

OVERVIEW

The SM8223A is a FSK (Frequency shift keying) decoder and DTMF (Dual tone multi-frequency) receiver IC. It is fabricated using a CMOS process and features a power-down function for low power dissipation operation. The FSK decoder and DTMF receiver have the same performance characteristics as dedicated ICs that perform the same functions, with the added benefit of an FSK decoder/DTMF receiver auto-select function¹ using the telephone tip/ring input signal. It also features a ring (call signal) signal detection circuit, making for easy construction of low power dissipation, high-performance analog telephone-related applications.

FEATURES

- Both FSK signal caller-ID information services and DTMF signal caller-ID information services supported
- FSK decoder/DTMF receiver auto-select function
- Ring (call signal) signal detection circuit built-in
- Serial I/O
- Input gain adjustment circuit built-in
- Power-down mode
- Single supply operation: 3.0V ± 10%
- 3.579545MHz external crystal oscillator frequency
- Molybdenum-gate CMOS process

APPLICATIONS

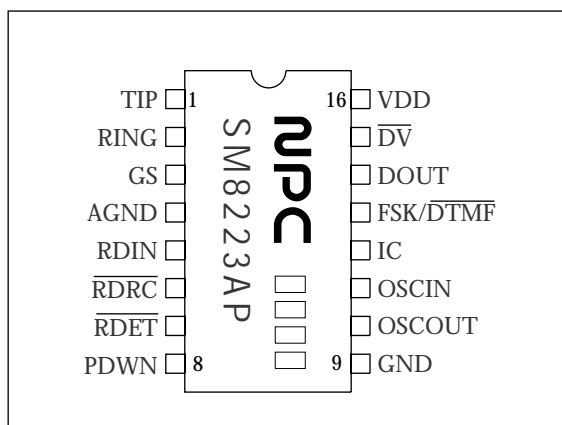
- Telephones, fax machines and modems that support caller-ID information services
- Adapters for caller-ID information service functions
- Telephones, fax machines and modems that support remote operation functions

ORDERING INFORMATION

| Device | Package |
|---------|------------|
| SM8223A | 16-pin DIP |
| CF8223A | Chip |

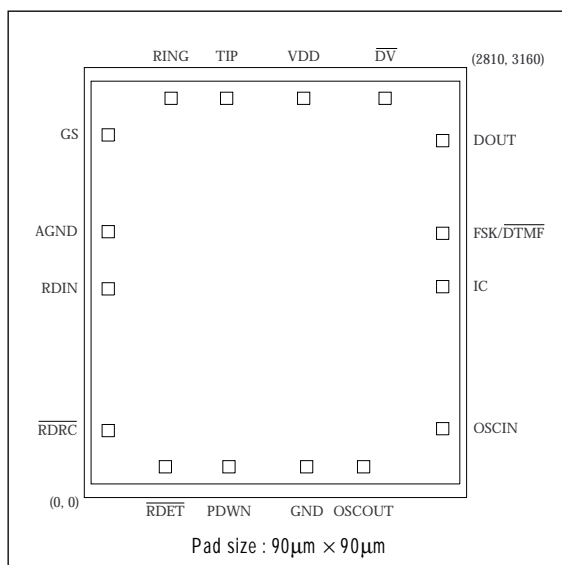
PINOUT

(Top view)



PINOUT

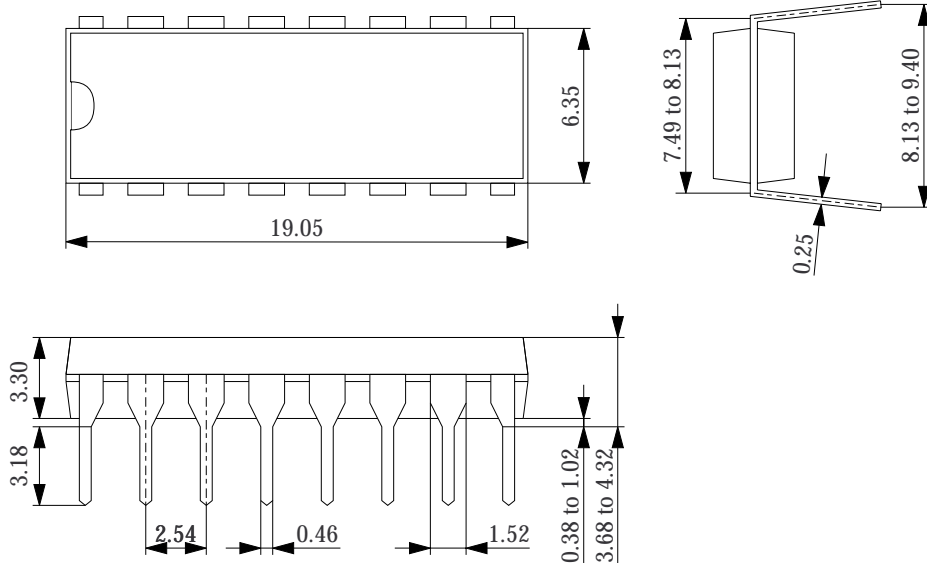
(Unit: μm)



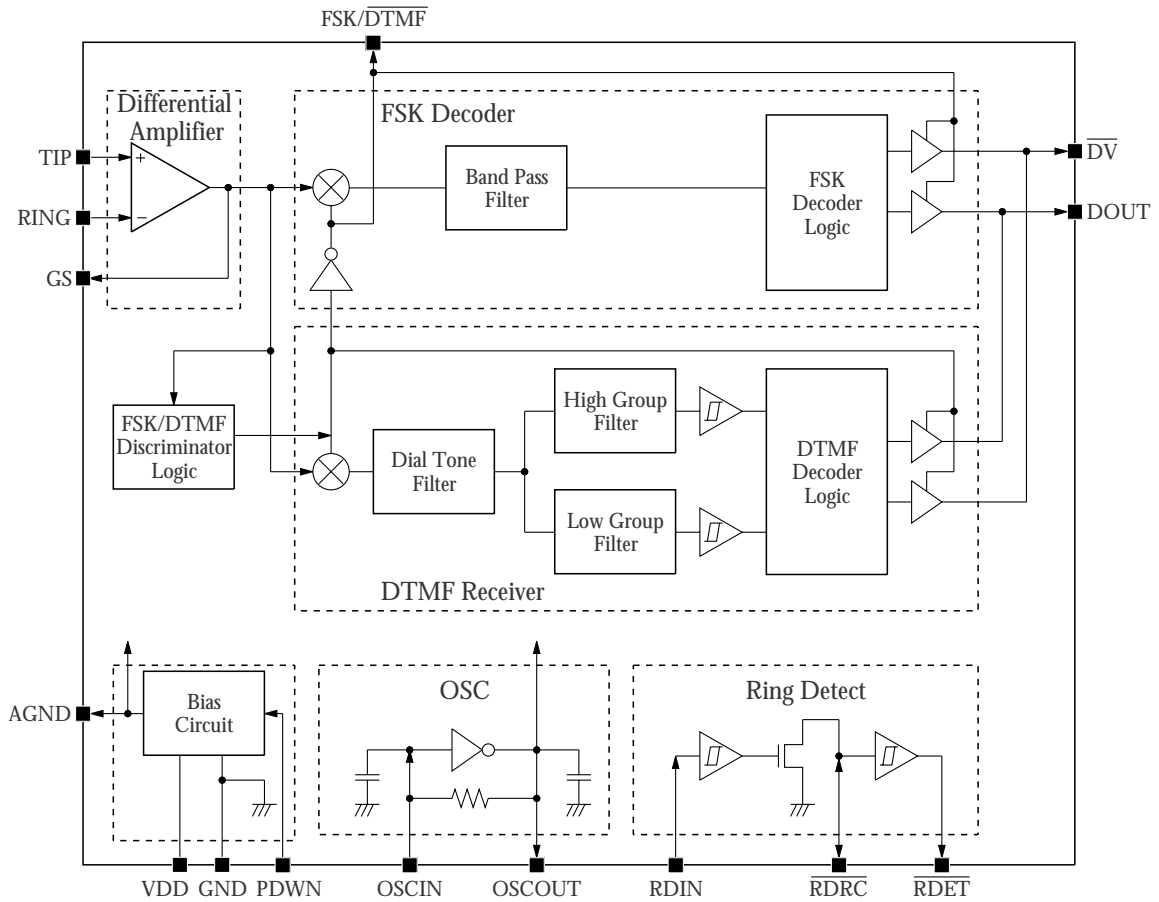
1. Auto-select function operates if the FSK signal conforms to the Bellcore GR-30-CORE standard.

PACKAGE DIMENSIONS

(Unit: mm)



BLOCK DIAGRAM



PIN DESCRIPTION

| Number | Name | I/O | Function | Pad dimensions (μm) | |
|--------|-------------------------------------|-----|---|---------------------|------|
| | | | | X | Y |
| 1 | TIP | I | Tip input. Connected to the telephone line through a protection circuit | 1046 | 2934 |
| 2 | RING | I | Ring input. Connected to the telephone line through a protection circuit | 638 | 2934 |
| 3 | GS | O | Input-stage amplifier gain-select output. Used to adjust the gain of the input-stage amplifier. | 176 | 2665 |
| 4 | AGND | O | Analog ground output. Internal reference voltage ($V_{DD}/2$) output level | 176 | 1954 |
| 5 | RDIN | I | Ring detector input. Used for line reversal and ring signal detection. Connected for ring detection of attenuated ring signals. | 176 | 1534 |
| 6 | $\overline{\text{RDRC}}$ | I/O | Ring detector RC terminal. Connected to an RC network which sets the ring detector delay time. | 176 | 492 |
| 7 | $\overline{\text{RDET}}$ | O | Ring detector output. $\overline{\text{RDRC}}$ -input Schmitt-trigger buffer output. LOW-level output when ring signal is detected. | 596 | 226 |
| 8 | PDWN | I | Power-down control input. LOW-level for normal operation. HIGH-level for power-down state. In the power-down state, pins AGND, OSCOUT, DOUT, and $\overline{\text{DV}}$ are HIGH. | 1063 | 226 |
| 9 | GND | - | Ground. Connected to the system ground potential. | 1634 | 226 |
| 10 | OSCOUT | O | Crystal oscillator output. The crystal oscillator element is connected between this pin and OSCIN. | 2053 | 226 |
| 11 | OSCIN | I | Crystal oscillator input. The crystal oscillator element is connected between this pin and OSCOUT. | 2634 | 506 |
| 12 | IC | I | Test input. Tied LOW for normal operation. | 2634 | 1550 |
| 13 | $\text{FSK}/\overline{\text{DTMF}}$ | O | FSK/DTMF discriminator output. HIGH-level output when receiving FSK signal, and LOW-level output when receiving DTMF signal. | 2634 | 1942 |
| 14 | DOUT | O | Demodulator output. Demodulated FSK or DTMF signal output. HIGH-level output in power-down state. | 2634 | 2623 |
| 15 | $\overline{\text{DV}}$ | O | Data trigger output. Data is output on DOUT when this pin goes LOW. | 2211 | 2934 |
| 16 | VDD | - | Supply | 1612 | 2934 |

SPECIFICATIONS

Absolute Maximum Ratings

GND = 0V

| Parameter | Symbol | Rating | Unit |
|---------------------------|-----------|------------------------|------|
| Supply voltage range | V_{DD} | -0.5 to 5.0 | V |
| Input voltage range | V_{IN} | -0.3 to $V_{DD} + 0.3$ | V |
| DC input current | I_{IN} | ± 10 | mA |
| Storage temperature range | T_{stg} | -40 to 125 | °C |

Recommended Operating Conditions

GND = 0V

| Parameter | Symbol | Condition | Rating | | | Unit |
|--------------------------|--------------|-----------|--------|----------|------|------|
| | | | min | typ | max | |
| Supply voltage | V_{DD} | | 2.7 | - | 3.3 | V |
| Clock frequency | f_{CLK} | | - | 3.579545 | - | MHz |
| Clock frequency accuracy | Δf_C | | -0.1 | - | +0.1 | % |
| Operating temperature | T_a | | -20 | - | 85 | °C |

DC Electrical Characteristics

 $V_{DD} = 3.0V \pm 0.3V$, GND = 0V, $f_{CLK} = 3.579545MHz$, $T_a = -20$ to $85^\circ C$ unless otherwise noted.

| Parameter | Symbol | Condition | Rating | | | Unit |
|--|-----------|--|-------------|-----|-------------|---------|
| | | | min | typ | max | |
| Supply current consumption | I_{DD} | PDWN = 0V, RDIN = 0V, \overline{RDRC} = 0V, all other inputs open | - | - | 4.5 | mA |
| Power-down state current | I_{DPD} | PDWN = V_{DD} , RDIN = 0V, \overline{RDRC} = 0V, all other inputs open | - | - | 15 | μA |
| PDWN, RDIN, \overline{RDRC} LOW-level input voltage | V_{IL1} | | - | - | $0.3V_{DD}$ | V |
| PDWN, RDIN, \overline{RDRC} HIGH-level input voltage | V_{IH1} | | $0.7V_{DD}$ | - | - | V |
| OSCIN LOW-level input voltage | V_{IL2} | When external clock input | - | - | $0.3V_{DD}$ | V |
| OSCIN HIGH-level input voltage | V_{IH2} | When external clock input | $0.7V_{DD}$ | - | - | V |
| DOUT, \overline{DV} , \overline{RDET} , FSK/DTMF LOW-level output current | I_{OL} | | 2 | - | - | mA |
| DOUT, \overline{DV} , \overline{RDET} , FSK/DTMF HIGH-level output current | I_{OH} | | - | - | -0.8 | mA |
| PDWN, RDIN input leakage current | I_{IN} | | -1 | - | 1 | μA |
| \overline{RDRC} output leakage current | I_{OFF} | | - | - | 1 | μA |

AC Electrical Characteristics

FSK decoder

$V_{DD} = 3.0V \pm 0.3V$, $GND = 0V$, $f_{CLK} = 3.579545MHz$, $T_a = -20$ to $85^\circ C$ unless otherwise noted.

| Parameter | Symbol | Condition | Rating | | | Unit |
|-----------------------|--------|---|--------|-------|-----|------|
| | | | min | typ | max | |
| Detection sensitivity | | Typical application circuit | -40 | -37.5 | 0 | dBm |
| Noise reduction ratio | | Mark signal and SPACE signal are same level. Noise: Random noise from 200Hz to 3400Hz. | 20 | - | - | dB |

DTMF receiver

$V_{DD} = 3.0V \pm 0.3V$, $GND = 0V$, $f_{CLK} = 3.579545MHz$, $T_a = -20$ to $85^\circ C$ unless otherwise noted.

| Parameter | Symbol | Condition | Rating | | | Unit |
|-----------------------------------|--------|--|-------------------|-----|-------|------|
| | | | min | typ | max | |
| Detection frequency deviation | | Typical application circuit | $\pm 1.5\% \pm 2$ | - | - | Hz |
| Non-detection frequency deviation | | | ± 3.5 | - | - | % |
| Detection sensitivity | | | -32.0 | - | 0.0 | dBm |
| Non-detection sensitivity | | | - | - | -50.0 | dBm |
| Signal level error | | Typical application circuit ¹ | - | - | 6 | dB |
| High-frequency rejection ratio | | | - | 18 | - | dB |
| Noise rejection ratio | | | - | 12 | - | dB |
| Dial tone rejection ratio | | | - | 20 | - | dB |

1. Input signal is up to V_{DD} level.

Input-stage amplifier Characteristics

$V_{DD} = 3.0V \pm 0.3V$, $GND = 0V$, $f_{CLK} = 3.579545MHz$, $T_a = -20$ to $85^\circ C$ unless otherwise noted.

| Parameter | Symbol | Condition | Rating | | | Unit |
|---------------------------|-----------|-----------|--------|-----|-----|------------|
| | | | min | typ | max | |
| Input leakage current | I_{IN} | | - | - | 1 | μA |
| Input resistance | R_{IN} | | - | 1 | - | $M\Omega$ |
| DC open-loop voltage gain | A_{VOL} | | 30 | - | - | dB |
| Unity gain frequency | f_C | | 80 | - | - | kHz |
| Load capacitance | C_L | | - | - | 100 | pF |
| Load resistance | R_L | | 50 | - | - | k Ω |

Timing Characteristics

Oscillator

$V_{DD} = 3.0V \pm 0.3V$, $GND = 0V$, $T_a = -20$ to $85^\circ C$ unless otherwise noted.

| Parameter | Symbol | Condition | Rating | | | Unit |
|-----------------------------|----------|-----------|--------|-----|-----|------|
| | | | min | typ | max | |
| Clock HIGH-level pulsewidth | t_{WH} | | 110 | - | - | ns |
| Clock LOW-level pulsewidth | t_{WL} | | 110 | - | - | ns |
| Clock rise time | t_r | | - | - | 30 | ns |
| Clock fall time | t_f | | - | - | 30 | ns |

FSK decoder

$V_{DD} = 3.0V \pm 0.3V$, $GND = 0V$, $f_{CLK} = 3.579545MHz$, $T_a = -20$ to $85^\circ C$ unless otherwise noted.

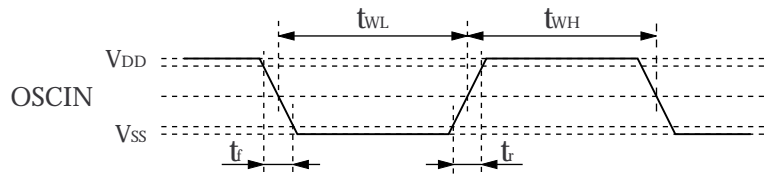
| Parameter | Symbol | Condition | Rating | | | Unit |
|--|-------------|-----------------------|--------|------|-------------------|---------|
| | | | min | typ | max | |
| Power-down release time | t_{DPD} | | - | 8 | - | ms |
| Oscillator start-up time | t_{DOSC} | | - | 5 | - | ms |
| Mark signal to \overline{DV} ON time | t_{DED} | $\overline{DV} = LOW$ | - | - | 3.75 | ms |
| FSK flag setup time | t_{AF} | | - | - | 833 (1/1.2kHz) | μs |
| FSK flag hold time | t_{AH} | | - | - | 10 | ns |
| Input to DOUT delay time | t_{ADD} | | - | 1 | 5 | ms |
| DOUT rise time | t_{Dr0} | | - | - | 20 | ns |
| DOUT fall time | t_{Df0} | | - | - | 20 | ns |
| DOUT data rate | $t_{DWL/H}$ | | 1188 | 1200 | 1212 | baud |

DTMF receiver

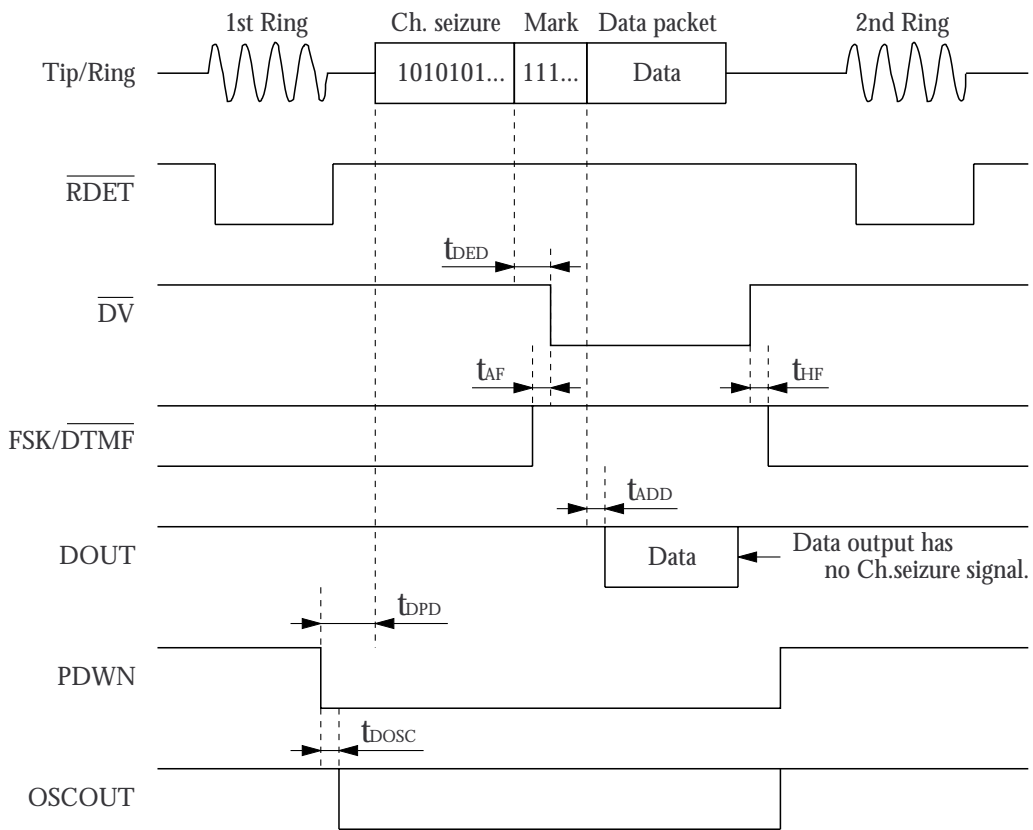
$V_{DD} = 3.0V \pm 0.3V$, $GND = 0V$, $f_{CLK} = 3.579545MHz$, $T_a = -20$ to $85^\circ C$ unless otherwise noted.

| Parameter | Symbol | Condition | Rating | | | Unit |
|--|-------------|-----------------|--------|------|-------------------|---------|
| | | | min | typ | max | |
| DOUT, \overline{DV} rise time | t_{Dr0} | | - | - | 20 | ns |
| DOUT, \overline{DV} fall time | t_{Df0} | | - | - | 20 | ns |
| Signal detection time | t_{RE} | \overline{DV} | - | - | 45 | ms |
| Received signal non-detection time | t_{RE} | \overline{DV} | 20 | - | - | ms |
| Pause detection time | t_{PA} | \overline{DV} | - | - | 25 | ms |
| Pause non-detection time | t_{PR} | \overline{DV} | 20 | - | - | ms |
| \overline{DV} output data delay time | t_{BDD} | | - | - | 5 | ms |
| Power-down release time | t_{DPD} | | - | 8 | - | ms |
| Oscillator start-up time | t_{DOSC} | | - | 5 | - | ms |
| DOUT data rate | $t_{DWL/H}$ | | 1188 | 1200 | 1212 | baud |
| DTMF flag setup time | t_{AF} | | - | - | 833 (1/1.2kHz) | μs |

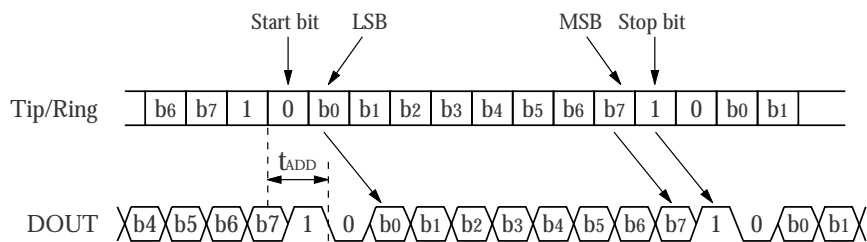
OSCIN input timing (when external input)



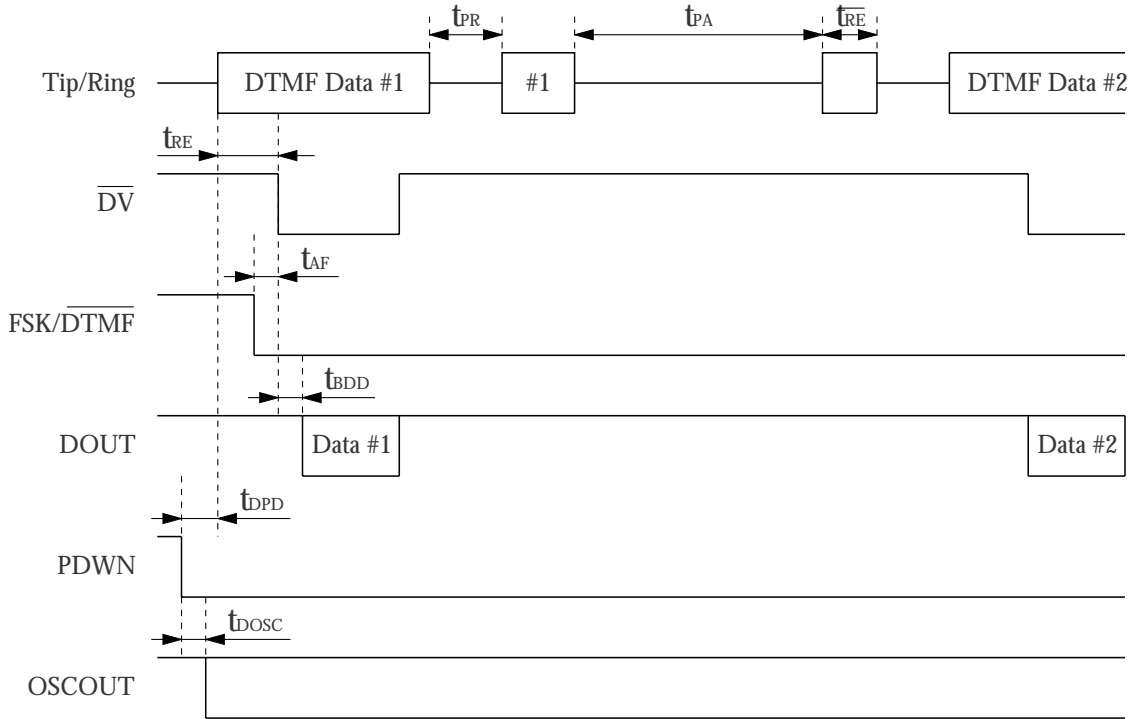
FSK receive timing (1)



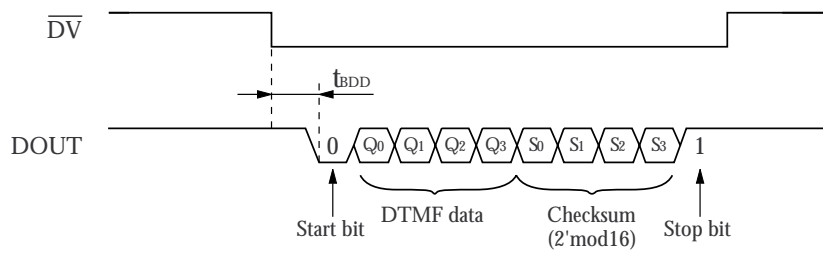
FSK receive timing (2)



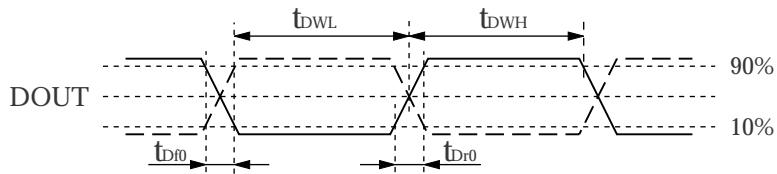
DTMF receive timing (1)



DTMF receive timing (2)



(FSK/DTMF) DOUT output timing



FUNCTIONAL DESCRIPTION

Ring Signal Detector

The telephone tip and ring signals pass through a protection circuit and are input to a resistor, capacitor and diode bridge network, shown in figure 1.

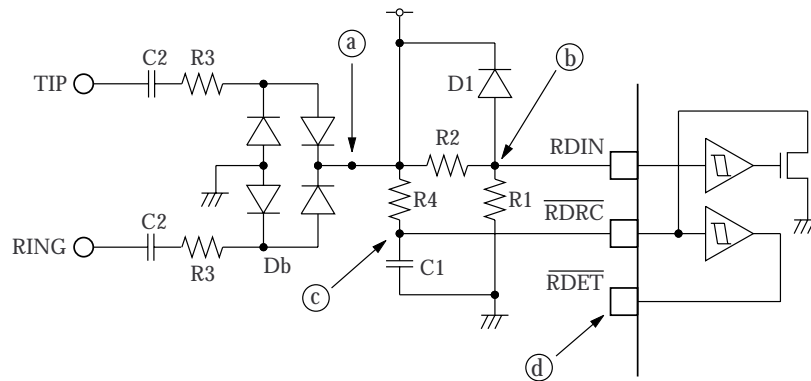


Figure 1. Ring signal detector circuit

The diode bridge full-wave rectified output signal (point a) is reduced in level by a resistor voltage divider comprising R_1 and R_2 (point b), and then input on RDIN. When the ring signal input on RDIN exceeds the Schmitt buffer trigger voltage ($0.7V_{DD}$), the output switches the open-drain RDRC pin. The signal at RDRC (point c) drives a time-constant cir-

cuit comprised by resistor R_4 and capacitor C_1 connected to the input of a second Schmitt buffer to generate the detector signal output on RDET (point d). Thus, RDET goes LOW when the ring or tip signal exceeds the level set by the resistor voltage divider.

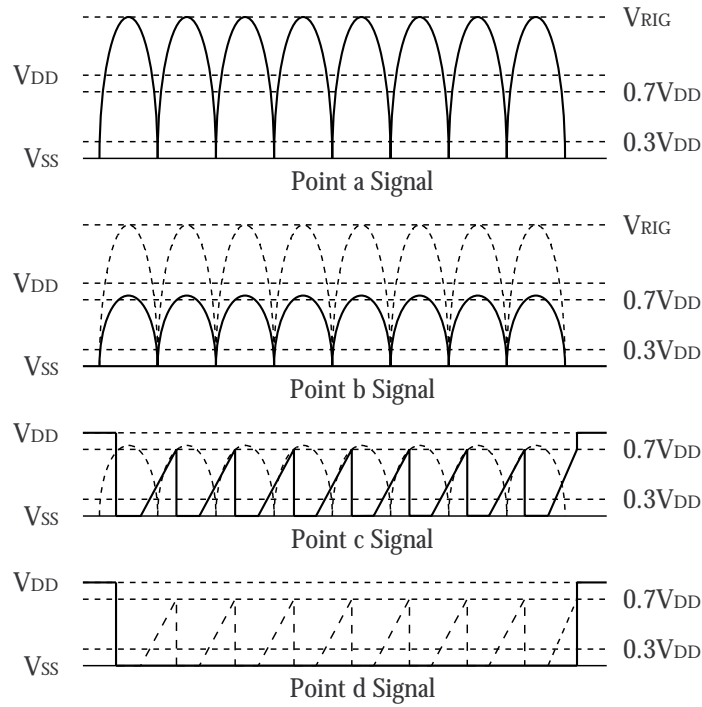


Figure 2. Ring signal detector circuit waveform transitions

The voltage divider level and RC time constant are given by the following equations, respectively.

$$0.7V_{DD} = \frac{R_1}{R_1 + R_2 + R_3} \cdot V_{RIG}$$

$$C_1 R_4 = \frac{t}{\ln\left(\frac{V_{DD}}{V_{DD} - V_T}\right)}$$

where t is the guard time, and the trigger level satisfies the expression $0.3V_{DD} \leq V_T \leq 0.7V_{DD}$.

Input Differential Amplifier

The SM8223A uses an input differential amplifier for input gain adjustment of the tip/ring signal input to the FSK detector or DTMF receiver. Differential input configuration and single-ended input configuration

circuits are shown in figure 3. A bypass capacitor should be connected between GND and AGND in both circuit configurations.

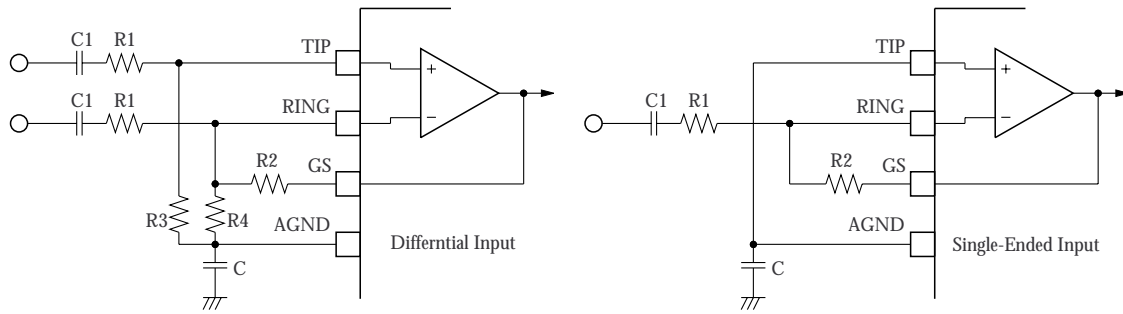


Figure 3. Input circuits

The gain for single-ended configurations is given by the following equation.

$$A_V = \frac{R_2}{R_1}$$

The gain for differential configurations is given by the following equation,

$$A_V = \frac{R_2}{R_1} \text{ where } R_3 = \frac{R_2 R_4}{R_2 + R_4}$$

and the input impedance is given by the following equation.

$$Z_i = 2 \sqrt{R_1^2 + \left(\frac{1}{\omega C_1}\right)^2}$$

FSK/DTMF Auto-discriminator

The SM8223A examines the tip/ring input signal and determines the nature of the signal, FSK or DTMF, and invokes the corresponding circuits, FSK decoder or DTMF receiver, respectively. It determines whether the input signal is an FSK signal or DTMF

signal by the presence or otherwise of the channel seizure information in the FSK signal header. This function automatically discriminates between the input signals if the FSK signal conforms to the Bellcore GR-30-CORE standard.

FSK Demodulator

When an FSK signal is received, the FSK/DTMF signal discriminator circuit sets the FSK/DTMF pin HIGH and connects the input signal to the FSK demodulator circuit. Demodulated data is output on DOUT with the format shown in figure 4. The FSK signal conforms to the following Bellcore standard.

Table 1. FSK signal

| Parameter | Description |
|------------------------|--|
| Modulation type | Continuous-phase binary frequency-shift-keying |
| Logic "1" data (mark) | 1200 ± 12 Hz |
| Logic "0" data (space) | 2200 ± 22 Hz |
| Signal level (mark) | -32 to -12 dBm |
| Signal level (space) | -36 to -12 dBm |
| Data transfer rate | 1200 ± 12 baud |

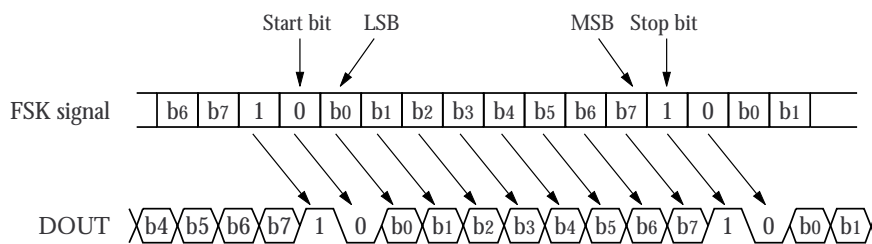


Figure 4. FSK signal to DOUT output

DTMF Demodulator

When a DTMF signal is received, the FSK/DTMF signal discriminator circuit sets the FSK/DTMF pin LOW and connects the input signal to the DTMF demodulator circuit. The DTMF signal is comprised by a high-group frequency and a low-group frequency which, in combination, represent a point in the DTMF matrix.

Table 2. DTMF matrix

| Low group | High group | | | |
|-----------|------------|--------|--------|--------|
| | 1209Hz | 1336Hz | 1477Hz | 1633Hz |
| 697Hz | 1 | 2 | 3 | A |
| 770Hz | 4 | 5 | 6 | B |
| 852Hz | 7 | 8 | 9 | C |
| 941Hz | * | 0 | # | D |

The DTMF receiver demodulates the received DTMF signal and outputs data bits Q₀ to Q₃ and a 4-bit (2-mod-16) checksum S₀ to S₃ in serial format on DOUT.

Table 3. DTMF signal output (DOUT)

| Matrix input | DTMF | | | | Checksum | | | |
|--------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| | D ₀ | D ₁ | D ₂ | D ₃ | D ₄ | D ₅ | D ₆ | D ₇ |
| | Q ₀ | Q ₁ | Q ₂ | Q ₃ | S ₀ | S ₁ | S ₂ | S ₃ |
| 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 3 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 |
| 4 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 5 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |
| 6 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 |
| 7 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 |
| 8 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 9 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 |
| * | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| # | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| A | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| B | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| C | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

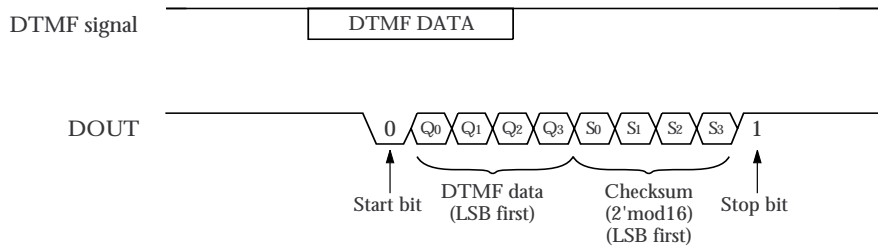
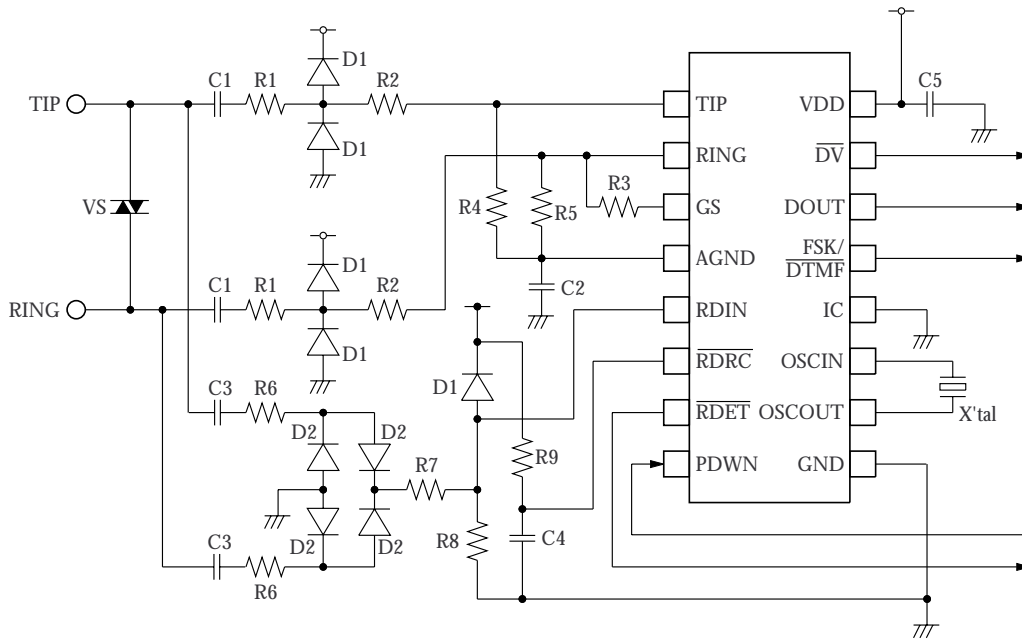


Figure 5. DTMF signal to DOUT output

The DTMF receiver determines whether the received data (DTMF signal) is valid after an interval of $t_{\text{REC}} \geq 40\text{ms}$ stable reception. If valid, $\overline{\text{DV}}$ goes LOW and data is output on DOUT. If DTMF data is not detected after an interval $t_{\text{SPA}} \geq 20\text{ms}$, a data pause is activated and the next DTMF signal is in a

wait state (see timing diagrams in AC Electrical Characteristics). The SM8223A DTMF receiver can be used as a general-purpose DTMF receiver without the need for the external time constant circuit, in which case the resistor/capacitor/diode network can be omitted.

TYPICAL APPLICATION CIRCUIT



| Symbol | Rating | Unit |
|----------------|----------|------------|
| R_1^1 | 240 | k Ω |
| R_2^1 | 34 | k Ω |
| R_3^1 | 464 | k Ω |
| R_4^1 | 53.6 | k Ω |
| R_5^1 | 60.4 | k Ω |
| D ₁ | 1N4003 | - |
| C ₁ | 22 | nF |
| C ₂ | 0.1 | μ F |
| R_6^2 | 430 | k Ω |
| R_7^2 | 270 | k Ω |
| R_8^2 | 27 | k Ω |
| R_9^2 | 270 | k Ω |
| C ₃ | 22 | nF |
| C_4^2 | 470 | nF |
| D ₂ | 1N4004 | - |
| C ₅ | 0.1 | μ F |
| VS | - | - |
| X'tal | 3.579545 | MHz |

1. Refer to the Input Differential Amplifier.
2. Refer to the Ring Signal Detector.

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