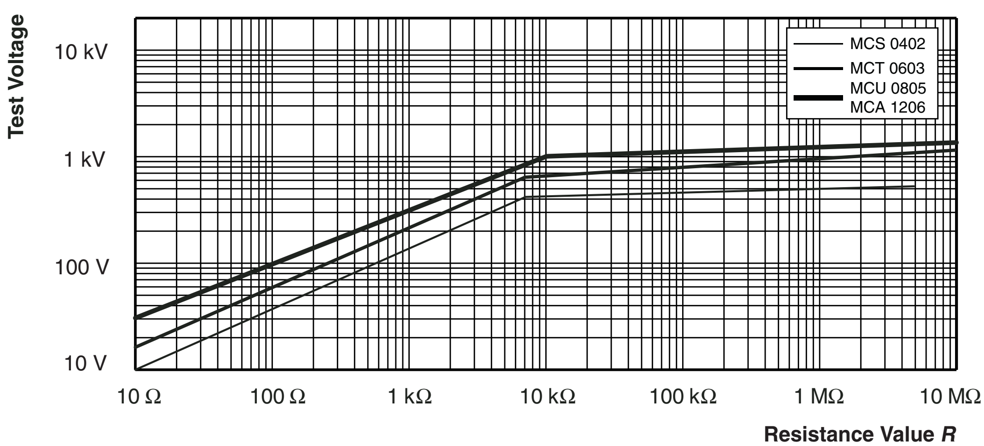
Maximum pulse load, continuous pulses; applicable if $\bar{P} \leq P(\vartheta_{amb})$ and $\hat{U} \leq \hat{U}_{max.}$;
for permissible resistance change equivalent to 8000 h operation in standard operation mode

Continuous Pulse



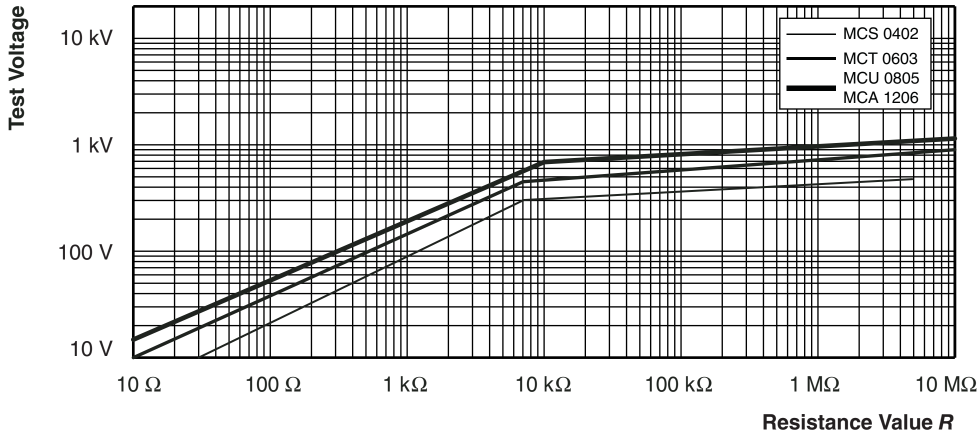
Maximum pulse voltage, single and continuous pulses; applicable if $\hat{P} \leq \hat{P}_{max.}$;
for permissible resistance change equivalent to 8000 h operation in standard operation mode

Pulse Voltage



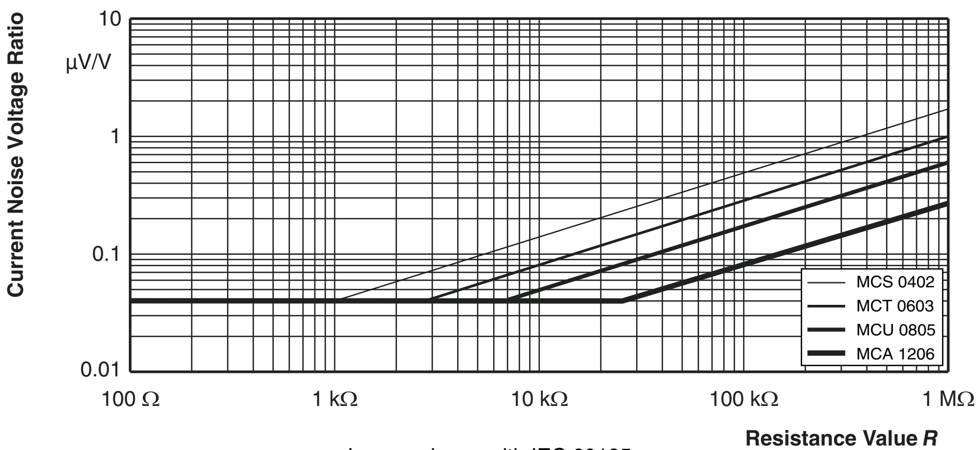
Pulse load rating in accordance with EN 60115-1 clause 4.27; 1.2 µs/50 µs; 5 pulses at 12 s interval;
for permissible resistance change ± (0.5 % R + 0.05 Ω)

1.2/50 Pulse



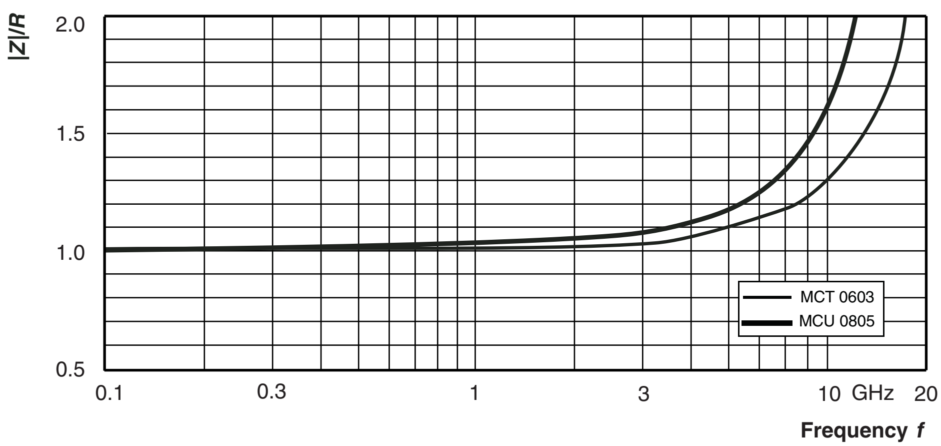
Pulse load rating in accordance with EN 60115-1 clause 4.27; 10 µs/700 µs;
10 pulses at 1 min intervals; for permissible resistance change ± (0.5 % R + 0.05 Ω)

10/700 Pulse



In accordance with IEC 60195

Current Noise Voltage Ratio



Relative impedance for 49.9 Ω chip resistor

RF-Behavior

TESTS AND REQUIREMENTS

All tests are carried out in accordance with the following specifications:

EN 60115-1, generic specification

EN 60115-8 (successor of EN 140400), sectional specification

EN 140401-801, detail specification

IEC 60068-2-xx, test methods

The components are approved under the IECQ-CECC quality assessment system for electronic components.

The parameters stated in the Test Procedures and Requirements table are based on the required tests and permitted limits of EN 140401-801. The table presents only the most important tests, for the full test schedule refer to the documents listed above. However, some additional tests and a number of improvements against those minimum requirements have been included.

The testing also covers most of the requirements specified by EIA/ECA-703 and JIS-C-5201-1.

The tests are carried out under standard atmospheric conditions in accordance with IEC 60068-1, 4.3, whereupon the following values are applied:

Temperature: 15 °C to 35 °C

Relative humidity: 25 % to 75 %

Air pressure: 86 kPa to 106 kPa (860 mbar to 1060 mbar)

A climatic category LCT / UCT / 56 is applied, defined by the lower category temperature (LCT), the upper category temperature (UCT), and the duration of exposure in the damp heat, steady state test (56 days).

The components are mounted for testing on printed circuit boards in accordance with EN 60115-8, 2.4.2, unless otherwise specified.

TEST PROCEDURES AND REQUIREMENTS

EN 60115-1 CLAUSE	IEC 60068-2 (1) TEST METHOD	TEST	PROCEDURE	REQUIREMENTS PERMISSIBLE CHANGE (ΔR) STABILITY CLASS 0.5	STABILITY CLASS 1
			Stability for product types:		
			MCS 0402	10 Ω to 33.2 kΩ	> 33.2 kΩ to 4.99 MΩ
			MCT 0603	10 Ω to 100 kΩ	1 Ω to < 10 Ω; > 100 kΩ to 10 MΩ
			MCU 0805	10 Ω to 221 kΩ	1 Ω to < 10 Ω; > 221 kΩ to 10 MΩ
			MCA 1206	10 Ω to 332 kΩ	1 Ω to < 10 Ω; > 332 kΩ to 2 MΩ
4.5	-	Resistance	-	± 1 % *R*; ± 0.5 % *R*	
4.8	-	Temperature coefficient	At (20 / -55 / 20) °C and (20 / 125 / 20) °C	± 50 ppm/K; ± 25 ppm/K	
4.25.1	-	Endurance at 70 °C: standard operation mode	$U = \sqrt{P_{70} \times R}$ or $U = U_{max.}$; whichever is the less severe; 1.5 h on; 0.5 h off;		
			70 °C; 1000 h	± (0.25 % *R* + 0.05 Ω)	
			70 °C; 8000 h	± (0.5 % *R* + 0.05 Ω)	
		Endurance at 70 °C: power operation mode	$U = \sqrt{P_{70} \times R}$ or $U = U_{max.}$; whichever is the less severe; 1.5 h on; 0.5 h off;		
			70 °C; 1000 h	± (0.5 % *R* + 0.05 Ω)	
			70 °C; 8000 h	± (1 % *R* + 0.05 Ω)	
4.25.3	-	Endurance at upper category temperature	125 °C; 1000 h	± (0.25 % *R* + 0.05 Ω)	± (0.5 % *R* + 0.05 Ω)
			155 °C; 1000 h	± (0.5 % *R* + 0.05 Ω)	± (1 % *R* + 0.05 Ω)
4.24	78 (Cab)	Damp heat, steady state	(40 ± 2) °C; 56 days; (93 ± 3) % RH	± (0.5 % *R* + 0.05 Ω)	± (1 % *R* + 0.05 Ω)

TEST PROCEDURES AND REQUIREMENTS

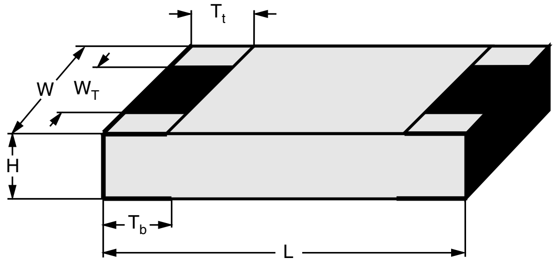
EN 60115-1 CLAUSE	IEC 60068-2 [1] TEST METHOD	TEST	PROCEDURE	REQUIREMENTS PERMISSIBLE CHANGE (ΔR)	
				STABILITY CLASS 0.5	STABILITY CLASS 1
			Stability for product types:		
			MCS 0402	10 Ω to 33.2 kΩ	> 33.2 kΩ to 4.99 MΩ
			MCT 0603	10 Ω to 100 kΩ	1 Ω to < 10 Ω; > 100 kΩ to 10 MΩ
			MCU 0805	10 Ω to 221 kΩ	1 Ω to < 10 Ω; > 221 kΩ to 10 MΩ
			MCA 1206	10 Ω to 332 kΩ	1 Ω to < 10 Ω; > 332 kΩ to 2 MΩ
4.23		Climatic sequence: standard operation mode:		± (0.5 % R + 0.05 Ω)	± (1 % R + 0.05 Ω)
4.23.2	2 (Bb)	dry heat	125 °C; 16 h		
4.23.3	30 (Db)	damp heat, cyclic	55 °C; 24 h; > 90 % RH; 1 cycle		
4.23.4	1 (Ab)	cold	-55 °C; 2 h		
4.23.5	13 (M)	low air pressure	8.5 kPa; 2 h; (25 ± 10) °C		
4.23.6	30 (Db)	damp heat, cyclic	55 °C; 24 h; > 90 % RH; 5 cycles		
4.23.7	-	DC load	$U = \sqrt{P_{70} \times R} \leq U_{max.}$; 1 min.		
-	1 (Aa)	Cold	-55 °C; 2 h	± (0.1 % R + 0.01 Ω)	± (0.25 % R + 0.05 Ω)
4.19	14 (Na)	Rapid change of temperature	30 min at LCT and 30 min at UCT; LCT = -55 °C; UCT = 125 °C; 5 cycles	± (0.1 % R + 0.01 Ω) no visible damage	
			LCT = -55 °C; UCT = 125 °C; 1000 cycles	± (0.25 % R + 0.05 Ω) no visible damage	
4.13	-	Short time overload: standard operation mode	$U = 2.5 \times \sqrt{P_{70} \times R}$ or $U = 2 \times U_{max.}$; whichever is the less severe; 5 s	± (0.1 % R + 0.01 Ω)	± (0.25 % R + 0.05 Ω)
		Short time overload: power operation mode	$U = 2.5 \times \sqrt{P_{70} \times R}$ or $U = 2 \times U_{max.}$; whichever is the less severe; 5 s	± (0.25 % R + 0.05 Ω)	± (0.5 % R + 0.05 Ω)
4.27	-	Single pulse high voltage overload: standard operation mode	Severity no. 4: $U = 10 \times \sqrt{P_{70} \times R}$ or $U = 2 \times U_{max.}$; whichever is the less severe; 10 pulses 10 µs/700 µs	± (0.5 % R + 0.05 Ω) no visible damage	
4.39	-	Periodic electric overload: standard operation mode	$U = \sqrt{15 \times P_{70} \times R}$ or $U = 2 \times U_{max.}$; 0.1 s on; 2.5 s off; whichever is the less severe; 1000 cycles	± (0.5 % R + 0.05 Ω) no visible damage	
		Periodic electric overload: power operation mode	$U = \sqrt{15 \times P_{70} \times R}$ or $U = 2 \times U_{max.}$; 0.1 s on; 2.5 s off; whichever is the less severe; 1000 cycles	± (1 % R + 0.05 Ω) no visible damage	

TEST PROCEDURES AND REQUIREMENTS					
EN 60115-1 CLAUSE	**IEC 60068-2 (1) TEST METHOD**	**TEST**	**PROCEDURE**	**REQUIREMENTS PERMISSIBLE CHANGE (ΔR)**	
				STABILITY CLASS 0.5	**STABILITY CLASS 1**
			Stability for product types:		
			MCS 0402	10 Ω to 33.2 kΩ	> 33.2 kΩ to 4.99 MΩ
			MCT 0603	10 Ω to 100 kΩ	1 Ω to < 10 Ω; > 100 kΩ to 10 MΩ
			MCU 0805	10 Ω to 221 kΩ	1 Ω to < 10 Ω; > 221 kΩ to 10 MΩ
			MCA 1206	10 Ω to 332 kΩ	1 Ω to < 10 Ω; > 332 kΩ to 2 MΩ
4.38	-	Electro static discharge (human body model)	IEC 61340-3-1 (1); 3 pos. + 3 neg. (equivalent to MIL-STD-883, method 3015) MCS 0402: 500 V MCT 0603: 1000 V MCU 0805: 1500 V MCA 1206: 2000 V	± (0.5 % R + 0.05 Ω)	
4.22	6 (Fc)	Vibration	Endurance by sweeping; 10 Hz to 2000 Hz; no resonance; amplitude ≤ 1.5 mm or ≤ 200 m/s²; 7.5 h	± (0.1 % R + 0.01 Ω) no visible damage	
4.17	58 (Td)	Solderability	Solder bath method; SnPb40; non-activated flux; (215 ± 3) °C; (3 ± 0.3) s	Good tinning (≥ 95 % covered); no visible damage	
			Solder bath method; SnAg3Cu0.5 or SnAg3.5; non-activated flux; (235 ± 3) °C; (2 ± 0.2) s	Good tinning (≥ 95 % covered); no visible damage	
4.18	58 (Td)	Resistance to soldering heat	Solder bath method; (260 ± 5) °C; (10 ± 1) s	± (0.1 % R + 0.01 Ω) no visible damage	± (0.25 % R + 0.05 Ω) no visible damage
4.29	45 (XA)	Component solvent resistance	Isopropyl alcohol +50 °C; method 2	No visible damage	
4.32	21 (Ue_3)	Shear (adhesion)	MCS 0402 and MCT 0603: 9 N	No visible damage	
			MCU 0805 and MCA 1206: 45 N		
4.33	21 (Ue_1)	Substrate bending	Depth 2 mm, 3 times	± (0.1 % R + 0.01 Ω) no visible damage, no open circuit in bent position	
4.7	-	Voltage proof	$U_{RMS} = U_{ins}$; (60 ± 5) s	No flashover or breakdown	
4.35	-	Flammability	IEC 60695-11-5 (1), needle flame test; 10 s	No burning after 30 s	

Note

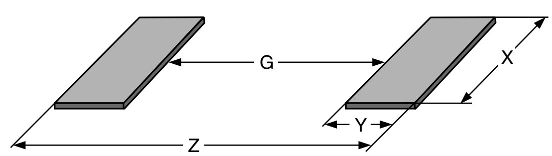
(1) The quoted IEC standards are also released as EN standards with the same number and identical contents.

DIMENSIONS



DIMENSIONS AND MASS							
TYPE / SIZE	**H (mm)**	**L (mm)**	**W (mm)**	**W_T (mm)**	**T_t (mm)**	**T_b (mm)**	**MASS (mg)**
MCS 0402	0.32 ± 0.05	1.0 ± 0.05	0.5 ± 0.05	> 75 % of W	0.2 + 0.1 / - 0.15	0.2 ± 0.1	0.6
MCT 0603	0.45 + 0.1 / - 0.05	1.55 ± 0.05	0.85 ± 0.1	> 75 % of W	0.3 + 0.15 / - 0.2	0.3 + 0.15 / - 0.2	1.9
MCU 0805	0.45 + 0.1 / - 0.05	2.0 ± 0.1	1.25 ± 0.15	> 75 % of W	0.4 + 0.1 / - 0.2	0.4 + 0.1 / - 0.2	4.6
MCA 1206	0.55 ± 0.1	3.2 + 0.1 / - 0.2	1.6 ± 0.15	> 75 % of W	0.5 ± 0.25	0.5 ± 0.25	9.2

SOLDER PAD DIMENSIONS



RECOMMENDED SOLDER PAD DIMENSIONS								
TYPE / SIZE	**WAVE SOLDERING**				**REFLOW SOLDERING**			
	G (mm)	**Y (mm)**	**X (mm)**	**Z (mm)**	**G (mm)**	**Y (mm)**	**X (mm)**	**Z (mm)**
MCS 0402	-	-	-	-	0.35	0.55	0.55	1.45
MCT 0603	0.55	1.10	1.10	2.75	0.65	0.70	0.95	2.05
MCU 0805	0.80	1.25	1.50	3.30	0.90	0.90	1.40	2.70
MCA 1206	1.40	1.50	1.90	4.40	1.50	1.15	1.75	3.80

Notes

- The given solder pad dimensions reflect the considerations for board design and assembly as outlined e.g. in standards IEC 61188-5-x [(1)], or in publication IPC-7351.

[(1)] The quoted IEC standards are also released as EN standards with the same number and identical contents.

HISTORICAL 12NC INFORMATION

- The resistors had a 12-digit numeric code starting with 2312.
- The subsequent 4 digits indicated the resistor type, specification and packaging; see the 12NC table.
- The remaining 4 digits indicated the resistance value:
  - The first 3 digits indicated the resistance value.
  - The last digit indicated the resistance decade in accordance with the last digit of 12NC indicating resistance decade table.

Last Digit of 12NC Indicating Resistance Decade

RESISTANCE DECADE	LAST DIGIT
1 Ω to 9.99 Ω	8
10 Ω to 99.9 Ω	9
100 Ω to 999 Ω	1
1 kΩ to 9.99 kΩ	2
10 kΩ to 99.9 kΩ	3
100 kΩ to 999 kΩ	4
1 MΩ to 9.99 MΩ	5
10 MΩ to 99.9 MΩ	6

Historical 12NC example

The 12NC of a MCT 0603 resistor, value 47 kΩ and TCR 50 with ± 1 % tolerance, supplied in cardboard tape of 5000 units per reel was: 2312 215 14703.

HISTORICAL 12NC - Resistor type and packaging

DESCRIPTION			2312...		
			CARDBOARD TAPE ON REEL		
TYPE	TCR	TOL.	P5 (5000 UNITS)	E0 (10 000 UNITS)	PW (20 000 UNITS)
MCS 0402	± 50 ppm/K	± 1 %	-	275 1....	-
		± 0.5 %	-	275 5....	-
	± 25 ppm/K	± 0.5 %	-	276 5....	-
	Jumper	-	-	275 90001	-
MCT 0603	± 50 ppm/K	± 1 %	215 1....	-	205 1..
		± 0.5 %	215 5....	-	205 5....
	± 25 ppm/K	± 0.5 %	216 5....	-	206 5....
	Jumper	-	215 90001	-	205 90001
MCU 0805	± 50 ppm/K	± 0.5 %	255 5....	-	245 5....
	± 25 ppm/K	± 0.5 %	256 5....	-	246 5....
	Jumper	-	255 90001	-	245 90001

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