

# NCN5193

## HART Modem

### Description

The NCN5193 is a single-chip, CMOS modem for use in highway addressable remote transducer (HART) field instruments and masters. The modem and a few external passive components provide all of the functions needed to satisfy HART physical layer requirements including modulation, demodulation, receive filtering, carrier detect, and transmit-signal shaping. In addition, the NCN5193 also has an integrated DAC for low-BOM current loop slave transmitter implementation.

The NCN5193 uses phase continuous frequency shift keying (FSK) at 1200 bits per second. To conserve power the receive circuits are disabled during transmit operations and vice versa. This provides the half-duplex operation used in HART communications.

### Features

- Single-chip, Half-duplex 1200 Bits per Second FSK Modem
- Bell 202 Shift Frequencies of 1200 Hz and 2200 Hz
- 1.8 V – 3.5 V Power Supply
- Transmit-signal Wave Shaping
- Receive Band-pass Filter
- Low Power: Optimal for Intrinsically Safe Applications
- Compatible with 1.8 V or 3.3 V Microcontroller
- Internal Oscillator Requires 460.8 kHz, 920 kHz, 1.84 MHz or 3.68 MHz Crystal or Ceramic Resonator
- SPI Communication
- Integrated 17 bit Sigma-Delta DAC
- Meets HART Physical Layer Requirements
- Industrial Temperature Range of -40°C to +85°C
- Available in 32-pin NQFP Package
- These are Pb-Free Devices

### Applications

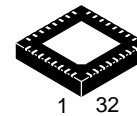
- HART Multiplexers
- HART Modem Interfaces
- 4 – 20 mA Loop Powered Transmitters



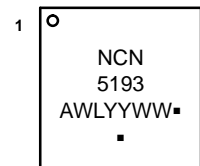
**ON Semiconductor®**

[www.onsemi.com](http://www.onsemi.com)

### MARKING DIAGRAM



QFN32  
CASE 485EK



NCN5193 = Specific Device Code

A = Assembly Location

WL = Wafer Lot

YY = Year

WW = Work Week

▪ = Pb-Free Package

(Note: Microdot may be in either location)

### ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 13 of this data sheet.

**HART**<sup>®</sup>  
COMMUNICATION PROTOCOL

# NCN5193

## BLOCK DIAGRAM

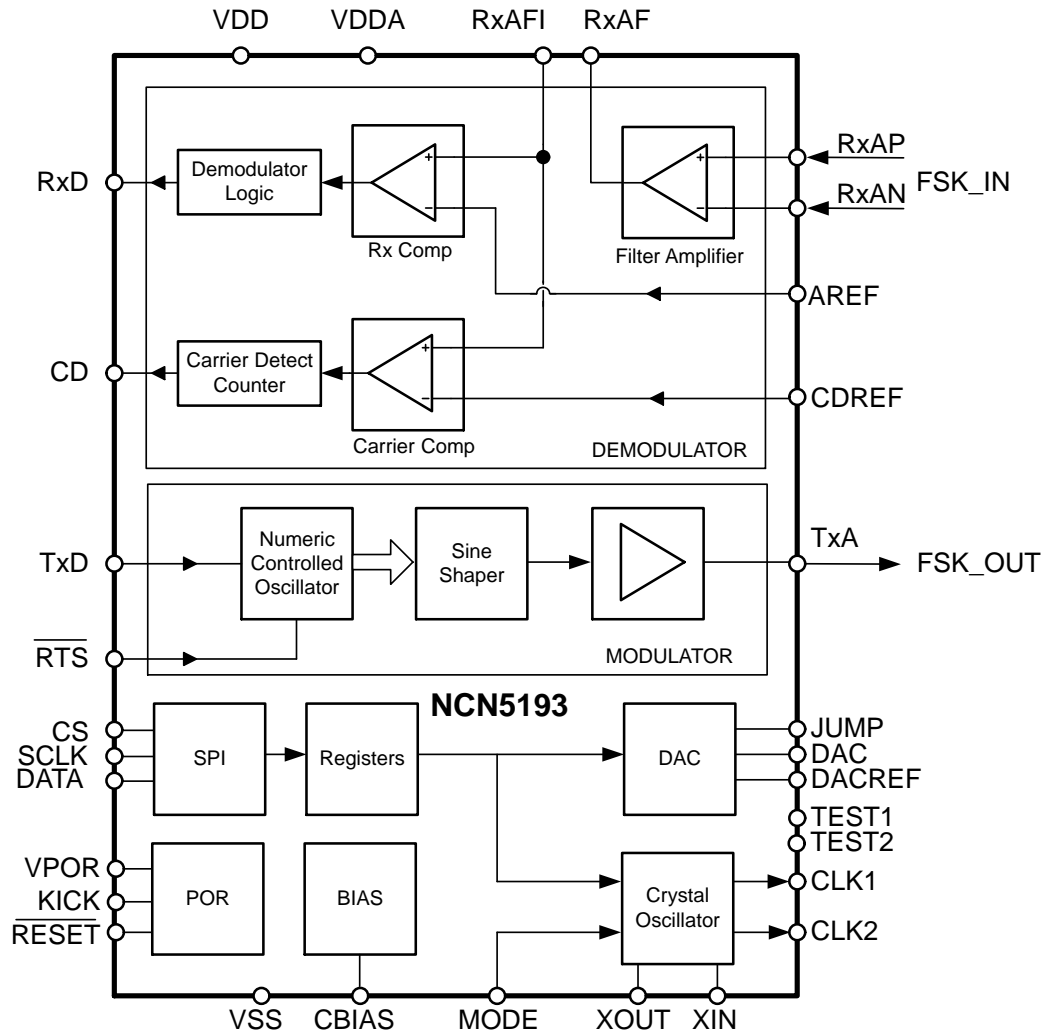


Figure 1. Block Diagram NCN5193

## ELECTRICAL SPECIFICATIONS

Table 1. ABSOLUTE MAXIMUM RATINGS (Note 1)

| Symbol            | Parameter            | Min  | Max            | Units |
|-------------------|----------------------|------|----------------|-------|
| $T_A$             | Ambient Temperature  | -40  | +85            | °C    |
| $T_S$             | Storage Temperature  | -55  | +150           | °C    |
| $T_J$             | Junction Temperature | -40  | +150           | °C    |
| $V_{DD}$          | Supply Voltage       | -0.3 | 4.0            | V     |
| $V_{IN}, V_{OUT}$ | DC Input, Output     | -0.3 | $V_{DD} + 0.3$ | V     |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

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

# NCN5193

**Table 2. DC CHARACTERISTICS** ( $V_{DD} = 1.8\text{ V to }3.5\text{ V}$ ,  $V_{SS} = 0\text{ V}$ ,  $T_A = -40^\circ\text{C to }+85^\circ\text{C}$ )

| Symbol                 | Parameter   | $V_{DD}$    | Min            | Typ   | Max            | Units         |
|------------------------|---|-------------|----------------|-------|----------------|---------------|
| $V_{DD}$               | DC Supply Voltage   |             | 1.8            |       | 3.5            | V             |
| $V_{IL}$               | Input Voltage, Low  | 1.8 – 3.5 V |                |       | $0.2 * V_{DD}$ | V             |
| $V_{IH}$               | Input Voltage, High   | 1.8 – 3.5 V | $0.8 * V_{DD}$ |       |                | V             |
| $V_{OL}$               | Output Voltage, Low ( $I_{OL} = 0.67\text{ mA}$ )   | 1.8 – 3.5 V |                |       | 0.4            | V             |
| $V_{OH}$               | Output Voltage, High ( $I_{OH} = -0.67\text{ mA}$ )   | 1.8 – 3.5 V | $V_{DD} - 0.4$ |       |                | V             |
| $I_{IL}/I_{IH}$        | Input Leakage Current   |             |                |       | $\pm 1$        | $\mu\text{A}$ |
| $I_{DD}$               | Total Power Supply Current  |             | 70             | 190   | 500            | $\mu\text{A}$ |
| $I_{DDA}$              | Static Analog Supply Current  |             | 45             |       | 270            | $\mu\text{A}$ |
| $I_{DDQ}$              | Static Digital Current  |             | 0              |       | 30             | $\mu\text{A}$ |
| $I_{DDD}$              | Dynamic Digital Current   |             | 25             |       | 200            | $\mu\text{A}$ |
| $A_{REF}$              | Analog Reference  |             | 1.2            | 1.235 | 2.6            | V             |
| $CD_{REF}$<br>(Note 2) | Carrier Detect Reference ( $A_{REF} - 0.08\text{ V}$ )                                      |             |                | 1.15  |                | V             |
| $I_{BIAS}$             | Comparator Bias Current<br>( $R_{BIAS} = 120\text{ k}\Omega$ , $A_{REF} = 1.235\text{ V}$ ) |             |                | 10    |                | $\mu\text{A}$ |

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

2. The HART specification requires carrier detect (CD) to be active between 80 and 120 mVp-p. Setting  $CD_{REF}$  at  $A_{REF} - 0.08\text{ VDC}$  will set the carrier detect to a nominal 100 mVp-p.

**Table 3. AC CHARACTERISTICS** ( $V_{DD} = 1.8\text{ V to }3.5\text{ V}$ ,  $V_{SS} = 0\text{ V}$ ,  $T_A = -40^\circ\text{C to }+85^\circ\text{C}$ ) (Note 3)

| Pin Name   | Description  | Min          | Typ                                     | Max                       | Units                                      |
|------------|--|--------------|---|---------------------------|--|
| RxAP, RxAN | Receive analog input<br>Leakage current<br>Frequency – mark (logic 1)<br>Frequency – space (logic 0)   | 1190<br>2180 | 1200<br>2200                            | $\pm 150$<br>1210<br>2220 | nA<br>Hz<br>Hz                             |
| RxAF       | Output of the high-pass filter<br>Slew rate<br>Gain bandwidth (GBW)<br>Voltage range   | 300<br>0.15  | 0.04                                    | $V_{DD} - 0.15$           | V/ $\mu\text{s}$<br>kHz<br>V               |
| RxAFI      | Carrier detect and receive filter input<br>Leakage current   |              |   | $\pm 500$                 | nA   |
| TxA        | Modulator output<br>Frequency – mark (logic 1)<br>Frequency – space (logic 0)<br>Amplitude (IAREF 1.235 V)<br>Slew Rate – mark (logic 1)<br>Slew Rate – space (logic 0)<br>Loading (IAREF = 1.235 V) | 30           | 1196.9<br>2194.3<br>500<br>1860<br>3300 |                           | Hz<br>Hz<br>mV<br>V/s<br>V/s<br>k $\Omega$ |
| RxD        | Receive digital output<br>Rise/fall time   |              |   | 20                        | ns   |
| CD         | Carrier detect output<br>Rise/fall time  |              |   | 20                        | ns   |

3. The modulator output frequencies are proportional to the input clock frequency (460.8 kHz/920 kHz/1.84 MHz / 3.68 MHz).

# NCN5193

**Table 4. MODEM CHARACTERISTICS** ( $V_{DD} = 1.8\text{ V to }3.5\text{ V}$ ,  $V_{SS} = 0\text{ V}$ ,  $T_A = -40^\circ\text{C to }+85^\circ\text{C}$ )

| Parameter   | Min | Typ | Max | Units      |
|---|-----|-----|-----|------------|
| Demodulator jitter<br>Conditions<br>1. Input frequencies at $1200\text{ Hz} \pm 10\text{ Hz}$ , $2200\text{ Hz} \pm 20\text{ Hz}$<br>2. Clock frequency of $460.8\text{ kHz} \pm 0.1\%$<br>3. Input (RxAP) asymmetry, 0 |     |     | 12  | % of 1 bit |

**Table 5. CERAMIC RESONATOR AND CRYSTAL – External Clock Specifications**

( $V_{DD} = 1.8\text{ V to }3.5\text{ V}$ ,  $V_{SS} = 0\text{ V}$ ,  $T_A = -40^\circ\text{C to }+85^\circ\text{C}$ )

| Parameter  | Min | Typ                     | Max | Units  |
|--|-----|-------------------------|-----|--------|
| 460.8 kHz / 920 kHz / 1.84 MHz / 3.68 MHz Ceramic resonator or crystal oscillation frequency tolerance |     |                         | 1.0 | %      |
| External Clock<br>Duty cycle<br>Amplitude  | 35  | 50<br>$V_{OH} - V_{OL}$ | 65  | %<br>V |

**Table 6. DAC CHARACTERISTICS** ( $V_{DD} = 3.0\text{ V to }5.5\text{ V}$ ,  $V_{SS} = 0\text{ V}$ ,  $T_A = -40^\circ\text{C to }+85^\circ\text{C}$ )

| Parameter                        | Min | Typ         | Max | Units |
|----------------------------------|-----|-------------|-----|-------|
| Bandwidth (Note 4)               |     | 25          |     | Hz    |
| Resolution                       |     | 17          |     | Bit   |
| Maximum Output<br>Return-to-Zero |     | $AV_{DD}/2$ |     | V     |

4. The DAC is a sigma-delta type modulator. Therefore, the bandwidth is determined by the external filter. Decreasing the bandwidth will increase DAC accuracy.

# NCN5193

## TYPICAL APPLICATION

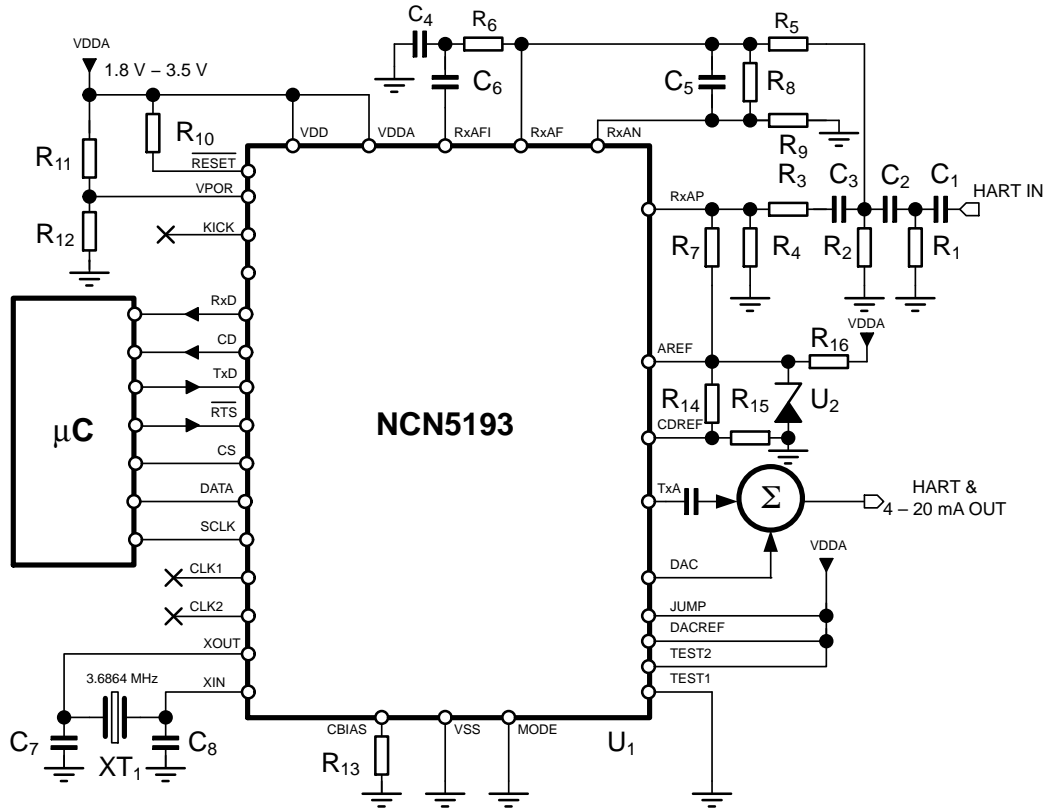


Figure 2. Application Diagram NCN5193

Table 7. TYPICAL BILL OF MATERIALS

| Reference Designator | Value (Typical) | Tolerance | Manufacturer     | Part Number  |
|----------------------|-----------------|-----------|------------------|--------------|
| U1                   | -               | -         | ON Semiconductor | NCN5193      |
| U2                   | -               | -         | ON Semiconductor | LM285        |
| R1, R2               | 1.5M            | 1%        |                  |              |
| R3, R5               | 806k            | 1%        |                  |              |
| R4                   | 1.3M            | 1%        |                  |              |
| R6                   | 174k            | 1%        |                  |              |
| R7                   | 2.2M            | 1%        |                  |              |
| R8, R9               | 422k            | 1%        |                  |              |
| R11                  | 240k            | 1%        |                  |              |
| R12, R15, R10        | 200k            | 1%        |                  |              |
| R13                  | 120k            | 1%        |                  |              |
| R14, R16             | 14k7            | 1%        |                  |              |
| C1                   | 1 nF            | 5%        |                  |              |
| C2                   | 470 pF          | 5%        |                  |              |
| C3                   | 200 pF          | 5%        |                  |              |
| C4                   | 220 pF          | 5%        |                  |              |
| C5                   | 20 pF           | 5%        |                  |              |
| C6                   | 330 pF          | 5%        |                  |              |
| C7, C8               | 18 pF           | 10%       |                  |              |
| XT1                  | 3.6864 MHz      | 100 ppm   | Raltron          | AS-3.6864-18 |

# NCN5193

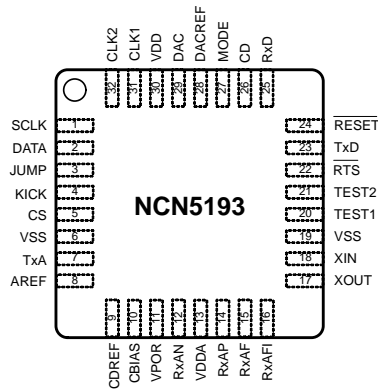


Figure 3. Pin Out NCN5193 in 32-pin NQFP (top view)

Table 8. PIN OUT SUMMARY 32-PIN NQFP

| Pin No. | Signal Name | Type       | Pin Description   |
|---------|-------------|------------|---|
| 1       | SCLK        | Input      | SPI Serial Clock  |
| 2       | DATA        | Input      | SPI Serial Data   |
| 3       | JUMP        | Input      | Sigma-Delta Modulator Alarm condition value                         |
| 4       | KICK        | Input      | Watchdog kick   |
| 5       | CS          | Input      | SPI Serial Chip Select  |
| 6       | VSS         | Ground     | Ground  |
| 7       | TxA         | Output     | Transmit Data Modulator output                                      |
| 8       | AREF        | Input      | Analog reference voltage  |
| 9       | CDREF       | Input      | Carrier detect reference voltage                                    |
| 10      | CBIAS       | Output     | Comparator bias current   |
| 11      | VPOR        | Input      | POR measurement point   |
| 12      | RxAN        | Input      | Receive filter amplifier negative terminal                          |
| 13      | VDDA        | Power      | Analog supply voltage   |
| 14      | RxAP        | Input      | Receive filter amplifier positive terminal                          |
| 15      | RxAF        | Output     | Analog receive filter output  |
| 16      | RxAFI       | Input      | Analog receive comparator input                                     |
| 17      | XOUT        | Output     | Crystal oscillator output   |
| 18      | XIN         | Input      | Crystal oscillator input  |
| 19      | VSS         | Ground     | Ground  |
| 20      | TEST1       | Input      | Test pin. Tie to GND  |
| 21      | TEST2       | Input      | Test pin. Tie to VDD  |
| 22      | RTSB        | Input      | Request to send   |
| 23      | TxD         | Input      | Input transmit data, transmit HART data stream from microcontroller |
| 24      | RESETB      | Open Drain | Reset all digital logic when low                                    |
| 25      | RxD         | Output     | Received demodulated HART data to microcontroller                   |
| 26      | CD          | Output     | Carrier detect output   |
| 27      | MODE        | Input      | Mode pin to select external or internal oscillator                  |
| 28      | DACREF      | Input      | Sigma-Delta Modulator Reference Voltage                             |
| 29      | DAC         | Output     | Sigma-Delta Modulator Output  |
| 30      | VDD         | Power      | Digital supply voltage  |
| 31      | CLK1        | Output     | Programmable Clock Output 1   |
| 32      | CLK2        | Output     | Programmable Clock Output 2   |
| -       | EP          | Ground     | Exposed pad. Connect to GND   |

Table 9. PIN DESCRIPTIONS

| Symbol | Pin Name                                  | Description   |
|--------|---|---|
| AREF   | Analog reference voltage                  | Receiver Reference Voltage. See Table 2.  |
| CDREF  | Carrier detect reference voltage          | Carrier Detect Reference voltage. The value should be 80 mV below AREF to set the carrier detection to a nominal of 100 mV <sub>p-p</sub> .   |
| RESETB | Reset digital logic                       | When at logic low (V <sub>SS</sub> ) this input holds all the digital logic in reset. During normal operation RESETB should be at V <sub>DD</sub> .   |
| RTSB   | Request to send                           | Active-low input selects the operation of the modulator. TxA is enabled when this signal is low. This signal must be held high during power-up.   |
| RxAP   | Analog filter amplifier positive terminal | Positive terminal of the receive filter. For a reference implementation of the receive filter see Figure 2  |
| RxAN   | Analog filter amplifier positive terminal | Negative terminal of the receive filter. For a reference implementation of the receive filter see Figure 2  |
| RxAFI  | Analog receive comparator input           | Positive input of the carrier detect comparator and the receiver filter comparator.   |
| TxD    | Digital transmit input                    | Input to the modulator accepts digital data in NRZ form. When TxD is low, the modulator output frequency is 2200 Hz. When TxD is high, the modulator output frequency is 1200 Hz.   |
| XIN    | Oscillator input                          | Input to the internal oscillator must be connected to a parallel mode ceramic resonator when using the internal oscillator or grounded when using an external clock signal.   |
| XOUT   | Oscillator output                         | Output from the internal oscillator must be connected to an external clock signal or to a parallel mode ceramic resonator when using the internal oscillator.   |
| CLK1   | Programmable Clock Output                 | Output signal derived from oscillator output, frequency division set by internal register.  |
| CLK2   | Programmable Clock Output                 | Output signal derived from oscillator output, frequency division set by internal register.  |
| CBIAS  | Comparator bias current                   | Connection to the external bias resistor. R <sub>BIAS</sub> should be selected such that AREF / R <sub>BIAS</sub> = 10 μA ± 5%  |
| CD     | Carrier detect output                     | Output goes high when a valid input is recognized on RxA. If the received signal is greater than the threshold specified on CDREF for four cycles of the RxA signal, the valid input is recognized.   |
| RxAF   | Analog receive filter output              | The output of the three pole high pass receive data filter  |
| RxD    | Digital receive output                    | Signal outputs the digital receive data. When the received signal (RxA) is 1200 Hz, RxD outputs logic high. When the received signal (RxA) is 2200 Hz, RxD outputs logic low. The HART receive data stream is only active if Carrier Detect (CD) is high. |
| MODE   | Digital input                             | Selects the clock source. Connecting this pin to VDD disables the internal oscillator. The chip then requires an external clock source. Connecting this pin to VSS enables the internal oscillator to drive the external crystal or ceramic resonator     |
| TxA    | Analog transmit output                    | Transmit Data Modulator Output. A trapezoidal shaped waveform with a frequency of 1200 Hz or 2200 Hz corresponding to a data value of 1 or 0 respectively applied to TxD. TxA is active when RTSB is low. TxA equals 0.5 V when RTSB is high.             |
| SCLK   | SPI bus clock line                        | Serial communication clock line   |
| DATA   | SPI bus data line                         | Serial communication data line.   |
| CS     | SPI bus chip select                       | Serial communication chip select line. Pulled high by microcontroller while a frame is transmitted.   |
| JUMP   | DAC Alarm value                           | When a problem is detected, such as a clock failure or the watchdog going off, the DAC will jump to VSS or DACREF, depending on whether this pin is connected to VSS or VDD respectively.   |
| DACREF | DAC Reference                             | This is the high value of the output and can be connected to any voltage between AREF and VDD.  |
| DAC    | DAC Output                                | Output of a 17 bit Sigma-Delta Modulator  |
| KICK   | Watchdog Kick                             | Periodically a pulse should be provided to reset the watchdog. This can be configured in internal registers for an internal 1.8kHz signal, or to an external signal provided to this pin.   |
| VPOR   | POR Input                                 | Input to the POR comparator. The voltage on this pin is compared with AREF. An external resistor divider should divide the supply voltage to this pin.  |
| VDD    | Digital power                             | Power for the digital modem circuitry   |
| VDDA   | Analog supply voltage                     | Power for the analog modem circuitry  |
| VSS    | Ground                                    | Digital ground  |
| VSSA   | Analog ground                             | Analog ground   |

**Functional Description**

The NCN5193 is a single-chip modem for use in Highway Addressable Remote Transducer (HART) field instruments and masters. The modem IC contains a transmit data modulator with signal shaper, carrier detect circuitry, an analog receiver, demodulator circuitry and an oscillator, as shown in the block diagram in Figure 1.

The modulator accepts digital data at its digital input TxD and generates a trapezoidal shaped FSK modulated signal at the analog output TxA. A digital “1” or mark is represented with a frequency of 1200 Hz. A digital “0” or space is represented with a frequency of 2200 Hz. The used bit rate is 1200 baud.

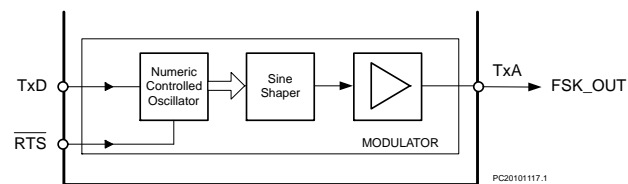
The demodulator receives the FSK signal at its analog input, filters it with a band-pass filter and generates 2 digital signals: RxD: Received Data and CD: Carrier Detect. At the digital output RxD the original modulated signal is received. CD outputs the Carrier Detect signal. It goes logic high if the received signal is above 100 mVpp during 4 consecutive carrier periods.

The oscillator provides the modem with a stable time base using either a simple external resonator or an external clock source.

**Detailed Description**

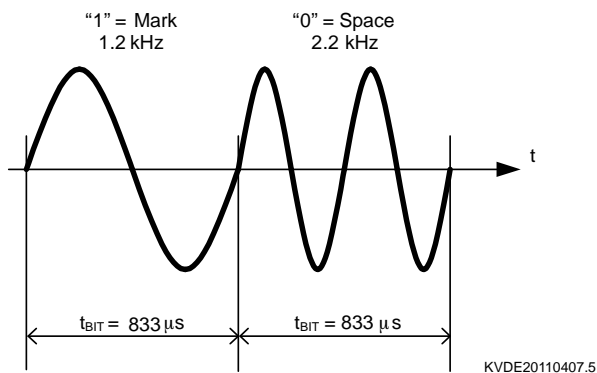
**Modulator**

The modulator accepts digital data in NRZ form at the TxD input and generates the FSK modulated signal at the TxA output.



**Figure 4. Modulator Block Diagram**

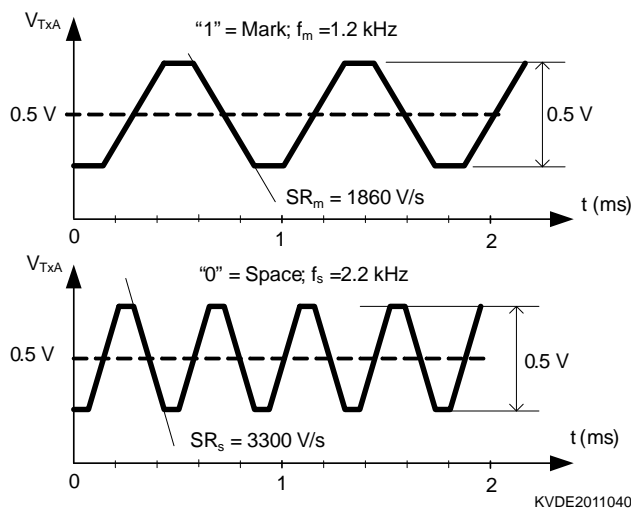
A logic “1” or mark is represented by a frequency  $f_m = 1200$  Hz. A logic “0” or space is represented by a frequency  $f_s = 2200$  Hz.



**Figure 5. Modulation Timing**

The Numeric Controlled Oscillator (NCO) works in a phase continuous mode preventing abrupt phase shifts when switching between mark and space frequency. The control signal “Request To Send” (RTSB) enables the NCO. When RTSB is logic low the modulator is active and NCN5193 is in transmit mode. When RTSB is logic high the modulator is disabled and NCN5193 is in receive mode.

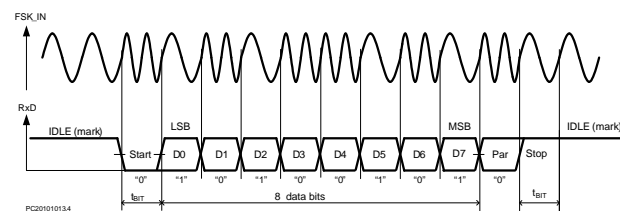
The digital outputs of the NCO are shaped in the Wave Shaper block to a trapezoidal signal. This circuit controls the rising and falling edge to be inside the standard HART waveshape limits. Figure 6 shows the transmit-signal forms captured at TxA for mark and space frequency. The slew rates are  $SR_m = 1860$  V/s at the mark frequency and  $SR_s = 3300$  V/s at the space frequency. For  $A_{REF} = 1.235$  V, TxA will have a voltage swing from approximately 0.25 to 0.75  $V_{DC}$ .



**Figure 6. Modulator shaped output signal for Mark and Space frequency at TxA pin.**

**Demodulator**

The demodulator accepts a FSK signal at the RxA input and reconstructs the original modulated signal at the RxD output. Figure 7 illustrates the demodulation process.



**Figure 7. Modulation Timing**

This HART bit stream follows a standard 11-bit UART frame with Start, Stop, 8 Data – and 1 Parity bit (odd). The communication speed is 1200 baud.

**Receive Filter and Comparator**

The received FSK signal first is filtered using a band-pass filter build around the low noise receiver operational amplifier. This filter blocks interferences outside the HART signal band.



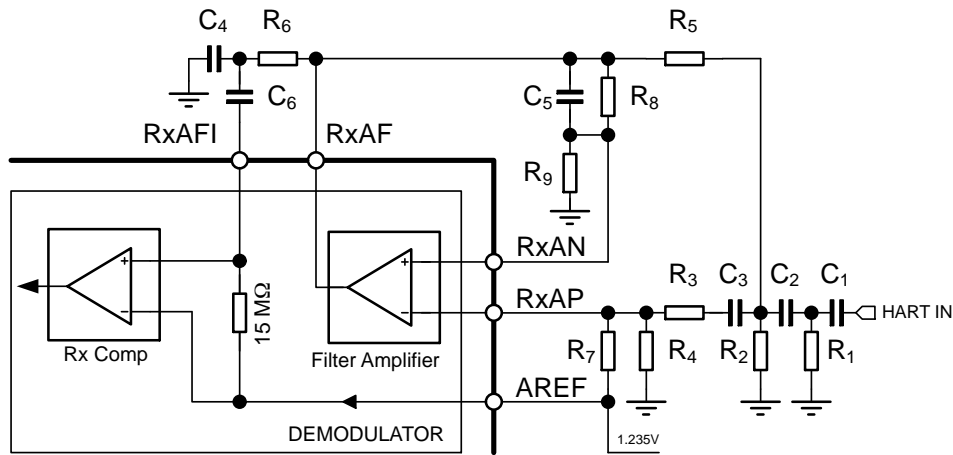


Figure 8. Demodulator Receive Filter and Signal Comparator

The filter output is fed into the Rx comparator. The threshold value equals the analog ground making the comparator to toggle on every zero crossing of the filtered FSK signal. The maximum demodulator jitter is 12% of one bit given the input frequencies are within the HART specifications, a clock frequency of 460.8 kHz ( $\pm 1.0\%$ ) and zero input (RxA) asymmetry.

### Carrier Detect Circuitry

Low HART input signal levels increases the risk for the generation of bit errors. Therefore the minimum signal amplitude is set to 80–120 mVpp. If the received signal is below this level the demodulator is disabled.

This level detection is done in the Carrier Detector. The output of the demodulator is qualified with the carrier detect signal (CD), therefore, only RxA signals large enough to be detected (100 mV<sub>p-p</sub> typically) by the carrier detect circuit produce received serial data at RxD.

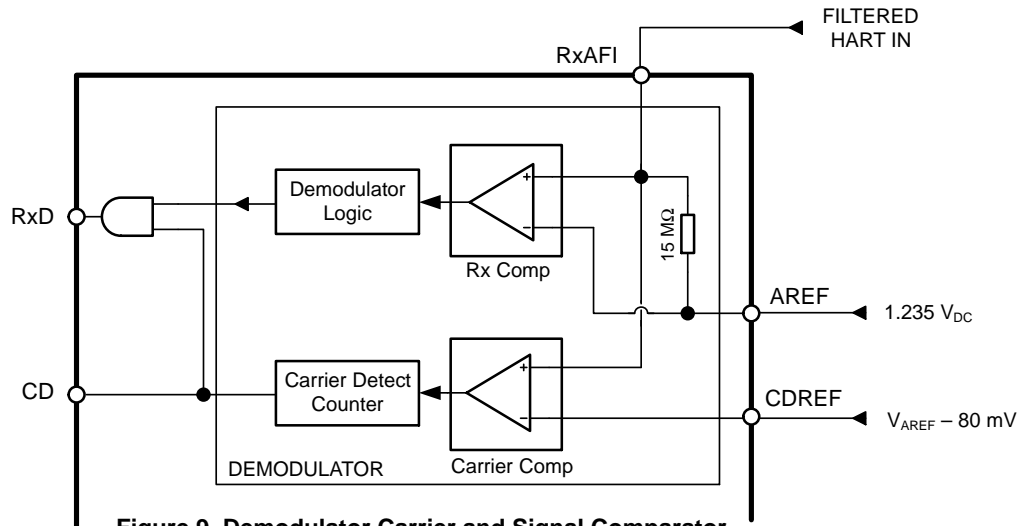


Figure 9. Demodulator Carrier and Signal Comparator

The carrier detect comparator shown in Figure 9 generates logic low output if the RxAFI voltage is below CDREF. The comparator output is fed into a carrier detect block. The carrier detect block drives the carrier detect output pin CD high if RTSB is high and four consecutive pulses out of the comparator have arrived. CD stays high as long as RTSB is high and the next comparator pulse is received in less than 2.5 ms. Once CD goes inactive, it takes four consecutive pulses out of the comparator to assert CD again. Four consecutive pulses amount to 3.33 ms when the received signal is 1200 Hz and to 1.82 ms when the received signal

is 2200 HZ. The difference between RxD and RxD\_ENH is evident when CD is low: RxD is then also low, while RxD\_ENH is then high. When CD is high, RxD and RxD\_ENH have the same output.

### Miscellaneous Analog Circuitry

#### Voltage References

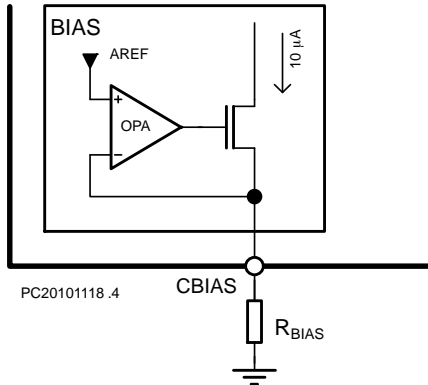
The NCN5193 requires two voltage references, AREF and CDREF. AREF sets the DC operating point of the internal operational amplifiers and is the reference for the

Rx comparator. The ON Semiconductor LM285D 1.235 V reference is recommended.

The level at which CD (Carrier Detect) becomes active is determined by the DC voltage difference (CDREF - AREF). Selecting a voltage difference of 80 mV will set the carrier detect to a nominal 100 mV<sub>p-p</sub>.

**Bias Current Resistor**

The NCN5193 requires a bias current resistor R<sub>BIAS</sub> to be connected between CBIAS and V<sub>SS</sub>. The bias current controls the operating parameters of the internal operational amplifiers and comparators and should be set to 10 μA.



**Figure 10. Bias Circuit**

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

$$R_{BIAS} = \frac{AREF}{10 \mu A}$$

The recommended bias current resistor is 120 KΩ when AREF is equal to 1.235 V.

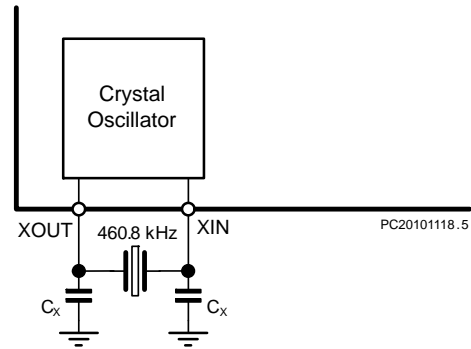
**Oscillator**

The clock signal used by NCN5193 can either be 460.8 kHz, 921.6 kHz, 1.8432 MHz or 3.6864 MHz. This can be provided by an external clock or a resonator or crystal connected to the internal oscillator. This is selected by connecting pin 27 to VDD (for external oscillator) or VSS (for internal oscillator). The correct divider value must be chosen so that the internal system clock is always 460.8 kHz. This divider value can be set in the Clock Configuration Register (CCR), bits 1–0. In the CCR, divider values can also be chosen for the CLK1 and CLK2 outputs. These values can be freely chosen and do not affect operation of the HART transceiver.

**Internal Oscillator Option**

The oscillator cell will function with a 460.8 kHz, 921.6 kHz, 1.8432 MHz or 3.6864 MHz crystal or ceramic resonator. A parallel resonant ceramic resonator can be connected between XIN and XOUT. Figure 11 illustrates the crystal option for clock generation using a 460.8 kHz (±1% tolerance) parallel resonant crystal and two tuning capacitors C<sub>x</sub>. The actual values of the capacitors may depend on the recommendations of the manufacturer of the

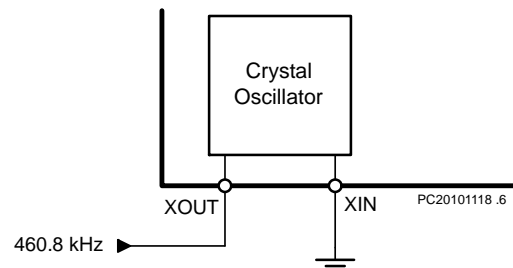
resonator. Typically, capacitors in the range of 10 pF to 470 pF are used. Additionally, a resistor may be required between XOUT and the crystal terminal, depending on manufacturer recommendation.



**Figure 11. Crystal Oscillator**

**External Clock Option**

It may be desirable to use an external clock as shown in Figure 12 rather than the internal oscillator. In addition, the NCN5193 consumes less current when an external clock is used. Minimum current consumption occurs with the clock connected to XOUT and XIN connected to V<sub>SS</sub>.



**Figure 12. Oscillator with External Clock**

**Reset**

The NCN5193 modem includes a Power on Reset block. An external resistor division of the supply voltage is required, and should be tied to pin VPOR. This pin is attached to an internal comparator, and is compared to the AREF voltage. When this comparator trips, the RESETB pin will be pulled low and the IC will reset. After VPOR returns to a valid level, the RESETB pin will be held low for at least an additional 35 ms (may be longer depending on clock frequency). The RESETB pin will also be pulled low when a failure is detected by the watchdog timer. When the microcontroller fails to provide a periodical kick signal, either by a pulse on the kick pin or by an update to the sigma-delta register (configurable in the GCR), the watchdog will pull down the RESETB pin for 140 μs. A kick signal should be provided to the IC at least every 53 ms. The watchdog timer can also guard against system clock failures if bit 2 of the GCR is set. In this case, the RESETB pin will also be pulled low when the system clock frequency is outside of 0.5x – 2x the nominal frequency (460.8 kHz).

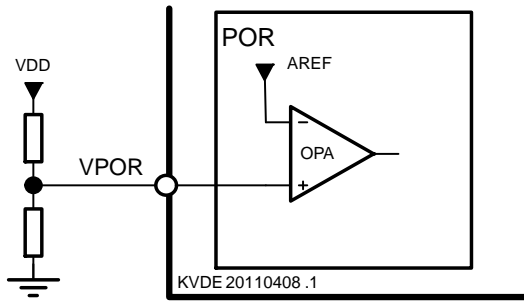


Figure 13. Power on Reset Block

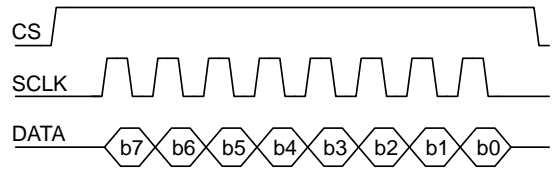


Figure 14. SPI Frame

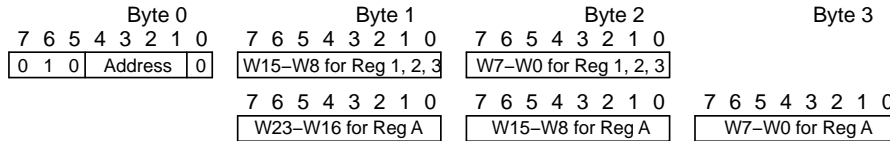


Figure 15. Register Write Format

**SPI Communication**

The SPI bus on the NCN5193 is made up of three signals; DATA, SCLK, and CS operating in SPI mode 1 (CPOL = 0, CPHA = 1, as shown in Figure 14).

CS should first go high at least one clock cycle before the other signals change. One clock cycle is 2.17 μs at a master clock frequency of 460.8 kHz.

SCLK can begin to clock in DATA serially to the chip on the falling edge of SCLK. SCLK should have a maximum frequency of 460.8 kHz. The format of the data should be most significant bit first.

DATA is shifted into the chip on the falling edge of SCLK, and thus for correct operation DATA should change only on the rising edge of SCLK. The first bit shifted in is the MSB.

Once the data is shifted in, CS should go low no sooner than one clock cycle after the last rising edge of the last byte of SCLK. To write to a register, first a command byte must be sent which includes the register address (as shown in Figure 15), followed by 2 bytes (for GCR, CCR, and ACR) or 3 bytes (for SDR) of data. When writing data to the GCR, CCR, or ACR registers, the first byte must be the bitwise inverse of the configuration data in the second byte.

**Internal Registers**

The NCN5193 has four registers to setup its internal operation. In Tables 10 to 16 an explanation of their usage is given, together with their reset values.

Table 10. GENERAL CONFIGURATION REGISTER (GCR)

| Address |       | Bit 7 | Bit 6 | Bit 5 | Bit 4    | Bit 3 | Bit 2   | Bit 1    | Bit 0 |
|---------|-------|-------|-------|-------|----------|-------|---------|----------|-------|
| 0x01    | Reset | 1     | 0     | 0     | 0        | 0     | 1       | 0        | 1     |
|         | Data  | -     | -     | -     | RXD_IDLE | -     | WDT_CLK | WDT_KICK |       |

The general configuration register is used to set the RxD idle state, enable or disable the monitoring of the system clock and setting the watchdog timer kick source. A write to this register should always be preceded with an inverted value to the shadow register.

Table 11. GENERAL CONFIGURATION REGISTER PARAMETERS

| Parameter | Value |             | Description   | Info |
|-----------|-------|-------------|---|------|
| RXD_IDLE  | 0     | Low         | Sets the idle state for the RxD pin (when CD is low)                    |      |
|           | 1     | High        |   |      |
| WDT_CLK   | 0     | Enable      | Disable/Enable monitoring of the clock frequency by the watchdog timer. |      |
|           | 1     | Disable     |   |      |
| WDT_KICK  | 00    | Disable     | Kick signal to watchdog timer is disabled                               |      |
|           | 01    | External    | Watchdog kick source is a pulse on the KICK pin                         |      |
|           | 10    | Sigma-Delta | Watchdog kick source is an write to the Sigma-Delta Data register (SDR) |      |
|           | 11    |             |   |      |

**Table 12. CLOCK CONFIGURATION REGISTER (CCR)**

| Address |       | Bit 7    | Bit 6 | Bit 5 | Bit 4    | Bit 3 | Bit 2 | Bit 1      | Bit 0 |
|---------|-------|----------|-------|-------|----------|-------|-------|------------|-------|
| 0x02    | Reset | 1        | 0     | 1     | 1        | 0     | 1     | 1          | 1     |
|         | Data  | CLK2_DIV |       |       | CLK1_DIV |       |       | SYSCLK_DIV |       |

The clock configuration register is used to set the correct division ratios for both clock outputs and the system clock. A write to this register should always be preceded with an inverted value to the shadow register.

**Table 13. CLOCK CONFIGURATION REGISTER PARAMETERS**

| Parameter  | Value |              | Description  | Info |
|------------|-------|--------------|--|------|
| CLK2_DIV   | 000   | Divide by 1  | Set the clock division value for clock output 2 (CLK2) with regard to the oscillator frequency.  |      |
|            | 001   | Divide by 2  |  |      |
|            | 010   | Divide by 3  |  |      |
|            | 011   | Divide by 4  |  |      |
|            | 100   | Divide by 5  |  |      |
|            | 101   | Divide by 8  |  |      |
|            | 110   | Divide by 16 |  |      |
|            | 111   | Divide by 32 |  |      |
| CLK1_DIV   | 000   | Divide by 1  | Set the clock division value for clock output 1 (CLK1) with regard to the oscillator frequency.  |      |
|            | 001   | Divide by 2  |  |      |
|            | 010   | Divide by 3  |  |      |
|            | 011   | Divide by 4  |  |      |
|            | 100   | Divide by 5  |  |      |
|            | 101   | Divide by 8  |  |      |
|            | 110   | Divide by 16 |  |      |
|            | 111   | Divide by 32 |  |      |
| SYSCLK_DIV | 00    | Divide by 1  | Set the clock division value for the system clock with regard to the oscillator frequency. These bits must be set so the system clock is 460.8 kHz |      |
|            | 01    | Divide by 2  |  |      |
|            | 10    | Divide by 4  |  |      |
|            | 11    | Divide by 8  |  |      |

**Table 14. ANALOG CONFIGURATION REGISTER – ACR**

| General Configuration Register (GCR) |       |        |          |          |          |          |           |          |          |
|--------------------------------------|-------|--------|----------|----------|----------|----------|-----------|----------|----------|
| Address                              |       | Bit 7  | Bit 6    | Bit 5    | Bit 4    | Bit 3    | Bit 2     | Bit 1    | Bit 0    |
| 0x03                                 | Reset | 1      | 1        | 1        | 1        | 1        | 1         | 0        | 1        |
|                                      | Data  | MOD_EN | RXAMP_EN | RXCMP_EN | CDCMP_EN | TXAMP_EN | MODDAC_EN | WDOSC_EN | SDDAC_EN |

The analog configuration register is used to enable or disable various analog blocks. A write to this register should always be preceded with an inverted value to the shadow register.

**Table 15. ANALOG CONFIGURATION REGISTER PARAMETERS**

| Parameter | Value |         | Description   | Info |
|-----------|-------|---------|---|------|
| MOD_EN    | 0     | Enable  | Disable/Enable the modulator/demodulator                                |      |
|           | 1     | Disable |   |      |
| RXAMP_EN  | 0     | Enable  | Disable/Enable the receive filter opamp                                 |      |
|           | 1     | Disable |   |      |
| RXCMP_EN  | 0     | Enable  | Disable/Enable the receive comparator                                   |      |
|           | 1     | Disable |   |      |
| CDCMP_EN  | 0     | Enable  | Disable/Enable the carrier detect comparator                            |      |
|           | 1     | Disable |   |      |
| TXAMP_EN  | 0     | Enable  | Disable/Enable the transmit output amplifier                            |      |
|           | 1     | Disable |   |      |
| MODDAC_EN | 0     | Enable  | Disable/Enable the DAC used to provide the waveshaping to the modulator |      |
|           | 1     | Disable |   |      |
| WDOSC_EN  | 0     | Enable  | Disable/Enable the watchdog timer oscillator                            |      |
|           | 1     | Disable |   |      |
| SDDAC_EN  | 0     | Enable  | Disable/Enable the sigma-delta DAC                                      |      |
|           | 1     | Disable |   |      |

**Table 16. SIGMA-DELTA DAC REGISTER – SDR**

| General Configuration Register (GCR) |       |           |          |        |         |
|--------------------------------------|-------|-----------|----------|--------|---------|
| Address                              |       | Bit 23:16 | Bit 15:8 | Bit 7  | Bit 6:0 |
| 0x0A                                 | Reset | 0x00      | 0x00     | 0      | 0x00    |
|                                      | Data  | Data 16:9 | Data 8:1 | Data 0 | -       |

The sigma-delta register is used to update the output value of the 17-bit sigma delta modulator. The sigma-delta modulator is disabled at reset and must be enabled in the ACR first before the value in the SDR will appear at the sigma-delta output.

**Sigma Delta DAC**

The NCN5193 Modem has an integrated Sigma-Delta Modulator for use in a current loop slave transmitter. Through this DAC, an analog value can be set and transmitted across the current loop. For more information on

how to create a current loop slave transmitter, see application notes on the ON Semiconductor website. The DAC output will switch between 0 V and the voltage provided to DACREF. To achieve maximum accuracy, the DACREF voltage should be kept stable, so that power supply variations are not visible in the DAC output. The Sigma-Delta modulator output can be set through the Sigma Delta Register (SDR). When a clock failure is detected, using an internal oscillator, the DAC output will jump to the level set by the JUMP pin, until the IC is reset or a rising flank is detected on KICK.

**Ordering Information**

The NCN5193 is available in a 32-pin no lead quad flat pack (NQFP). Use the following part numbers when ordering. Contact your local sales representative for more information: [www.onsemi.com](http://www.onsemi.com).

**Table 17. ORDERING INFORMATION**

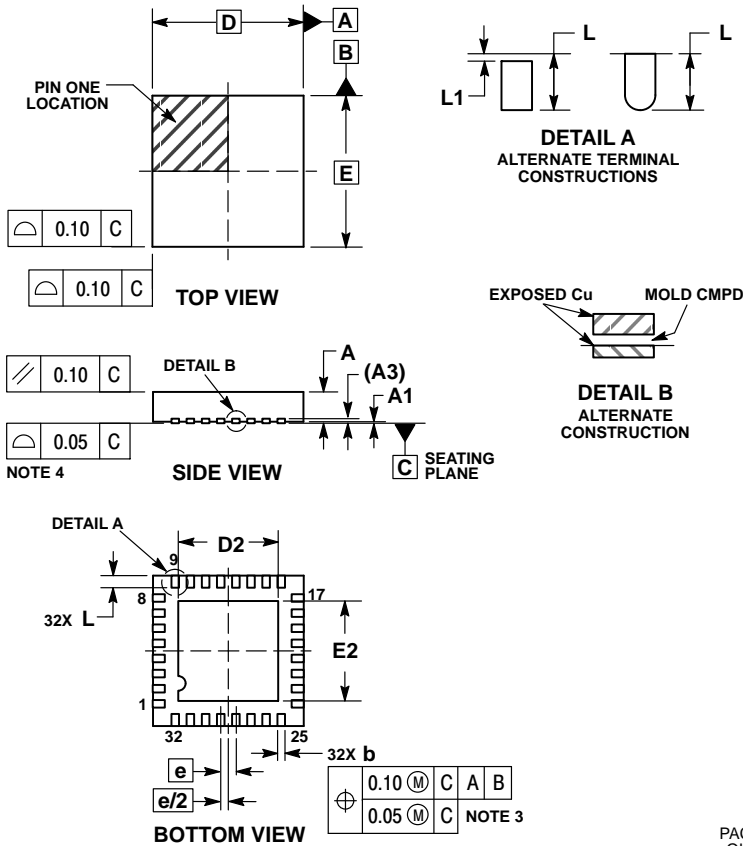
| Part Number  | Temperature Range           | Package                             | Shipping†          |
|--------------|-----------------------------|-------------------------------------|--------------------|
| NCN5193MNTWG | -40°C to +85°C (Industrial) | 32-pin NQFP<br>Green/RoHS compliant | 1000 / Tape & Reel |

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

# NCN5193

## PACKAGE DIMENSIONS

QFN32 5x5, 0.5P  
CASE 485EK  
ISSUE A

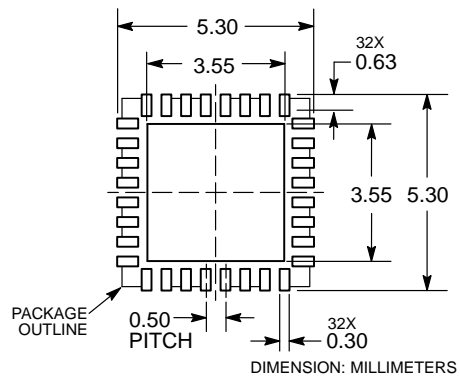


**NOTES:**

1. DIMENSIONS AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.15 AND 0.30MM FROM THE TERMINAL TIP.
4. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.

| DIM | MILLIMETERS |      |
|-----|-------------|------|
|     | MIN         | MAX  |
| A   | 0.80        | 0.90 |
| A1  | —           | 0.05 |
| A3  | 0.20 REF    |      |
| b   | 0.18        | 0.30 |
| D   | 5.00 BSC    |      |
| D2  | 3.20        | 3.40 |
| E   | 5.00 BSC    |      |
| E2  | 3.20        | 3.40 |
| e   | 0.50 BSC    |      |
| L   | 0.35        | 0.45 |
| L1  | —           | 0.15 |

### RECOMMENDED SOLDERING FOOTPRINT\*



\*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

ON Semiconductor and are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at [www.onsemi.com/site/pdf/Patent-Marketing.pdf](http://www.onsemi.com/site/pdf/Patent-Marketing.pdf). ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use ON Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that ON Semiconductor was negligent regarding the design or manufacture of the part. ON Semiconductor is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

### PUBLICATION ORDERING INFORMATION

**LITERATURE FULFILLMENT:**

Literature Distribution Center for ON Semiconductor  
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA  
Phone: 303-675-2175 or 800-344-3860 Toll Free USA/Canada  
Fax: 303-675-2176 or 800-344-3867 Toll Free USA/Canada  
Email: [orderlit@onsemi.com](mailto:orderlit@onsemi.com)

**N. American Technical Support:** 800-282-9855 Toll Free  
USA/Canada  
**Europe, Middle East and Africa Technical Support:**  
Phone: 421 33 790 2910  
**Japan Customer Focus Center**  
Phone: 81-3-5817-1050

**ON Semiconductor Website:** [www.onsemi.com](http://www.onsemi.com)

**Order Literature:** <http://www.onsemi.com/orderlit>

For additional information, please contact your local Sales Representative