NIPPON PRECISION CIRCUITS INC.

# SM5023 series

## Miniature-package Crystal Oscillator Module ICs

## OVERVIEW

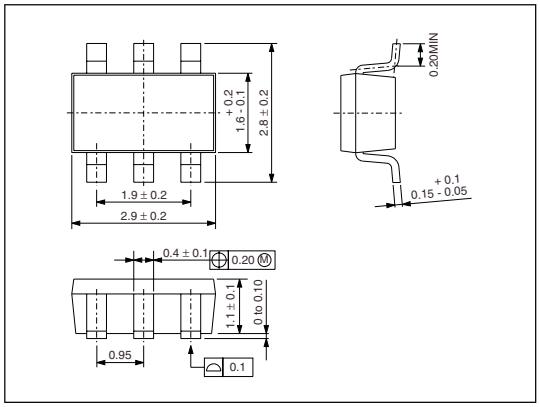
The SM5023 series are 3rd overtone crystal oscillator module ICs. They feature built-in oscillator capacitors with excellent frequency response. As cutoff frequency can be configured by using an external feedback resistor $R_{fo}$, a favorable 3rd overtone oscillation can be realized with a few external components. The oscillator circuit characteristics are optimized for a 3rd overtone oscillation by round blank. They also feature a built-in output buffer with high output drive capability and are available in miniature 6-pin package, making them ideal as DIP-type crystal oscillators.

## FEATURES

- Operating supply voltage range
  - 3V operation: 2.7 to 3.6V
  - 5V operation: 4.5 to 5.5V
- 4MHz to 70MHz operating frequency range (Oscillation frequency is settable by external components)
- –40 to 85°C operating temperature range
- Oscillator capacitors $C_G$, $C_D$ built-in (BN×H version only)
- Cutoff frequency setting using external feedback resistor $R_{fo}$
- Output drive capability
  - 8mA ($V_{DD}$ = 2.7V)
  - 16mA ($V_{DD}$ = 4.5V)
- Output three-state function built-in
  - High impedance output in standby mode
- CMOS output duty level (1/2VDD)
- Molybdenum-gate CMOS process
- Package: SOT23-6 (SM5023×××H)

## PACKAGE DIMENSIONS

(Unit: mm)




## APPLICATIONS

- DIP-type crystal oscillator modules

## SERIES CONFIGURATION

| Version | Operating Supply voltage range [V] | Recommended operating frequency range[1] [MHz] | Oscillator circuit constants | | | | Output duty level | Standby mode | |
|---|---|---|---|---|---|---|---|---|---|
| | | | gm ratio | Built-in capacitance | | Rf [kΩ] | | Oscillator | Output state |
| | | | | $C_G$ [pF] | $C_D$ [pF] | | | | |
| SM5023BNDH | 2.7 to 3.6 | 22 to 70 | 3 | 8 | 15 | – | CMOS | Operation | Hi-Z |
| | 4.5 to 5.5 | | | | | | | | |
| SM5023BNEH | 2.7 to 3.6 | 50 to 70 | 4 | 8 | 12 | – | CMOS | Operation | Hi-Z |
| SM5023CNDH | 2.7 to 3.6 | 4 to 70 | 3 | – | – | – | CMOS | Operation | Hi-Z |
| | 4.5 to 5.5 | | | | | | | | |

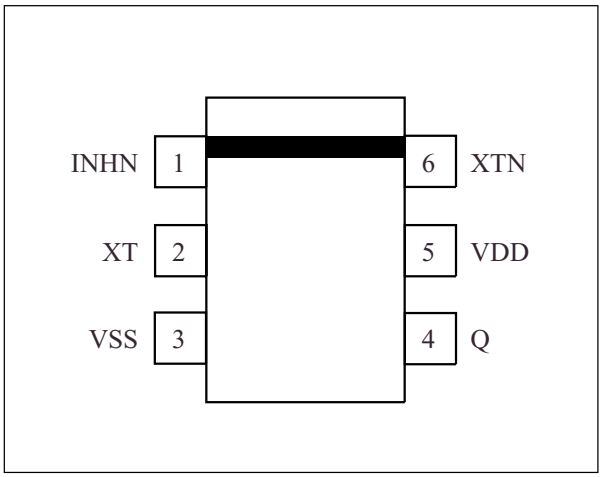
1. The 3rd overtone frequency range using an external resistor to set the cutoff frequency. The recommended operating frequency is a yardstick value derived from the crystal used for NPC characteristics authentication. However, the oscillator frequency band is not guaranteed. Specifically, the characteristics can vary greatly due to crystal characteristics and mounting conditions, so the oscillation characteristics of components must be carefully evaluated.

## ORDERING INFORMATION

| Device | Package |
|---|---|
| SM5023×××H | SOT23-6 |

## PINOUT

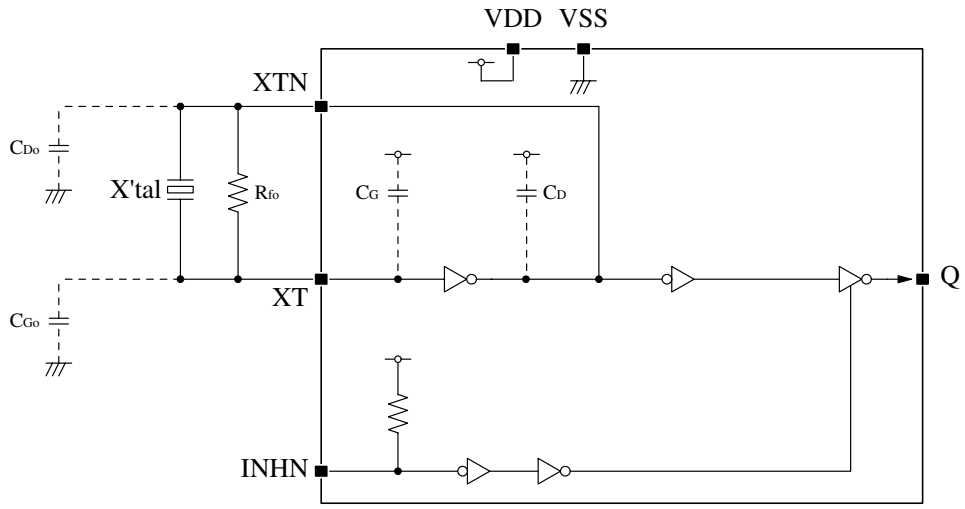
(Top view)




## PIN DESCRIPTION

| Name | I/O | Description | |
|---|---|---|---|
| INHN | I | Output state control input. High impedance when LOW.<br>Pull-up resistor built-in. | |
| XT | I | Amplifier input | Crystal connection pins.<br>Crystal is connected between XT and XTN. |
| XTN | O | Amplifier output | |
| VSS | – | Ground | |
| Q | O | Output. $f_O$ (XT pin input frequency) | |
| VDD | – | Supply voltage | |

## BLOCK DIAGRAM




INHN = LOW active

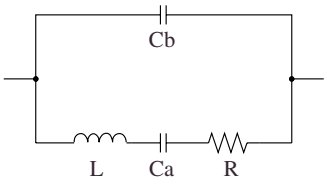
# FUNCTIONAL DESCRIPTION

## Standby Function

When INHN goes LOW, the oscillator output on Q becomes high impedance.

| INHN | Q | Oscillator |
|---|---|---|
| HIGH (or open) | $f_O$ | Normal operation |
| LOW | High impedance | Normal operation |

## Current consumption and Output waveform with NPC's standard crystal




| f [MHz] | R [Ω] | L [mH] | Ca [fF] | Cb [pF] |
|---|---|---|---|---|
| 30 | 18.62 | 16.24 | 1.733 | 5.337 |
| 40 | 20.53 | 11.34 | 1.396 | 3.989 |
| 50 | 22.17 | 7.40 | 1.370 | 4.105 |
| 60 | 22.20 | 5.05 | 1.388 | 4.226 |
| 70 | 25.42 | 4.18 | 1.254 | 5.170 |

# SPECIFICATIONS

## Absolute Maximum Ratings

$V_{SS}$ = 0V

| Parameter | Symbol | Rating | Unit |
|---|---|---|---|
| Supply voltage range | $V_{DD}$ | –0.5 to +7.0 | V |
| Input voltage range | $V_{IN}$ | –0.5 to $V_{DD}$ + 0.5 | V |
| Output voltage range | $V_{OUT}$ | –0.5 to $V_{DD}$ + 0.5 | V |
| Operating temperature range | $T_{opr}$ | –40 to +85 | °C |
| Storage temperature range | $T_{STG}$ | –55 to +125 | °C |
| Output current | $I_{OUT}$ | 20 | mA |
| Power dissipation | $P_D$ | 250 | mW |

## Recommended Operating Conditions

### 3V operation: SM5023BNDH, BNEH, CNDH

$V_{SS}$ = 0V, f ≤ 70MHz, $C_L$ ≤ 15pF unless otherwise noted.

| Parameter | Symbol | Rating | | | Unit |
|---|---|---|---|---|---|
| Operating supply voltage | $V_{DD}$ | 2.7 | – | 3.6 | V |
| Input voltage | $V_{IN}$ | $V_{SS}$ | – | $V_{DD}$ | V |
| Operating temperature | $T_{OPR}$ | –20 | – | +80 | °C |

### 5V operation: SM5023BNDH, CNDH

$V_{SS}$ = 0V, f ≤ 50MHz, $C_L$ ≤ 50pF unless otherwise noted.
$V_{SS}$ = 0V, f ≤ 70MHz, $C_L$ ≤ 15pF unless otherwise noted.

| Parameter | Symbol | Rating | | | Unit |
|---|---|---|---|---|---|
| Operating supply voltage | $V_{DD}$ | 4.5 | – | 5.5 | V |
| Input voltage | $V_{IN}$ | $V_{SS}$ | – | $V_{DD}$ | V |
| Operating temperature | $T_{OPR}$ | –40 | – | +85 | °C |

## Electrical Characteristics

### 3V operation: SM5023BNDH, BNEH, CNDH

$V_{DD}$ = 2.7 to 3.6V, $V_{SS}$ = 0V, Ta = –20 to +80°C unless otherwise noted.

| Parameter | Symbol | Condition | | Rating min | Rating typ | Rating max | Unit |
|---|---|---|---|---|---|---|---|
| HIGH-level output voltage | $V_{OH}$ | Q: Measurement cct 1, $V_{DD}$ = 2.7V, $I_{OH}$ = 8mA | | 2.1 | 2.4 | – | V |
| LOW-level output voltage | $V_{OL}$ | Q: Measurement cct 2, $V_{DD}$ = 2.7V, $I_{OL}$ = 8mA | | – | 0.3 | 0.5 | V |
| HIGH-level input voltage | $V_{IH}$ | INHN | | 2.0 | – | – | V |
| LOW-level input voltage | $V_{IL}$ | INHN | | – | – | 0.5 | V |
| Output leakage current | $I_Z$ | Q: Measurement cct 2, INHN = LOW, $V_{DD}$ = 3.3V | $V_{OH} = V_{DD}$ | – | – | 10 | µA |
| | | | $V_{OL} = V_{SS}$ | – | – | 10 | µA |
| Current consumption | $I_{DD}$ | Measurement cct 3, load cct 1, INHN = open, $C_L$ = 15pF, f = 70MHz | | – | 15 | 30 | mA |
| INHN pull-up resistance | $R_{UP}$ | Measurement cct 4 | | 25 | 100 | 250 | kΩ |
| Built-in capacitance | $C_G$ | Design value. A monitor pattern on a wafer is tested. | SM5023BNDH SM5023BNEH | 7.44 | 8 | 8.56 | pF |
| | $C_D$ | Design value. A monitor pattern on a wafer is tested. | SM5023BNDH | 13.95 | 15 | 16.05 | pF |
| | | | SM5023BNEH | 11.16 | 12 | 12.84 | pF |

### 5V operation: SM5023BNDH, CNDH

$V_{DD}$ = 4.5 to 5.5V, $V_{SS}$ = 0V, Ta = –40 to +85°C unless otherwise noted.

| Parameter | Symbol | Condition | | Rating min | Rating typ | Rating max | Unit |
|---|---|---|---|---|---|---|---|
| HIGH-level output voltage | $V_{OH}$ | Q: Measurement cct 1, $V_{DD}$ = 4.5V, $I_{OH}$ = 16mA | | 3.9 | 4.2 | – | V |
| LOW-level output voltage | $V_{OL}$ | Q: Measurement cct 2, $V_{DD}$ = 4.5V, $I_{OL}$ = 16mA | | – | 0.3 | 0.5 | V |
| HIGH-level input voltage | $V_{IH}$ | INHN | | 2.0 | – | – | V |
| LOW-level input voltage | $V_{IL}$ | INHN | | – | – | 0.8 | V |
| Output leakage current | $I_Z$ | Q: Measurement cct 2, INHN = LOW, $V_{DD}$ = 5.5V | $V_{OH} = V_{DD}$ | – | – | 10 | µA |
| | | | $V_{OL} = V_{SS}$ | – | – | 10 | µA |
| Current consumption | $I_{DD1}$ | Measurement cct 3, load cct 1, INHN = open | $C_L$ = 15pF f = 70MHz | – | 20 | 40 | mA |
| | $I_{DD2}$ | | $C_L$ = 50pF f = 50MHz | – | 25 | 50 | mA |
| INHN pull-up resistance | $R_{UP}$ | Measurement cct 4 | | 25 | 100 | 250 | kΩ |
| Built-in capacitance | $C_G$ | Design value. A monitor pattern on a wafer is tested. | SM5023BNDH | 7.44 | 8 | 8.56 | pF |
| | $C_D$ | Design value. A monitor pattern on a wafer is tested. | SM5023BNDH | 13.95 | 15 | 16.05 | pF |

## Switching Characteristics

### 3V operation: SM5023BNDH, BNEH, CNDH

$V_{DD}$ = 2.7 to 3.6V, $V_{SS}$ = 0V, Ta = –20 to +80°C unless otherwise noted.

| Parameter | Symbol | Condition | Rating | | | Unit |
|---|---|---|---|---|---|---|
| | | | min | typ | max | |
| Output rise time | $t_{r1}$ | Measurement cct 5, load cct 1, 0.1$V_{DD}$ to 0.9$V_{DD}$ , $C_L$ = 15pF | – | 2.5 | 5 | ns |
| Output fall time | $t_{f1}$ | Measurement cct 5, load cct 1, 0.9$V_{DD}$ to 0.1$V_{DD}$ , $C_L$ = 15pF | – | 2.5 | 5 | ns |
| Output duty cycle[1] | Duty1 | Measurement cct 5, load cct 1, $V_{DD}$ = 3.0V, Ta = 25°C, $C_L$ = 15pF, f ≤ 70MHz | 45 | – | 55 | % |
| Output disable delay time | $t_{PLZ}$ | Measurement cct 5, load cct 1, $V_{DD}$ = 3.0V, Ta = 25°C, $C_L$ = 15pF | – | – | 100 | ns |
| Output enable delay time | $t_{PZL}$ | | – | – | 100 | ns |

1. The duty cycle characteristic is checked the sample chips of each production lot.

### 5V operation: SM5023BNDH, CNDH

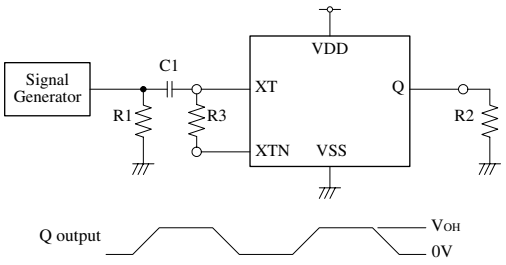
$V_{DD}$ = 4.5 to 5.5V, $V_{SS}$ = 0V, Ta = –40 to +85°C unless otherwise noted.

| Parameter | Symbol | Condition | | Rating | | | Unit |
|---|---|---|---|---|---|---|---|
| | | | | min | typ | max | |
| Output rise time | $t_{r1}$ | Measurement cct 5, load cct 1, 0.1$V_{DD}$ to 0.9$V_{DD}$ | $C_L$ = 15pF | – | 1.5 | 3 | ns |
| | $t_{r2}$ | | $C_L$ = 50pF | – | 3 | 6 | |
| Output fall time | $t_{f1}$ | Measurement cct 5, load cct 1, 0.9$V_{DD}$ to 0.1$V_{DD}$ | $C_L$ = 15pF | – | 1.5 | 3 | ns |
| | $t_{f2}$ | | $C_L$ = 50pF | – | 3 | 6 | |
| Output duty cycle[1] | Duty1 | Measurement cct 5, load cct 1, $V_{DD}$ = 5.0V, Ta = 25°C | $C_L$ = 15pF f ≤ 70MHz | 45 | – | 55 | % |
| | Duty2 | | $C_L$ = 50pF f ≤ 50MHz | 45 | – | 55 | % |
| Output disable delay time | $t_{PLZ}$ | Measurement cct 5, load cct 1, $V_{DD}$ = 5.0V, Ta = 25°C, $C_L$ = 15pF | | – | – | 100 | ns |
| Output enable delay time | $t_{PZL}$ | | | – | – | 100 | ns |

1. The duty cycle characteristic is checked the sample chips of each production lot.

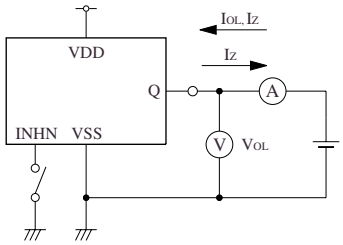
# MEASUREMENT CIRCUITS

## Measurement cct 1

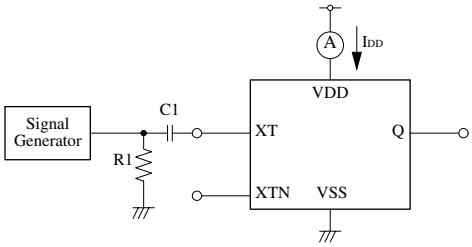



2.0Vp-p, 10MHz sine wave input signal (3V operation)
3.5Vp-p, 10MHz sine wave input signal (5V operation)
C1: 0.001µF
R1: 50Ω
R2: 263Ω (3V operation)
244Ω (5V operation)
R3: 100kΩ

## Measurement cct 2

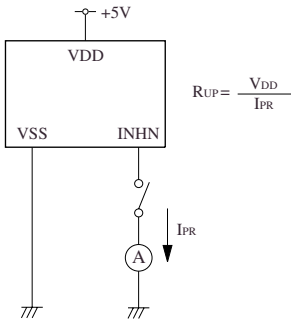



## Measurement cct 3

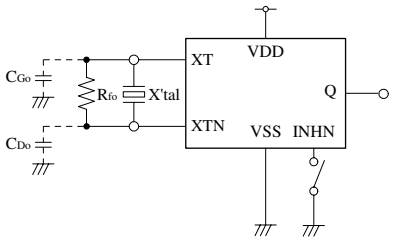



2.0Vp-p, 70MHz sine wave input signal (3V operation)
3.5Vp-p, 70MHz sine wave input signal (5V operation)
C1: 0.001µF
R1: 50Ω

## Measurement cct 4

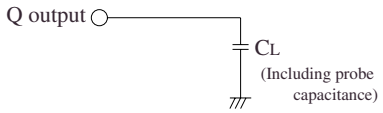



## Measurement cct 5




Crystal oscillation
$R_{fo}$: 1.5kΩ (3V, 70MHz operation)
3.9kΩ (5V, 70MHz operation)
5.6kΩ (5V, 50MHz operation)
SM5023CNDH: $C_{Go}$ = 8pF, $C_{Do}$ = 15pF

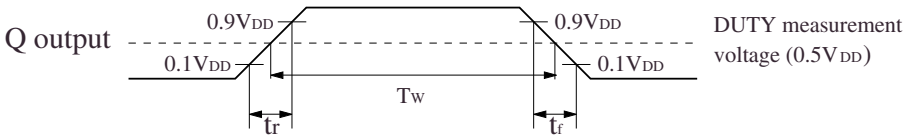
## Load cct 1



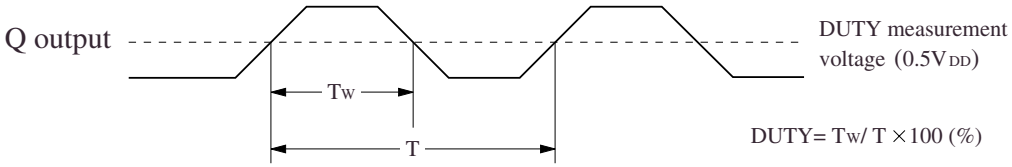

$C_L$ = 15pF: $t_{r1}$, $t_{f1}$, Duty1, $I_{DD1}$
$C_L$ = 50pF: $t_{r2}$, $t_{f2}$, Duty2, $I_{DD2}$

## Switching Time Measurement Waveform

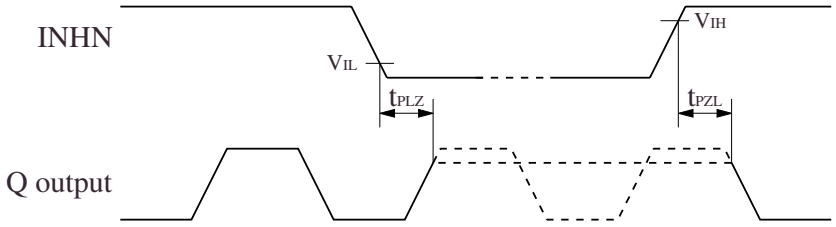
### Output duty level, $t_r$, $t_f$




### Output duty cycle




## Output Enable/Disable Delay




INHN input waveform $t_r = t_f \leq 10ns$

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