

## Ultra-Low Power Audio CODEC for Headphone/Headsets Application With 124dB Class G Headphone Drive and Advanced Headset Features

### Description

The NAU88L25 is an ultra-low power high performance audio codec designed for headphone or headset application in smartphone, tablet PC, Chromebooks, laptop, game controller, Bluetooth headphones and other portable devices. It includes one I2S/PCM interface, one high quality stereo DACs, one mono ADC, a Class G stereo headphone amplifier, and industry leading advanced headset features.

Advanced on-chip signal processing engine including dynamic range compressor (DRC), programmable bi-quad filters, sidetone and dital mixers, can maximize audio quali y enhancements and eliminate the undersirable frequency components. A frequency locked loop(FLL) is also integrated in the design to support various clocks wih less external components.

The NAU88L25 has powerful headset detection mechanism, which detects jack insertion / ejection, microphone presence, speaker impedance, and up-to 8 user defined buttons with long/short key press debouce circuit. It also supports headphone crosstalk detection/suppression, and automatic microphone & ground detection / switching to work automatically with different audio jack formats without using external chips or components.

The NAU88L25 operates with analog supply voltages from 1.6V to 1.8V, while the digital core can operate from 1.1V to 1.98V to conserve power. The NAU88L25 is specified for operation from -40°C to +85°C, and is available in QFN 32 or CSP package with 0.4mm pitch.

### Features

- DAC with auto attenuate : 124dB SNR; without auto mute: 113dB SNR, (A-weighted) @ 0dB gain, 1.8V and -89dB THD @ 20mW and RL= 32Ω, DAC playback to headphone output mode
- ADC : 101dB SNR (A-weighted) @ 0dB MIC gain, 1.8V, Fs = 48kHz and -91dB THD , 1.8V, MIC gain 0dB, OSR 128x
- 1 Digital I2S/PCM I/O port
- Dynamic Range Compressor (DRC)
- Programmable Biquad filter
- 1 Headset Mic, 1 Differential Analog Mic input, Line-input, or two single-ended Mic input
- Class G Headphone Amplifier(28mW @ 32Ω, 1% THD+N)

- Sampling rate from 8K to 192 KHz
- Headset Detection & Auto Headset switch for MIC and Ground
- Jack Insertion and Ejection Detection
- Distinct Keys Detection
- Package : 32 Pin QFN package, and Optional 42 Balls WLCSP with 0.4mm Pitch

### Applications

- Gaming Controller
- Ultra-Portable Laptop
- Mobile Device
- Wireless Headset
- Smart Remote Controller

## Block Diagram

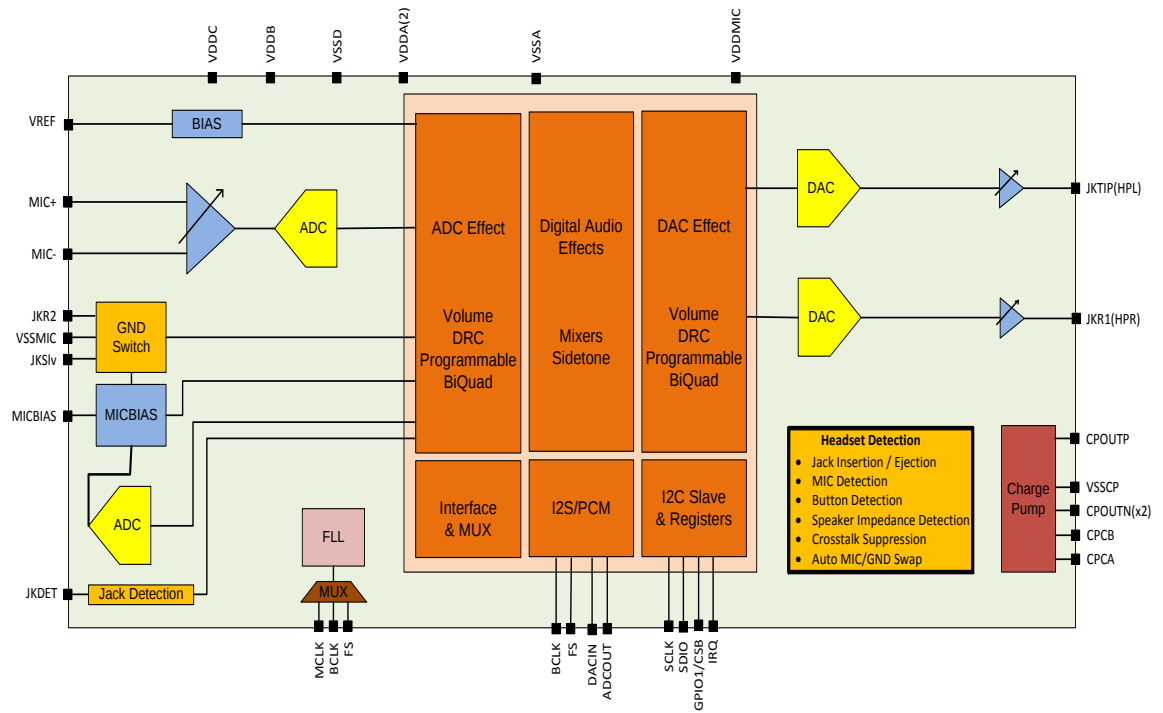
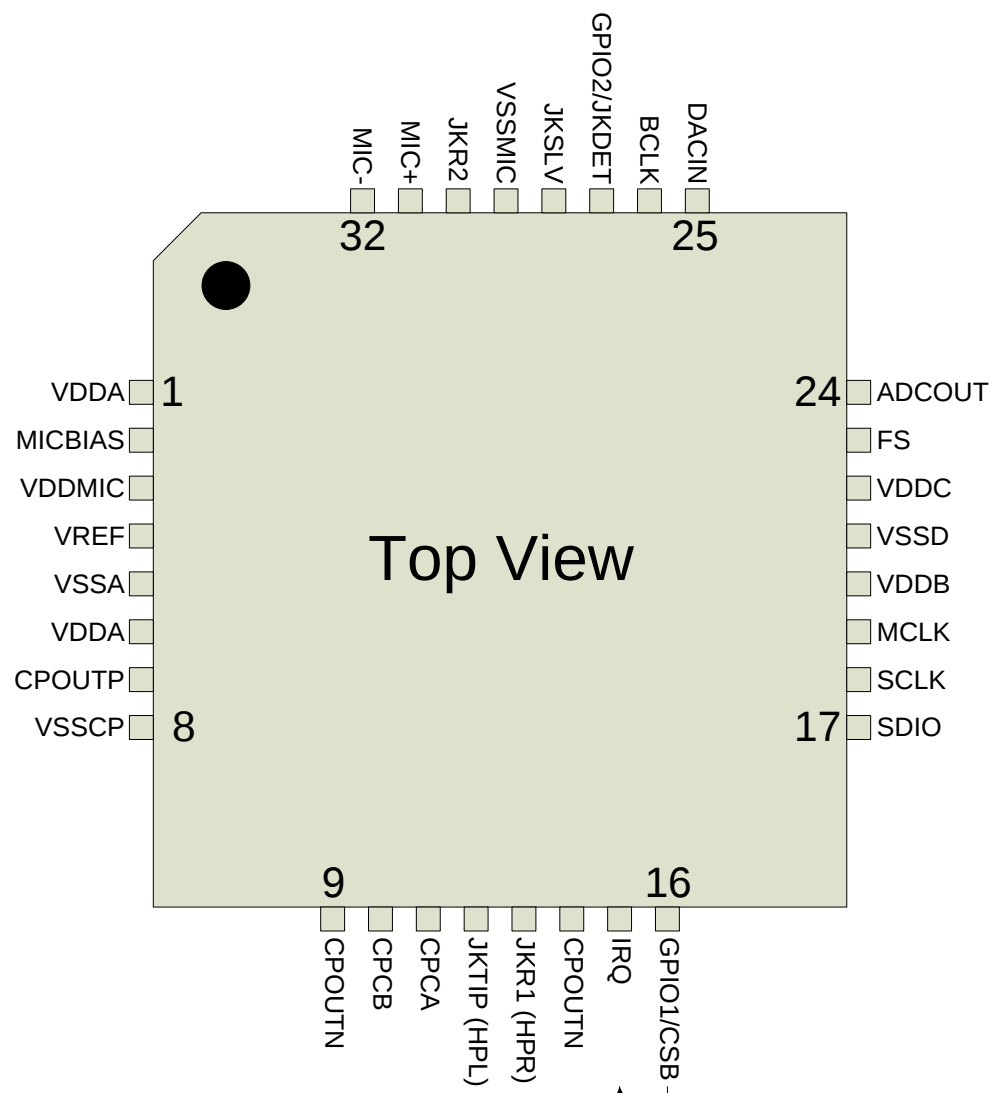


Figure 1: NAU88L25 Block Diagram

Pin Diagram



## Pin Descriptions

| Pin # | Name        | Type           | Functionality                                             |
|-------|-------------|----------------|-----------------------------------------------------------|
| 1     | VDDA        | Supply         | Analog Supply                                             |
| 2     | MICBIAS     | Analog Output  | Microphone Bias Output                                    |
| 3     | VDDMIC      | Supply         | Microphone supply                                         |
| 4     | VREF        | Analog I/O     | Internal DAC & ADC voltage reference decoupling I/O       |
| 5     | VSSA        | Ground         | Analog Supply Ground                                      |
| 6     | VDDA        | Supply         | Analog Supply                                             |
| 7     | CPOUTP      | Analog I/O     | Charge Pump positive voltage                              |
| 8     | VSSCP       | Ground         | Charge Pump Supply ground                                 |
| 9     | CPOUTN      | Analog I/O     | Charge Pump negative voltage                              |
| 10    | CPCB        | Analog I/O     | Charge Pump switching capacitor node B                    |
| 11    | CPCA        | Analog I/O     | Charge Pump switching capacitor node A                    |
| 12    | JKTIP (HPL) | Analog Output  | Headphone left channel output                             |
| 13    | JKR1 (HPR)  | Analog Output  | Headphone right channel output                            |
| 14    | CPOUTN      | Analog I/O     | Charge Pump negative voltage                              |
| 15    | IRQ         | Digital Output | Programmable Interrupt Output                             |
| 16    | GPIO1       | Digital I/O    | General Purpose IO/I2C Address/SPI_CSB                    |
| 17    | SDIO        | Digital I/O    | Serial Data for I2C or SPI                                |
| 18    | SCLK        | Digital Input  | Serial Data Clock for I2C or SPI                          |
| 19    | MCLK        | Digital Input  | CODEC Master clock input                                  |
| 20    | VDDDB       | Supply         | Digital IO Supply                                         |
| 21    | VSSD        | Ground         | Digital IO ground                                         |
| 22    | VDDC        | Supply         | Digital core supply                                       |
| 23    | FS          | Digital I/O    | Frame Sync input or output for I2S or PCM data            |
| 24    | ADCOUT      | Digital Output | Serial Audio data Output for I2S or PCM data              |
| 25    | DACIN       | Digital Input  | Serial Audio data input for I2S or PCM data               |
| 26    | BCLK        | Digital I/O    | Serial data bit clock input or output for I2S or PCM data |
| 27    | JKDET       | Analog Input   | Jack detect input                                         |
| 28    | JKSLV       | Analog I/O     | Headset Jack pin 4                                        |
| 29    | VSSMIC      | Ground         | Analog Supply Ground                                      |
| 30    | JKR2        | Analog I/O     | Headset Jack pin 3                                        |
| 31    | MIC+        | Analog Input   | PGA MIC1+ Analog Input                                    |
| 32    | MIC1-       | Analog Input   | PGA MIC1- Analog Input                                    |

## Electrical Characteristics

Conditions:  $V_{DDA} = V_{ddb} = V_{DDC} = 1.8V$ ;  $V_{DDMIC} = 4.2V$ .

$R_L(\text{Headphone}) = 32\ \Omega$ ,  $f = 1\text{kHz}$ ,  $MCLK = 12.88\text{MHz}$ , unless otherwise specified. Limits apply for  $T_A = 25^\circ\text{C}$

| Symbol                     | Parameter                         | Conditions                                                                                                                                                | Typical  | Limit | Units (Limit) |
|----------------------------|-----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-------|---------------|
| ISD                        | Shutdown Current                  | $V_{DDA}$ in Shutdown Mode                                                                                                                                | 0.2      | 1     | $\mu\text{A}$ |
|                            |                                   | $V_{DDA}$                                                                                                                                                 | 0.2      | 1     |               |
|                            |                                   | $V_{ddb}$                                                                                                                                                 | 0.2      | 1     |               |
|                            |                                   | $V_{DDC}$                                                                                                                                                 | 2        | 10    |               |
|                            |                                   | $V_{DDMIC}$                                                                                                                                               | 0.2      | 1     |               |
| $I_{DD}$                   | Standby Mode                      | MCLK off, Jack Insertion, IRQ enabled                                                                                                                     | 5        |       | $\mu\text{A}$ |
| <b>Headphone Amplifier</b> |                                   |                                                                                                                                                           |          |       |               |
| $P_O$                      | Output Power                      | Stereo $R_L = 32\Omega$ , DAC Input, $CPV_{DD} = 1.8V$ , $f = 1\text{kHz}$ , 22kHz BW, THD+N = 1%(CSP package), w. headset switch                         | 30       |       | mW            |
|                            |                                   | Stereo $R_L = 32\Omega$ , DAC Input, $CPV_{VDD} = 1.8V$ , $f = 1\text{kHz}$ , 22kHz BW, THD+N = 1% (QFN package), w. headset switch                       | 28       |       | mW            |
|                            |                                   | Stereo $R_L = 16\Omega$ , DAC Input, $CPV_{VDD} = 1.8V$ , $f = 1\text{kHz}$ , 22kHz BW, THD+N = 1% (CSP Package), w. headset switch                       | 35       |       | mW            |
|                            |                                   | Stereo $R_L = 16\Omega$ , DAC Input, $CPV_{VDD} = 1.8V$ , $f = 1\text{kHz}$ , 22kHz BW, THD+N = 1% (QFN Package), w. headset switch                       | 35       |       | mW            |
| THD+N                      | Total Harmonic Distortion + Noise | $R_L = 32\Omega$ , $f = 1\text{kHz}$ , $P_O = 20\text{mW}$ , with headset switch                                                                          | -89      |       | dB            |
| SNR                        | Signal to Noise Ratio             | $V_{OUT} = 1V_{RMS}$ , DAC Input, DAC_Gain = 0dB, HP_Gain = 0dB, Digital Zero Input, $f = 1\text{kHz}$ , A-Weighted), w. headset switch                   | 113      |       | dB            |
|                            |                                   | $V_{OUT} = 1V_{RMS}$ , DAC Input, DAC_Gain = 0dB, HP_Gain = 0dB, Digital Zero Input, $f = 1\text{kHz}$ , A-Weighted, auto mute enabled, w. headset switch | 124      |       | dB            |
| PSRR                       | Power Supply Rejection Ratio      | $f_{RIPPLE} = 217\text{Hz}$ , $V_{RIPPLE} = 200\text{mV}_{P-P}$ Input Referred, HP_GAIN = 0dB<br>DAC Input, DAC_Gain = 0dB Ripple Applied to $V_{DDA}$    | 81       |       | dB            |
| $X_{TALK}$                 | Channel Crosstalk                 | Left Channel to Right Channel, -1dBFS, Gain = 0dB, $f = 1\text{kHz}$ , MIC/GND Switching Off without HCS                                                  | 88       |       | dB            |
|                            |                                   | Left Channel to Right Channel, -1dBFS, Gain = 0dB, $f = 1\text{kHz}$ , MIC/GND Switching On with HCS                                                      | 91       |       | dB            |
|                            | Interchannel Level Mismatch       | Headphone Right and Left Channel Difference with 0dBFS Input Sweap from 20Hz to 20KHz                                                                     | +/- 0.1  |       | dB            |
|                            | Frequency Response                | $F = 20\text{Hz} \sim 20\text{KHz}$                                                                                                                       | +/-0.005 |       | dB            |

| Symbol     | Parameter                             | Conditions                                                                                                                 | Typical    | Limit     | Units (Limit) |
|------------|---------------------------------------|----------------------------------------------------------------------------------------------------------------------------|------------|-----------|---------------|
| $e_{OS}$   | Output Noise                          | DAC_Gain = 0dB, HP_Gain = 0dB, $f_s=48kHz$ , $OSR_{DAC} = 128$ , A-Weighted                                                | 2.2        |           | $\mu V_{RMS}$ |
|            | Out of Band Noise Level               | BW=400Hz-500kHz                                                                                                            | -86        |           | dB            |
| $V_{OS}$   | Output Offset Voltage                 | HP_Gain = 0dB, DAC_Gain= 0dB, DAC Input                                                                                    | 0.1        | $\pm 0.5$ | mV            |
|            | Power Consumption                     | No Load, No Signal, $f_s = 44.1kHz$ , 16Bit, $OSR = 32$ , Stereo DAC On, Amp On, $R_L = 32\Omega$ , $V_{DDC} = 1.2V$       | 5.7        |           | mW            |
|            | Pop and Click Noise                   | Into or Out of DAC to Headphone Shutdown, Headphone Impedance & Crosstalk Detection Disabled                               | 0.1        |           | mVrms         |
| <b>ADC</b> |                                       |                                                                                                                            |            |           |               |
| THD+N      | ADC Total Harmonic Distortion + Noise | MIC Input, MIC_GAIN = 0dB, $V_{IN} = 0.8V_{rms}$ , $f=1kHz$ , $f_s = 48kHz$ , Mono Differential Input                      | -91        |           | dB            |
|            |                                       | MIC Input, MIC_GAIN = 30dB, Volume = 0dB, $V_{in}=28.5V_{rms}$ , $f=1k$ , Digital Gain = 0dB, Mono Differential Input      | -80        |           | dB            |
| SNR        | Signal to Noise Ratio                 | Reference = $V_{OUT}(0dBFS)$ , A-Weighted, MIC Input, MIC Gain = 0dB, $f_s = 48kHz$ , Mono Differential Input              | 101        |           | dB            |
|            |                                       | Reference = $V_{OUT}(0dBFS)$ , A-Weighted, MIC Input, MIC Gain = 6dB, $f_s = 8kHz$ , Mono Differential Input               | 98         |           | dB            |
| PSRR       | Power Supply Rejection Ratio          | $V_{RIPPLE} = 200mV_{pp}$ applied to $V_{DDA}$ , $f_{RIPPLE} = 217Hz$ , Input Referred, MIC_GAIN = 0dB, Differential Input | 78         |           | dB            |
| CMRR       | Common Mode Rejection Ratio           | Differential Input $100V_{rms}$ , PGA gain = 20dB, frequency sweep from 20Hz to 20KHz                                      | 64         |           | dB            |
| $FS_{ADC}$ | ADC Full Scale Input Level            | $V_{DDA} = 1.8V$                                                                                                           | 1          |           | $V_{RMS}$     |
|            | Minimum Input Impedance               |                                                                                                                            | 12         |           | KOhm          |
|            | Frequency Response                    | $f = 20Hz \sim 20KHz$                                                                                                      | $\pm 0.02$ |           | dB            |
|            | Power Consumption                     | No Load, No Signal, ADC on, PGA on, $f_s = 44.1kHz$                                                                        | 5.4        |           | mW            |

## Absolute Maximum Ratings

| Parameter                      | Min        | Max       | Units |
|--------------------------------|------------|-----------|-------|
| Digital Supply Range           | -0.3       | 2.2       | V     |
| Digital I/O Supply Range       | -0.3       | 6.0       | V     |
| Analog Supply Range            | -0.3       | 2.2       | V     |
| Headphone Supply Range         | -0.3       | 2.2       | V     |
| Microphone Bias Supply Voltage | -0.3       | 6.0       | V     |
| Voltage Input Digital Range    | DGND - 0.3 | VDD + 0.3 | V     |
| Voltage Input Analog Range     | AGND - 0.3 | VDD + 0.3 | V     |
| Junction Temperature, $T_j$    | -40        | +150      | °C    |
| Storage Temperature            | -65        | +150      | °C    |

CAUTION: Do not operate at or near the maximum ratings listed for extended periods. Exposure to such conditions may adversely influence product reliability and result in failures not covered by warranty

## Operating Conditions

| Condition                      | Symbol | Min | Typical | Max  | Units |
|--------------------------------|--------|-----|---------|------|-------|
| Digital Supply Range           | VDDC   | 1.1 | 1.2     | 1.98 | V     |
| Digital I/O Supply Range       | VDDDB  | 1.6 | 1.8     | 3.6  | V     |
| Analog Supply Range            | VDDA   | 1.6 | 1.8     | 2.0  | V     |
| Headphone Supply Range         | VDDA   | 1.6 | 1.8     | 2.0  | V     |
| Microphone Bias Supply Voltage | VDDMIC | 2.5 | 4.2     | 5.0  | V     |
| Temperature Range              | $T_A$  | -40 |         | +85  | °C    |

## Digital I/O

| Parameter         | Symbol   | Comments/Conditions           | Min         | Max          | Units |
|-------------------|----------|-------------------------------|-------------|--------------|-------|
| Input LOW level   | $V_{IL}$ | VDDDB = 1.8V                  |             | 0.33 * VDDDB | V     |
|                   |          | VDDDB = 3.3V                  |             | 0.37*VDDDB   |       |
| Input HIGH level  | $V_{IH}$ | VDDDB = 1.8V                  | 0.67*VDDDB  |              | V     |
|                   |          | VDDDB = 3.3V                  | 0.63*VDDDB  |              |       |
| Output HIGH level | $V_{OH}$ | $I_{Load} = 1mA$ VDDDB=1.8V   | 0.9 * VDDDB |              | V     |
|                   |          | $I_{Load} = 1mA$ VDDDB = 3.3V | 0.95*VDDDB  |              |       |
| Output LOW level  | $V_{OL}$ | $I_{Load} = 1mA$ VDDDB = 1.8V |             | 0.1 * VDDDB  | V     |
|                   |          | $I_{Load} = 1mA$ VDDDB=3.3V   |             | 0.05*VDDDB   |       |

## Ordering Information

| Part Number | Dimension | Package | Package Material |
|-------------|-----------|---------|------------------|
| NAU88L25YG  | 5 x 5 mm  | QFN-32L | Green            |

## Nuvoton Part Number Description

NAU88L25YG

**Package Material:**

**G** = Pb-free Package

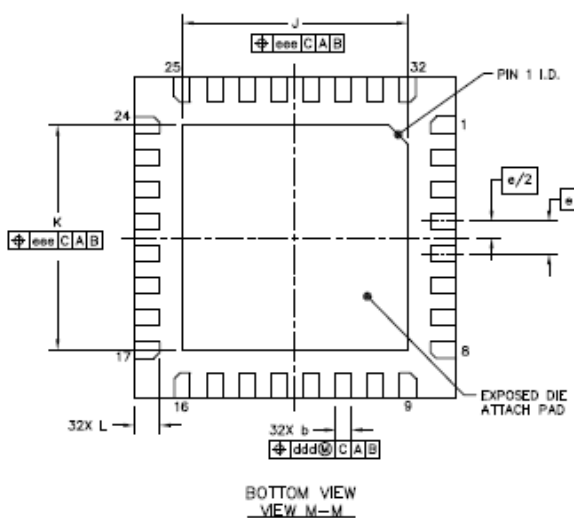
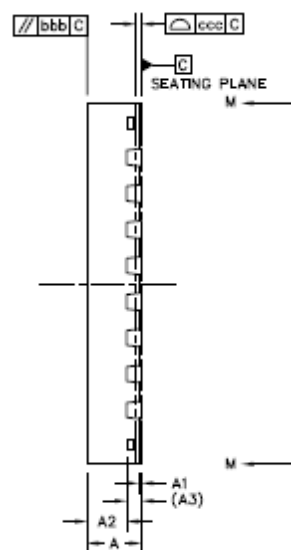
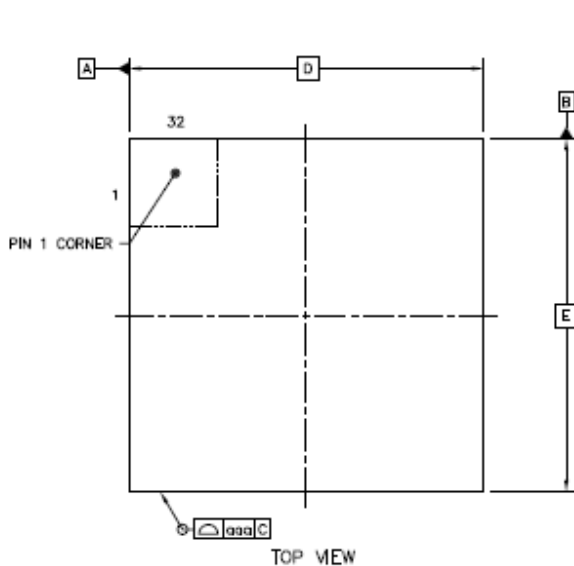
**Package Type:**

**Y** = QFN Package

# Package Information

QFN 32L 5X5 mm<sup>2</sup>, Thickness 0.8 mm(Max) ,Pitch 0.5 mm

(Saw Type) EP SIZE 3.5X3.5 mm



|                        |   | SYMBOL | MIN       | NOM   | MAX  |
|------------------------|---|--------|-----------|-------|------|
| TOTAL THICKNESS        |   | A      | 0.7       | 0.75  | 0.8  |
| STAND OFF              |   | A1     | 0         | 0.035 | 0.05 |
| MOLD THICKNESS         |   | A2     | ---       | 0.55  | 0.57 |
| L/F THICKNESS          |   | A3     | 0.203 REF |       |      |
| LEAD WIDTH             |   | b      | 0.2       | 0.25  | 0.3  |
| BODY SIZE              | X | D      | 5 BSC     |       |      |
|                        | Y | E      | 5 BSC     |       |      |
| LEAD PITCH             |   | e      | 0.5 BSC   |       |      |
| EP SIZE                | X | J      | 3.4       | 3.5   | 3.6  |
|                        | Y | K      | 3.4       | 3.5   | 3.6  |
| LEAD LENGTH            |   | L      | 0.35      | 0.4   | 0.45 |
| PACKAGE EDGE TOLERANCE |   | aaa    | 0.1       |       |      |
| MOLD FLATNESS          |   | bbb    | 0.1       |       |      |
| COPLANARITY            |   | ccc    | 0.08      |       |      |
| LEAD OFFSET            |   | ddd    | 0.1       |       |      |
| EXPOSED PAD OFFSET     |   | eee    | 0.1       |       |      |

## Version History

| VERSION | DATE       | PAGE                | DESCRIPTION                                                                                                                                   |
|---------|------------|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| 0.1     | 11/20/2014 | NA                  | Preliminary Version                                                                                                                           |
| 0.2     | 03/10/2015 |                     | Updated the pin-out and pin-descriptions                                                                                                      |
| 0.3     | 04/10/2015 | 8                   | Ordering info is added.                                                                                                                       |
| 0.4     | 06/15/2015 | 5, 6                | Updated Electrical Characteristics                                                                                                            |
| 0.5     | 07/16/2015 | 1                   | Updated the descriptions                                                                                                                      |
| 0.6     | 09/28/2015 | 1,<br>2,<br>7,<br>8 | Updated the descriptions and key features<br>Updated the block diagram<br>Changed VIH (input high voltage)<br>Updated the package information |
| 0.7     | 10/27/2015 | 9                   | Updated the package info                                                                                                                      |

Table 1: Version History

### Important Notice

Nuvoton products are not designed, intended, authorized or warranted for use as components in systems or equipment intended for surgical implantation, atomic energy control instruments, airplane or spaceship instruments, transportation instruments, traffic signal instruments, combustion control instruments, or for other applications intended to support or sustain life. Furthermore, Nuvoton products are not intended for applications wherein failure of Nuvoton products could result or lead to a situation wherein personal injury, death or severe property or environmental damage could occur.

Nuvoton customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Nuvoton for any damages resulting from such improper use or sales.