

# MAX270/MAX271

## Digitally-Programmed, Dual 2nd-Order Continuous Lowpass Filter

### General Description

The MAX270/MAX271 are digitally-programmed, dual second-order continuous-time lowpass filters. Their typical dynamic range of 96dB surpasses most switched capacitor filters which require additional filtering to remove clock noise. The MAX270/MAX271 are ideal for anti-aliasing and DAC smoothing applications and can be cascaded for higher-order responses.

The two filter sections are independently programmable by either microprocessor ( $\mu$ P) control or pin strapping. Cutoff frequencies in the 1kHz to 25kHz range can be selected.

The MAX270 has an on-board, uncommitted op amp, while the MAX271 has an internal track-and-hold (T/H).

### Applications

- Lowpass Filtering
- Anti-Aliasing Filter
- Output Smoothing
- Low-Noise Applications
- Anti-Aliasing and Track-and-Hold (MAX271)

### Features

- ◆ Continuous-Time Filtering - No Clock Required
- ◆ Dual 2nd-Order Lowpass Filters
- ◆ Sections Independently Programmable: 1kHz to 25kHz
- ◆ 96dB Dynamic Range
- ◆ No External Components
- ◆ Cascadable for Higher Order
- ◆ Low-Power Shutdown Mode
- ◆ Track-and-Hold (MAX271)

### Ordering Information

| PART      | TEMP RANGE     | PIN-PACKAGE |
|-----------|----------------|-------------|
| MAX270CPP | 0°C to +70°C   | 20 PDIP     |
| MAX270CWP | 0°C to +70°C   | 20 Wide SO  |
| MAX270EPP | -40°C to +85°C | 20 PDIP     |
| MAX270EWP | -40°C to +85°C | 20 Wide SO  |
| MAX271CNG | 0°C to +70°C   | 20 PDIP     |
| MAX271CWG | 0°C to +70°C   | 20 Wide SO  |
| MAX271ENG | -40°C to +85°C | 20 PDIP     |
| MAX271EWG | -40°C to +85°C | 20 Wide SO  |

Devices are available in a lead(Pb)-free/RoHS-compliant package. Specify lead-free by adding a plus (+) to the part number when ordering.

### Typical Operating Circuit



### Pin Configurations



For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim's website at [www.maximintegrated.com](http://www.maximintegrated.com).

# MAX270/MAX271

## Digitally-Programmed, Dual 2nd-Order Continuous Lowpass Filter

### ABSOLUTE MAXIMUM RATINGS

|                                                                    |                |
|--------------------------------------------------------------------|----------------|
| V+ to V-                                                           | -0.3V to +17V  |
| V+ to GND                                                          | -0.3V to +8.5V |
| V- to GND                                                          | -0.3V to -8.5V |
| Input Voltage to GND, Any Input Pin ... (V- - 0.3V) to (V+ + 0.3V) |                |
| Duration of Output Short Circuit to GND                            | Continuous     |
| Continuous Power Dissipation (T <sub>A</sub> = +70°C)              |                |
| MAX270                                                             |                |
| PDIP (derate 11.1mW/°C above +70°C)                                | 889mW          |
| SO (W) (derate 10mW/°C above +70°C)                                | 800mW          |
| MAX271                                                             |                |
| PDIP (derate 13.3mW/°C above +70°C)                                | 1067mW         |

|                                       |                 |
|---------------------------------------|-----------------|
| SO (W) (derate 11.7mW/°C above +70°C) | 941mW           |
| Operating Temperature Ranges:         |                 |
| MAX27_C_                              | 0°C to +70°C    |
| MAX27_E_                              | -40°C to +85°C  |
| Storage Temperature Range             | -65°C to +165°C |
| Lead Temperature (soldering, 10s)     | +300°C          |
| Soldering Temperature (reflow)        |                 |
| Lead(Pb)-free                         | +260°C          |
| Containing lead(Pb)                   | +240°C          |

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

### ELECTRICAL CHARACTERISTICS

(V+ = +5V, V- = -5V; T<sub>A</sub> = +25°C, unless otherwise noted.)

| PARAMETER                                                                                | SYMBOL | CONDITIONS                                                                                      | MIN                                      | TYP     | MAX  | UNITS |
|------------------------------------------------------------------------------------------|--------|-------------------------------------------------------------------------------------------------|------------------------------------------|---------|------|-------|
| <b>FILTER CHARACTERISTICS</b>                                                            |        |                                                                                                 |                                          |         |      |       |
| Operating Frequency Range                                                                |        | (Note 1)                                                                                        |                                          | 2       |      | MHz   |
| Programmed Cutoff Frequency (f <sub>C</sub> ) Range                                      |        |                                                                                                 |                                          | 1 to 25 |      | kHz   |
| Programmed Cutoff Frequency Error                                                        |        | f <sub>C</sub> code = 53 (2.536kHz typ)                                                         |                                          | ±2.9    |      | %     |
|                                                                                          |        | f <sub>C</sub> code = 127 (25kHz typ)                                                           |                                          | ±9.5    |      |       |
| Filter Gain                                                                              |        | f <sub>C</sub> code = 0 (1kHz typ),<br>T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>    | f <sub>IN</sub> = 1kHz                   | -3.6    | -2.4 | dB    |
|                                                                                          |        |                                                                                                 | f <sub>IN</sub> = 8kHz                   |         | -33  |       |
|                                                                                          |        | f <sub>C</sub> code = 127 (25kHz typ),<br>T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> | f <sub>IN</sub> = 25kHz                  | -6      | -0.5 |       |
|                                                                                          |        |                                                                                                 | f <sub>IN</sub> = 200kHz                 |         | -34  |       |
| Maximum Gain (Peaking)                                                                   |        | f <sub>C</sub> code = 0 (1kHz typ)                                                              |                                          |         | 0.15 | dB    |
|                                                                                          |        | f <sub>C</sub> code = 127 (25kHz typ)                                                           |                                          |         | 0.15 |       |
| Wideband Noise                                                                           |        | 50Hz to 50kHz bandwidth                                                                         | f <sub>C</sub> code = 0<br>(1kHz typ)    |         | 12   | μVRMS |
|                                                                                          |        |                                                                                                 | f <sub>C</sub> code = 127<br>(25kHz typ) |         | 38   |       |
| <b>DC CHARACTERISTICS</b>                                                                |        |                                                                                                 |                                          |         |      |       |
| DC Output Signal Swing<br>OUTA, OUTB, OP OUT (MAX270)<br>OUTA, OUTB, T/H OUT (MAX271)    |        | R <sub>LOAD</sub> = 5kΩ, T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>                  | -3                                       |         | +3   | V     |
| Offset Voltage at Outputs<br>OUTA, OUTB, OP OUT (MAX270)<br>OUTA, OUTB, T/H OUT (MAX271) |        |                                                                                                 | -2                                       |         | +2   | mV    |
| DC Input Leakage Current<br>INA, INB (MAX270)<br>INA, INB (MAX271)                       |        | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>                                           | -1                                       |         | +1   | μA    |

# MAX270/MAX271

## Digitally-Programmed, Dual 2nd-Order Continuous Lowpass Filter

### ELECTRICAL CHARACTERISTICS (continued)

(V<sub>+</sub> = +5V, V<sub>-</sub> = -5V; T<sub>A</sub> = +25°C, unless otherwise noted.)

| PARAMETER                                      | SYMBOL | CONDITIONS                                                                                                            | MIN | TYP             | MAX | UNITS |
|------------------------------------------------|--------|-----------------------------------------------------------------------------------------------------------------------|-----|-----------------|-----|-------|
| <b>DYNAMIC FILTER CHARACTERISTICS (MAX270)</b> |        |                                                                                                                       |     |                 |     |       |
| Total Harmonic Distortion                      | THD    | fC code = 44 (2.01kHz typ), V <sub>IN</sub> = 3.5V <sub>P-P</sub> at 390.625Hz (Notes 2 and 3)                        |     |                 | -70 | dB    |
| Signal Noise Plus Distortion                   | SINAD  |                                                                                                                       |     | 73              |     |       |
| Spurious-Free Dynamic Range                    | SFDR   |                                                                                                                       |     | 70              |     |       |
| <b>UNCOMMITTED AMPLIFIER (MAX270)</b>          |        |                                                                                                                       |     |                 |     |       |
| Slew Rate                                      |        |                                                                                                                       |     | 1.2             |     | V/μs  |
| Bandwidth                                      |        |                                                                                                                       |     | 2               |     | MHz   |
| <b>TRACK AND HOLD (MAX271)</b>                 |        |                                                                                                                       |     |                 |     |       |
| Hold Settling Time                             |        | To 0.1% (Note 4)                                                                                                      |     | 500             |     | ns    |
| Acquisition Time                               |        | To 0.1% (Note 5)                                                                                                      |     | 1.8             |     | μs    |
| Hold Step                                      |        |                                                                                                                       |     | 1               |     | mV    |
| Droop Rate                                     |        | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>                                                                 |     | 30              |     | μV/μs |
| Offset Voltage at T/H OUT                      |        | Includes filter offset                                                                                                | -6  |                 | +6  | mV    |
| T/H OUT Disabled Output Leakage Current        |        | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> , V <sub>T/H</sub> = 0V (Track Mode)                            | -10 |                 | +10 | μA    |
| Total Harmonic Distortion                      | THD    | fC code = 44 (2.01kHz typ), V <sub>IN</sub> = 3.5V <sub>P-P</sub> at 390.625Hz, sampling rate = 50kHz (Notes 2, 6, 7) |     |                 | -70 | dB    |
| Spurious-Free Dynamic Range                    | SFDR   |                                                                                                                       |     | 70              |     |       |
| <b>DIGITAL INPUTS</b>                          |        |                                                                                                                       |     |                 |     |       |
| Digital Input High Voltage                     |        | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> (Note 8)                                                        | 2.4 |                 |     | V     |
| Digital Input Low Voltage                      |        |                                                                                                                       |     |                 | 0.8 |       |
| Digital Input Current                          |        | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> , digital input held at ±5V, includes MODE (MAX271)(Note 8)     | -1  |                 | +1  | μA    |
| <b>POWER REQUIREMENTS</b>                      |        |                                                                                                                       |     |                 |     |       |
| Supply Voltage Range                           |        |                                                                                                                       |     | ±2.375<br>to ±8 |     | V     |
| Supply Current                                 |        | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> (Note 9)                                                        |     |                 | 6.5 | mA    |
| Shutdown Supply Current                        |        | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> (Note 10)                                                       |     |                 | 15  | μA    |
| Power-Supply Rejection Ratio at 1kHz           | PSRR   | fC code = 0 (1kHz typ), V <sub>+</sub> = 5VDC + 10mV <sub>P-P</sub> at 1kHz                                           |     | 30              |     | dB    |

**Note 1:** All internal amplifiers limited to 2MHz bandwidth.

**Note 2:** Only filter A tested for these parameters.

**Note 3:** Spurious-Free Dynamic Range is the ratio of the fundamental to the largest of any harmonic or noise spur in dB.

**Note 4:** Includes T/H propagation delays. With 5kΩ, parallel 100pF load.

**Note 5:** ±2V input step settling 0.1% with 5kΩ parallel 100pF load.

**Note 6:**  $\overline{T/H}$  pin toggled at sampling rate, 50% duty cycle.

**Note 7:** THD and SFDR specifications for T/H include contributions from filter.

**Note 8:** Digital pins include SHDN, WR, CS, A0, D0–D6 (MAX270) and SHDN, T/H, A/B, WR, T/H EN, CS, A0, A1, D0–D6, T/H (MAX271).

**Note 9:** Input of uncommitted op amp disconnected with a 5kΩ feedback resistor from input to output.

**Note 10:** WR, CS, A0, D0–D6 held at +5V; VSHDN = 0V (MAX270). WR, CS, A0, A1, D0–D6, T/H, T/H, A/B, T/H, MODE held at +5V; VSHDN = 0V (MAX271).

# MAX270/MAX271

## Digitally-Programmed, Dual 2nd-Order Continuous Lowpass Filter

### TIMING CHARACTERISTICS (Figure 2)

(V+ = +5V, V- = -5V; TA = +25°C, unless otherwise noted.)

| PARAMETER                                | SYMBOL   | CONDITIONS | MIN | TYP | MAX | UNITS |
|------------------------------------------|----------|------------|-----|-----|-----|-------|
| $\overline{CS}$ to $\overline{WR}$ Setup | $t_{WS}$ |            |     |     | 0   | ns    |
| $\overline{CS}$ to $\overline{WR}$ Hold  | $t_{WH}$ |            |     |     | 0   | ns    |
| $\overline{WR}$ Pulse Width              | $t_{SV}$ |            | 100 |     |     | ns    |
| Address-Setup Time                       | $t_{AS}$ |            | 30  |     |     | ns    |
| Address-Hold Time                        | $t_{AH}$ |            | 10  |     |     | ns    |
| Data-Setup Time                          | $t_{DS}$ |            | 30  |     |     | ns    |
| Data-Hold time                           | $t_{DH}$ |            | 10  |     |     | ns    |

**Note 11:** All input control signals specified with  $t_r = t_f = 5\text{ns}$  (10% to 90% of +5V) and timed from a +1.6V voltage level.

### Typical Operating Characteristics



# MAX270/MAX271

## Digitally-Programmed, Dual 2nd-Order Continuous Lowpass Filter

### Typical Operating Characteristics (continued)

**CASCADED FILTER GAIN vs. FREQUENCY (NORMALIZED TO CUTOFF FREQUENCY)**



**CASCADED FILTER GAIN vs. FREQUENCY (NORMALIZED TO CUTOFF FREQUENCY)**



**FILTER HARMONIC DISTORTION**



**FILTER TOTAL HARMONIC DISTORTION PLUS NOISE vs. INPUT FREQUENCY**

| $f_{IN}$ (Hz) | $f_C$ CODE | $f_C$ (Hz) (TYP) | THD PLUS NOISE (TYP) |
|---------------|------------|------------------|----------------------|
| 190           | 0          | 1k               | -78                  |
| 390           | 44         | 2.01k            | -73                  |
| 1367          | 100        | 7.01k            | -67                  |
| 4875          | 127        | 25k              | -66                  |

$V_+ = 5V, V_- = -5V, V_{IN} = 3.5V_{P-P}, T_A = +25^\circ C$

**FILTER TOTAL HARMONIC DISTORTION PLUS NOISE vs. INPUT AMPLITUDE**



**MAX271 FILTER PLUS TRACK-AND-HOLD SPURIOUS-FREE DYNAMIC RANGE vs. INPUT FREQUENCY**

| $f_{IN}$ (Hz) | $f_C$ CODE | $f_C$ (Hz) (TYP) | SFDR (dB) |
|---------------|------------|------------------|-----------|
| 195           | 0          | 1k               | 73.5      |
| 781           | 72         | 4.01k            | 69.5      |
| 1562.5        | 105        | 8.08k            | 66        |
| 3906          | 124        | 19.4k            | 61.5      |

$V_+ = 5V, V_- = -5V, V_{IN} = 3.5V_{P-P}, T/H$  SWITCHED AT 50kHz, 50% DUTY CYCLE;  $T_A = +25^\circ C$

**MAX271 FILTER PLUS TRACK-AND-HOLD SPURIOUS-FREE DYNAMIC RANGE vs. INPUT AMPLITUDE**



**MAX271 FILTER PLUS TRACK-AND-HOLD SPURIOUS-FREE DYNAMIC RANGE vs. SAMPLING FREQUENCY**

| $f_{SAMPLE}$ (Hz) | $f_{IN}$ (Hz) | $f_C$ CODE | $f_C$ (Hz) | SFDR (dB) |
|-------------------|---------------|------------|------------|-----------|
| 100k              | 781           | 72         | 4.01k      | 72        |
| 200k              | 1562          | 105        | 8.08k      | 72        |
| 500k              | 3906          | 124        | 19.4k      | 64        |

$V_+ = 5V, V_- = -5V, V_{IN} = 3.5V_{P-P}, T/H$  SWITCHED AT 50kHz, 50% DUTY CYCLE;  $T_A = +25^\circ C$

# MAX270/MAX271

## Digitally-Programmed, Dual 2nd-Order Continuous Lowpass Filter

### Detailed Description

Figures 1a, 1b, and 1c show the MAX270/MAX271 functional diagrams. Both the MAX270 and MAX271 contain two independent, second-order, Sallen-Key, lowpass filter sections, A and B to provide a frequency vs. gain rolloff of approximately 40dB/decade. These are not switched-capacitor filters, but have a continuous-time design similar to discrete active filters built around op amps. The MAX270/MAX271 eliminate clock noise and aliasing problems which limit low-noise performance of switched-capacitor filters; resulting dynamic range is over 96dB.

Each filter section contains two banks of programmable capacitors, controlled by an internal 7-bit memory, which set filter cutoff frequencies ( $f_c$ ) from 1kHz to 25kHz. The filters provide two program modes. In  $\mu P$  mode, cutoff frequencies are programmed by writing 7-bit data to one of two memory addresses (one for each filter section). Alternately, a pin-strap programming mode programs both filter sections simultaneously. In this mode, both memory latches are transparent (not addressable), and data pins D0–D6 may be pin-strapped (hard-wired) to set a common  $f_c$  for both filter sections.

The filters are trimmed at the wafer level, setting 0 for a maximum of 0.15dB passband peaking for  $f_c$  programmed to 1kHz. Maximum passband peaking at other codes is typically less than 0.15dB. Filter Q is not user-programmable.

The MAX270 includes an uncommitted op amp (noninverting input grounded); the MAX271 has an on-chip T/H that tracks and holds the output of either filter section (selectable). The held output is provided at T/H OUT. T/H functions are controlled by writing control bits to internal registers (in  $\mu P$  mode) or by control pins directly (in pin-strap mode).

The MAX270 and MAX271 provide a low quiescent current shutdown mode controlled by the  $\overline{\text{SHDN}}$  pin, which turns off internal amplifiers and disconnects all outputs, reducing quiescent operating current to less than 15 $\mu\text{A}$ . When the MAX271 is in  $\mu P$  mode, shutdown mode is selected by writing control bits to memory (the  $\overline{\text{SHDN}}$  pin is disabled).

### Pin Description

#### MAX270

| PIN   | NAME                     | FUNCTION                                                                                                                      |
|-------|--------------------------|-------------------------------------------------------------------------------------------------------------------------------|
| 1     | OP OUT                   | Uncommitted Op Amp Output                                                                                                     |
| 2     | V+                       | Positive Supply Voltage                                                                                                       |
| 3     | OUTA                     | Filter A Output                                                                                                               |
| 4     | $\overline{\text{SHDN}}$ | Shutdown Control. Low level disconnects OUTA, OUTB, and OP OUT and places device into shutdown mode.                          |
| 5     | INA                      | Filter A Input                                                                                                                |
| 6     | V-                       | Negative Supply Voltage                                                                                                       |
| 7     | INB                      | Filter B Input                                                                                                                |
| 8     | OUTB                     | Filter B Output                                                                                                               |
| 9     | GND                      | Ground                                                                                                                        |
| 10    | $\overline{\text{WR}}$   | Write Control Input. A low level writes data D0–D6 to program memory addressed by A0. High level latches data.                |
| 11    | CS                       | Chip-Select Input. Must be low for $\overline{\text{WR}}$ input to be recognized.                                             |
| 12    | A0                       | Three-Level Address Input<br>Logic High: Addresses filter A<br>Logic Low: Addresses filter B<br>Connect to V-: Pin-strap mode |
| 13-19 | D0–D6                    | 7-Bit Data Inputs. Allows programming of 128 cutoff frequencies in a 1kHz to 25kHz range.                                     |
| 20    | OP IN                    | Uncommitted Op Amp Input                                                                                                      |

**Note:** All digital input levels are TTL and CMOS compatible, unless otherwise noted.

# MAX270/MAX271

## Digitally-Programmed, Dual 2nd-Order Continuous Lowpass Filter

### Pin Description (continued)

#### MAX271

| PIN    | NAME                         | FUNCTION, FP MODE (MODE = GND OR V-)                                                                                                                                                                                                                                                                                                                                                                                                     | FUNCTION, FP MODE (MODE = GND OR V+)                                                                                                                           |
|--------|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1      | T/H OUT                      | Track-and-Hold Output                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                |
| 2      | V+                           | Positive Supply Voltage                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                |
| 3      | OUTA                         | Filter A Signal Output                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                |
| 4      | $\overline{\text{SHDN}}$     | —                                                                                                                                                                                                                                                                                                                                                                                                                                        | $\overline{\text{SHUTDOWN}}$ Control. A low level disconnects outputs and places device into shutdown mode                                                     |
| 5      | INA                          | Filter A Signal Input                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                |
| 6      | V-                           | Negative Supply Voltage                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                |
| 7      | INB                          | Filter B Signal Input                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                |
| 8      | MODE                         | Selects $\mu\text{P}$ mode when connected to GND or V- and pin-strap mode when connected to V+.                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                |
| 9      | OUTB                         | Filter B Signal Output                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                |
| 10     | GND                          | Ground                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                |
| 11     | T/H A/ $\overline{\text{B}}$ | —                                                                                                                                                                                                                                                                                                                                                                                                                                        | Track-and-Hold Input Control. A high/low level internally connects OUTNOUTB to input of Track-and-Hold                                                         |
| 12     | $\overline{\text{WR}}$       | $\overline{\text{WRITE}}$ Control Input. A low level writes data D0-D6 program memory addressed by A1, A0 (or performs function as described for address inputs). High level latches data.                                                                                                                                                                                                                                               | —                                                                                                                                                              |
| 13     | T/H EN                       | X                                                                                                                                                                                                                                                                                                                                                                                                                                        | Track-and-Hold Output Control. Low level disconnects T/H OUT. Connect pin high for normal operation                                                            |
| 14     | $\overline{\text{CS}}$       | Chip Select Input. Must be low for $\overline{\text{WR}}$ input to be recognized.                                                                                                                                                                                                                                                                                                                                                        | —                                                                                                                                                              |
| 15, 16 | A1, A0                       | Address and $\mu\text{P}$ Control Inputs.<br>0, 0 Programs $f_C$ , filter A<br>0, 1 Programs $f_C$ , filter B<br>1, 0 Controls T/H functions:<br>D0 performs T/H En pin function<br>D1 performs T/H A/ $\overline{\text{B}}$ pin function.<br>1, 1 Controls device shutdown:<br>D0 performs $\overline{\text{SHDN}}$ pin function<br>Note: The $\overline{\text{WR}}$ pin must be strobed low to initiate a program/function (Figure 2). | —                                                                                                                                                              |
| 17-23  | D0-D6                        | 7-bit Data Inputs. Allows programming of 128 cutoff frequencies (also performs control functions as described above).                                                                                                                                                                                                                                                                                                                    | 7-bit Data Inputs. Program memory latches are transparent in this mode. Connect pins high or low to program filters A and B simultaneously to the same $f_C$ . |
| 24     | $\overline{\text{T/H}}$      | Track-and-Hold Control. Low level causes T/H OUT to track selected filter output. Filter output level held at T/H OUT synchronous with $\overline{\text{T/H}}$ rising transition.                                                                                                                                                                                                                                                        |                                                                                                                                                                |

X = Pin has no function in this mode.

**Note:** All digital input levels are TTL and CMOS compatible, unless otherwise noted.

# MAX270/MAX271

## Digitally-Programmed, Dual 2nd-Order Continuous Lowpass Filter



Figure 1a. MAX270 Block Diagram



Figure 1b. MAX271 Block Diagram—μP Mode



# MAX270/MAX271

## Digitally-Programmed, Dual 2nd-Order Continuous Lowpass Filter



Figure 1c. MAX271 Block Diagram—Pin-Strap Mode

### Filter Programming Cutoff Frequency

$f_C$  is the frequency of 3dB attenuation in the filter response.

Table 1 shows how data pins D0–D6 allow programming of 128 cutoff frequencies from 1kHz to 25kHz.

The equations for calculating  $f_C$  from the programmed code are as follows:

$$f_C = \frac{87.5}{87.5 - \text{CODE}} \times 1\text{kHz} \quad \text{for codes 0 - 63} \\ (f_C = 1\text{kHz to } 3.57\text{kHz})$$

$$f_C = \frac{262.5}{137.5 - \text{CODE}} \times 1\text{kHz} \quad \text{for codes 64 - 127} \\ (f_C = 3.57\text{kHz to } 25\text{kHz})$$

where CODE is the data on pins D0–D6 (0–127). D6 is the most significant bit (MSB).

Actual cutoff frequencies are subject to some error for each programmed code. Highest accuracy occurs at CODE = 0 where filters are trimmed for a 1kHz cutoff frequency. At higher codes, CODE vs.  $f_C$  errors increase; the frequency error at CODE = 127 (highest code) remains typically within  $\pm 9.5\%$ . This means that the actual filter cutoff frequency, when programmed to CODE = 127, falls between 22.63kHz and 27.38kHz.

# MAX270/MAX271

## Digitally-Programmed, Dual 2nd-Order Continuous Lowpass Filter

Table 1. Programmed Cutoff Frequency Codes (typ)

| PROGRAMMED CODE | f <sub>c</sub> (kHz) | PROGRAMMED CODE | f <sub>c</sub> (kHz) | PROGRAMMED CODE | f <sub>c</sub> (kHz) | PROGRAMMED CODE | f <sub>c</sub> (kHz) |
|-----------------|----------------------|-----------------|----------------------|-----------------|----------------------|-----------------|----------------------|
| 0               | 1.000                | 32              | 1.576                | 64              | 3.571                | 96              | 6.325                |
| 1               | 1.011                | 33              | 1.605                | 65              | 3.620                | 97              | 6.481                |
| 2               | 1.023                | 34              | 1.635                | 66              | 3.671                | 98              | 6.645                |
| 3               | 1.035                | 35              | 1.666                | 67              | 3.723                | 99              | 6.818                |
| 4               | 1.047                | 36              | 1.699                | 68              | 3.777                | 100             | 7.008                |
| 5               | 1.060                | 37              | 1.732                | 69              | 3.832                | 101             | 7.191                |
| 6               | 1.073                | 38              | 1.767                | 70              | 3.888                | 102             | 7.394                |
| 7               | 1.087                | 39              | 1.804                | 71              | 3.947                | 103             | 7.608                |
| 8               | 1.100                | 40              | 1.842                | 72              | 4.007                | 104             | 7.835                |
| 9               | 1.114                | 41              | 1.881                | 73              | 4.069                | 105             | 8.076                |
| 10              | 1.129                | 42              | 1.923                | 74              | 4.133                | 106             | 8.333                |
| 11              | 1.143                | 43              | 1.966                | 75              | 4.200                | 107             | 8.606                |
| 12              | 1.158                | 44              | 2.011                | 76              | 4.268                | 108             | 8.898                |
| 13              | 1.174                | 45              | 2.058                | 77              | 4.338                | 109             | 9.210                |
| 14              | 1.190                | 46              | 2.108                | 78              | 4.411                | 110             | 9.545                |
| 15              | 1.206                | 47              | 2.160                | 79              | 4.487                | 111             | 9.905                |
| 16              | 1.223                | 48              | 2.215                | 80              | 4.565                | 112             | 10.294               |
| 17              | 1.241                | 49              | 2.272                | 81              | 4.646                | 113             | 10.714               |
| 18              | 1.259                | 50              | 2.333                | 82              | 4.729                | 114             | 11.170               |
| 19              | 1.277                | 51              | 2.397                | 83              | 4.816                | 115             | 11.666               |
| 20              | 1.296                | 52              | 2.464                | 84              | 4.906                | 116             | 12.209               |
| 21              | 1.315                | 53              | 2.536                | 85              | 5.000                | 117             | 12.804               |
| 22              | 1.335                | 54              | 2.611                | 86              | 5.097                | 118             | 13.461               |
| 23              | 1.356                | 55              | 2.692                | 87              | 5.198                | 119             | 14.189               |
| 24              | 1.378                | 56              | 2.777                | 88              | 5.303                | 120             | 15.000               |
| 25              | 1.400                | 57              | 2.868                | 89              | 5.412                | 121             | 15.909               |
| 26              | 1.422                | 58              | 2.966                | 90              | 5.526                | 122             | 16.935               |
| 27              | 1.446                | 59              | 3.070                | 91              | 5.645                | 123             | 18.103               |
| 28              | 1.470                | 60              | 3.181                | 92              | 5.769                | 124             | 19.444               |
| 29              | 1.495                | 61              | 3.301                | 93              | 5.898                | 125             | 21.000               |
| 30              | 1.521                | 62              | 3.431                | 94              | 6.034                | 126             | 22.826               |
| 31              | 1.548                | 63              | 3.571                | 95              | 6.176                | 127             | 25.000               |

Programmed code is the data on pins D0–D6 (0–127). D6 is the MSB.

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## Digitally-Programmed, Dual 2nd-Order Continuous Lowpass Filter

### MAX270 Control Interface

The A0 pin is a three-level input that selects the memory addresses for updating cutoff frequency data in  $\mu$ P mode:

| A0         | SELECTS  |
|------------|----------|
| Logic Low  | Filter B |
| Logic High | Filter A |

Figure 2 shows  $\mu$ P-mode interface timing.

Connecting A0 to the negative supply selects pin-strap mode. Pin-strap mode allows filter programming with no timing requirements. Internal memory latches are disabled, permitting filters A and B to be programmed directly to  $f_C$  data strapped on D0–D6. This mode disables  $\overline{CS}$  and  $\overline{WR}$  controls, and filters A and B are programmed to the same  $f_C$ .

A low level on the  $\overline{SHDN}$  pin shuts down all amplifiers and disconnects OUTA, OUTB, and OP OUT. Current consumption drops to less than 15 $\mu$ A in this mode.

### MAX271 Control Interface

Connecting the MODE pin to GND or V- selects the  $\mu$ P mode. In this mode, addressable program memory controls filter cutoff frequency programming and all T/H functions, except T/H. See the Figure 2 for timing characteristics. Table 2 describes available functions:



Figure 2. MAX270/MAX271 Digital Timing Diagram

In  $\mu$ P mode,  $\overline{SHDN}$ , T/H A/B, and T/H EN pins are disabled. T/H remains enabled and performs the T/H tracking/holding function.

Tying MODE to V+ selects pin-strap mode. In this mode, both memory latches are transparent, and data on D0–D6 controls the  $f_C$  of filters A and 8 directly (filters A and 8 are programmed to the same  $f_C$ ). Pin strap D0–D6 for operation without  $\mu$ P. A0, A1,  $\overline{CS}$ , and  $\overline{WR}$  are disabled.

Table 2. MAX271  $\mu$ P-Mode Interface

| A1 | A0 | 06               | 05 | 04 | 03 | 02 | 01 | D0 | FUNCTION                                                                 |
|----|----|------------------|----|----|----|----|----|----|--------------------------------------------------------------------------|
| 0  | 0  | 7-bit $f_C$ data |    |    |    |    |    |    | Selects filter A                                                         |
| 0  | 1  | 7-bit $f_C$ data |    |    |    |    |    |    | Selects filter B                                                         |
| 1  | 0  | X                | X  | X  | X  | X  | X  | 0  | T/H OUT disabled                                                         |
| 1  | 0  | X                | X  | X  | X  | X  | X  | 1  | T/H OUT enabled                                                          |
| 1  | 0  | X                | X  | X  | X  | X  | 0  | X  | Selects OUTB as input to T/H                                             |
| 1  | 0  | X                | X  | X  | X  | X  | 1  | X  | Selects OUTA as input to T/H                                             |
| 1  | 1  | X                | X  | X  | X  | X  | X  | 0  | Filter shutdown mode. All outputs floated, 15 $\mu$ A max supply current |
| 1  | 1  | X                | X  | X  | X  | X  | X  | 1  | Removes filter from shutdown mode                                        |

X = Don't care

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### Digital Threshold Levels

All digital inputs are TTL and CMOS compatible, unless otherwise stated. Inputs are CMOS gates with less than 1µA leakage current and 8pF capacitance loading. Typical logic voltage thresholds are a function of the V+ supply voltage as shown below (voltages are referenced to GND).

| V+ (V) | LOGIC THRESHOLD VOLTAGE (V) |
|--------|-----------------------------|
| 8      | +2.4                        |
| 7      | +2.3                        |
| 6      | +2.0                        |
| 5      | +1.75                       |
| 4      | +1.5                        |
| 2.5    | +1.0                        |

**Note:** For +5V single-supply operation, where incoming logic signals are referenced to V-, typical logic thresholds are +3.5V. Therefore, a CMOS (rail-to-rail) logic interface is recommended.

### Filter Performance

All MAX270/MAX271 internal amplifier and output stages for filter sections, uncommitted op amp, and T/H are identical. The outputs are designed to drive 5kΩ in parallel with a maximum capacitance of 100pF. At higher load levels, the output swing becomes asymmetric. All outputs can be short circuited to GND for an indefinite duration.

The MAX270/MAX271 operating frequency range is limited to approximately 2MHz by the bandwidth of the internal amplifiers.

### Filter Noise

Wideband filter noise over a 50kHz bandwidth is 12µVRMS and 38µVRMS per section for f<sub>C</sub> programmed to 1kHz and 25kHz, respectively. A dynamic range of over 96dB results.

### Filter Input Impedance

At DC, the input impedance at INA and INB is equal to the DC input impedance of the amplifier, which is about 5MΩ. At higher frequencies, internal capacitors contribute to an effective input impedance that may fall as low as 100kΩ at 25kHz.

### MAX271 Track-and-Hold

The MAX271 T/H is functionally equivalent to a switched 200pF capacitor buffered by a unity-gain amplifier (Figures 1b and 1c). When the T/H pin is driven low, the output of filter A or filter B (whichever is selected via control interface) internally connects to the amplifier, and T/H OUT follows the filter output. The offset at T/H OUT (±6mV max) is the combined offset of the filter amplifier and the T/H buffer. When T/H is pulled high, the switch disconnects the filter signal from the T/H. The T/H capacitor holds the stored charge, and that voltage is buffered at T/H OUT.

A low level at T/H EN disconnects T/H OUT, enabling multiplexed operation (Figure 3). T/H A/B selects between OUTA and OUTB as the T/H input. In FP mode, the T/H EN and T/H OUT functions are controlled by writing control bits to program memory, with T/H EN and T/H OUT pins disabled.

See the *Typical Operating Characteristics* graphs for T/H dynamic accuracy.

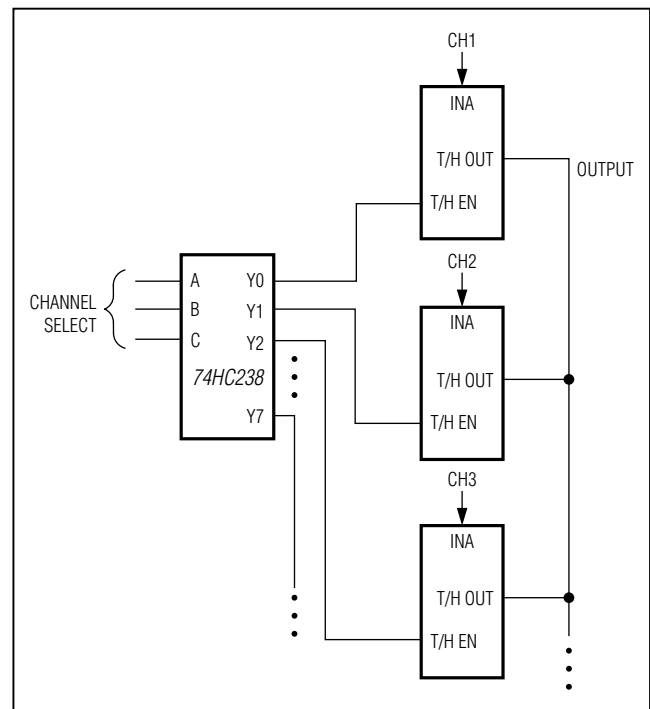


Figure 3. MAX271 Multiplexed Operation

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## Digitally-Programmed, Dual 2nd-Order Continuous Lowpass Filter

### Applications Information

#### Power-Supply Configurations

The MAX270/MAX271 power supplies must be properly bypassed. Best performance is achieved if V+ and V- are bypassed to GND with 4.7 $\mu$ F electrolytic (tantalum is preferred) and 0.1 $\mu$ F ceramic capacitors in parallel. These should be as close as possible to the chip supply pins.

Single supplies in the range of 4.75V to 16V may be used to power the MAX270/MAX271 as shown in Figure 4. Digital logic may be referenced to V- (system ground), but will not maintain TTL compatibility. CMOS (rail-to-rail) logic recommended. For  $\mu$ P-mode operation with a

single supply, the MAX270 A0 pin must be configured with a voltage divider (Figure 4).

Lowest quiescent current in shutdown mode is achieved when A0 is either at V+ or V-.

#### Independent $f_c$ Programming Without a $\mu$ P

Figure 6 shows how filter sections A and B may be programmed to different cutoff frequencies without the use of a  $\mu$ P. The MAX690  $\mu$ P supervisory circuit provides the proper programming sequence when the circuit is powered up by controlling the 74HC373 data buffer and the MAX270 addressing pin to load independent  $f_c$  data for filters A and B.



Figure 4. Power-Supply Configurations

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## Digitally-Programmed, Dual 2nd-Order Continuous Lowpass Filter

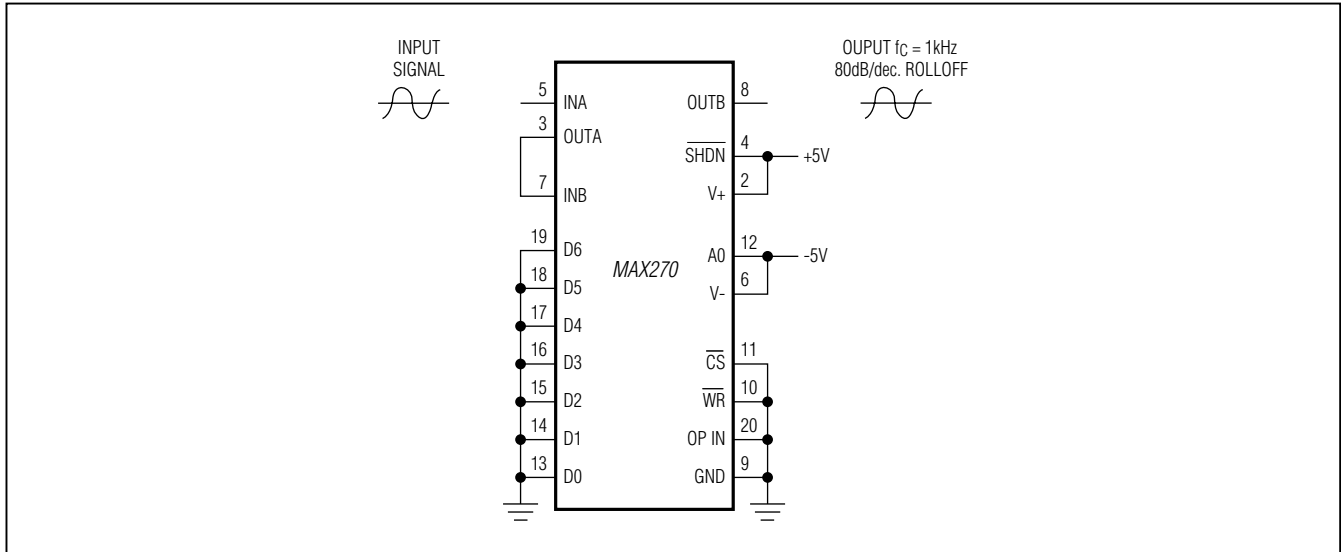


Figure 5. Cascading Filter Sections

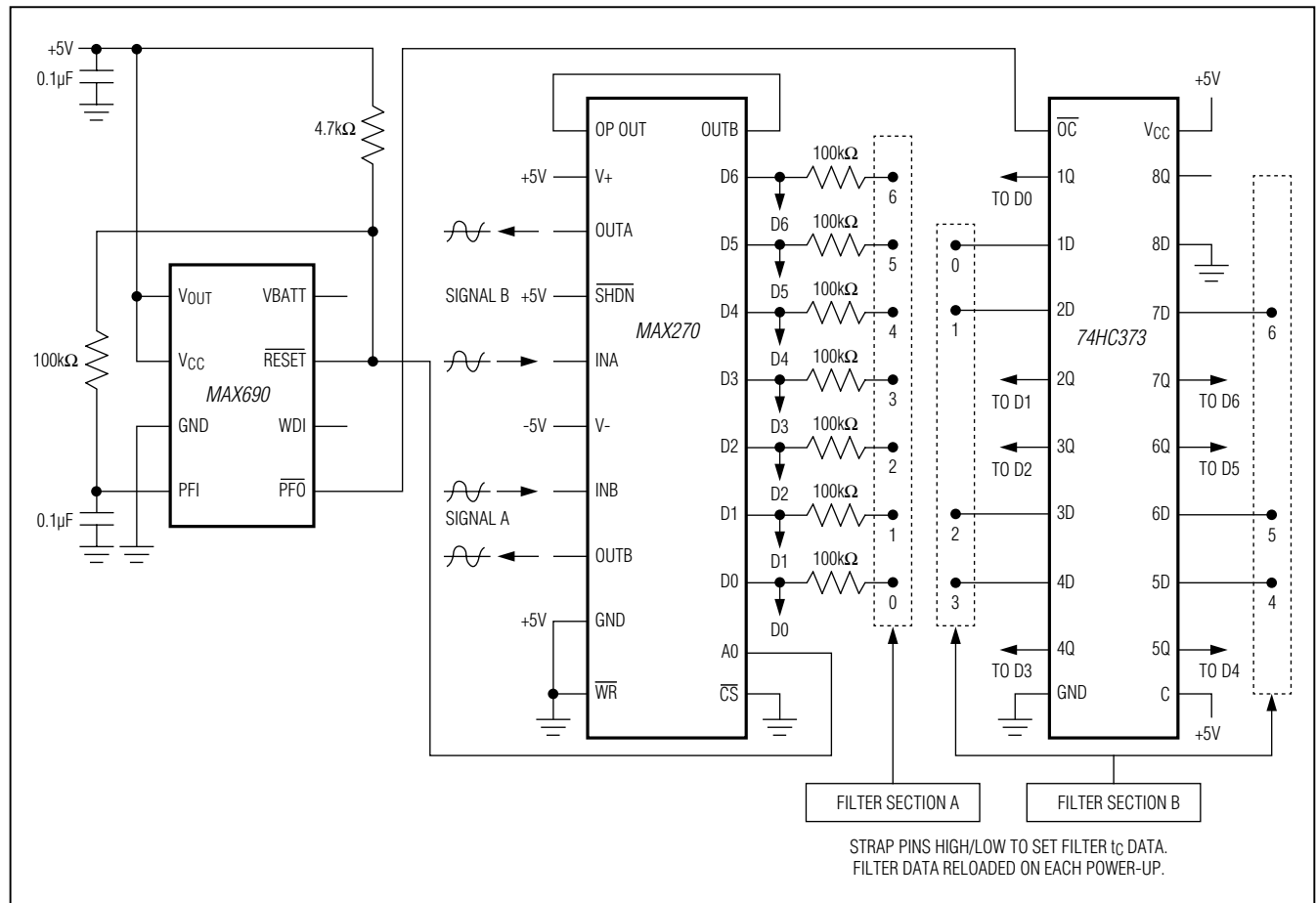


Figure 6. Independent  $f_c$  Programming without a  $\mu P$

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## Digitally-Programmed, Dual 2nd-Order Continuous Lowpass Filter

### Pin Configurations (continued)



### Chip Information

PROCESS: BiCMOS

### Package Information

For the latest package outline information and land patterns (footprints), go to [www.maximintegrated.com/packages](http://www.maximintegrated.com/packages). Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

| PACKAGE TYPE | PACKAGE CODE | OUTLINE NO.             | LAND PATTERN NO.        |
|--------------|--------------|-------------------------|-------------------------|
| 20 PDIP      | P20-2        | <a href="#">21-0043</a> | —                       |
| 20 SO (W)    | W20-3        | <a href="#">21-0042</a> | <a href="#">90-0108</a> |
| 24 PDIP      | N24-3        | <a href="#">21-0043</a> | —                       |
| 24 SO (W)    | W24-2        | <a href="#">21-0042</a> | <a href="#">90-0182</a> |

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### Revision History

| REVISION NUMBER | REVISION DATE | DESCRIPTION                                                               | PAGES CHANGED |
|-----------------|---------------|---------------------------------------------------------------------------|---------------|
| 0               | 4/91          | Initial release                                                           | —             |
| 1               | 8/91          | Revised <i>Electrical Characteristics</i>                                 | 2             |
| 2               | 1/12          | Revised <i>Ordering Information</i> and <i>Absolute Maximum Ratings</i> . | 1, 2          |



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