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# Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832
Email & Skype: info@chipsmall.com Web: www.chipsmall.com
Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China

19-4807; Rev 1; 2/10

# ±0.3% Accurate, Quad, Power-Supply Controller with Active-Voltage Output Control and PMBus Interface

MAX16064

## General Description

The MAX16064 is a fully integrated 4-channel digital power-supply controller and monitor IC that can be connected up to four power supplies to provide complete digital configurability. By interfacing to the power-supply reference input or feedback node, and the output enable, the MAX16064 takes control of the power supply to provide tracking, soft-start, sequencing, margining, and dynamic adjustment of the output voltage.

Power-supply sequencing can be performed autonomously or controlled over the PMBus™ interface. Sequencing is controlled during power-down as well as power-up. Multiple MAX16064s can be combined to autonomously sequence more supplies. The sequencing order is stored in an external configuration EEPROM so sequence order changes can be reprogrammed without changing the PCB layout.

The MAX16064 features an internal temperature sensor providing an additional level of system monitoring. Other features include a reset output and an SMBus™ alert output.

Each channel of the MAX16064 includes an accurate 12-bit analog-to-digital converter (ADC) input and a differential amplifier for accurately monitoring and reporting the voltage at the load without being influenced by any difference in ground potentials. An integrated 12-bit digital-to-analog converter (DAC) can margin power supplies and dynamically adjust the output voltage using a closed-loop control system to provide an output-voltage accuracy of ±0.3%.

The user-programmable registers provide flexible and accurate control of time events such as delay time and transition period, monitoring for overvoltage and undervoltage, overtemperature fault and warning handling. The closed-loop operation is also programmable to make sure the MAX16064 works with any existing power supply to provide superior regulation accuracy and accurate margining.

The MAX16064 operates using a PMBus-compliant communication protocol. The device can be programmed using this protocol or with a free graphic-user interface (GUI) available from the Maxim website that significantly reduces development time. Once the configuration is complete, the results can be saved into an EEPROM or loaded into the device through PMBus at power-up. This allows remote configuration of any power supply using the MAX16064, replacing expensive recalls or field service. The MAX16064 can be programmed with up to 114 distinct addresses to support large systems. The MAX16064 is offered in a space-saving, 36-pin, lead-free, 6mm x 6mm TQFN package and is fully specified from -40°C to +85°C.

## Features

- ♦ **Accurate Voltage Output Control (AVOC) Controls Output Voltage with ±0.3% Accuracy**
- ♦ **PMBus Interface for Programming, Monitoring, Sequencing Up and Down, and Margining**
- ♦ **Output Voltage and Temperature Monitoring with Adjustable Monitor Rate**
- ♦ **Programmable Soft-Start and Soft-Stop Ramp Rates**
- ♦ **Power-Supply Control using REFIN or FB Terminals**
- ♦ **Master-Slave Clocking Option Provides Accurate Timing Reference Across Multiple Devices**
- ♦ **External EEPROM Interface for Autoboot on Power-Up**
- ♦ **3.0V to 3.6V Operating Voltage Range**
- ♦ **6mm x 6mm, 36-Pin TQFN Package**

## Applications

Routers

Servers

Storage Systems

Telecom/Networking

DC-DC Modules and Power Supplies

## Ordering Information

| PART | TEMP RANGE | PIN-PACKAGE |
|---|---|---|
| MAX16064ETX+ | -40°C to +85°C | 36 TQFN-EP* |

*+Denotes a lead(Pb)-free/RoHS-compliant package.*
**EP = Exposed pad.*

***Pin Configuration and Typical Operating Circuit appears at end of data sheet.***

## ABSOLUTE MAXIMUM RATINGS

AVDD, DVDD to AGND ...........................................-0.3V to +4V
AVDD to DVDD......................................................-0.3V to +0.3V
AGND to DGND.....................................................-0.3V to +0.3V
AGND1 to DGND...................................................-0.3V to +0.3V
RS_+, RS_- to AGND...............................................-0.3V to +6V
RS_C, A1/SCLE, A2/SDAE,
A3/CONTROL to AGND ......................-0.3V to (AVDD + 0.3V)
RESET, SMBALERT, ENOUT_ to AGND...................-0.3V to +6V
SCL, SDA to DGND .................................................-0.3V to +4V
DACOUT_, EN, CLKIO, REFO to AGND.....-0.3V to (AVDD + 0.3V)
DACOUT_ Current .............................................................10mA
SDA Current.......................................................-1mA to +50mA
Input/Output Current (all other pins)..................................20mA
Continuous Power Dissipation ($T_A$ = +70°C)
36-Pin 6mm x 6mm TQFN
(derate 35.7mW/°C above +70°C)............................2857mW
Thermal Resistance (Note 1)
$\theta_{JA}$................................................................................28°C/W
$\theta_{JC}$..................................................................................1°C/W
Operating Temperature Range ...........................-40°C to +85°C
Junction Temperature.....................................................+150°C
Storage Temperature Range .............................-65°C to +150°C
Lead Temperature (soldering, 10s) .................................+300°C
Soldering Temperature (reflow) ......................................+260°C

**Note 1:** Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to **www.maxim-ic.com/thermal-tutorial**.

*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

($V_{AVDD}$ = $V_{DVDD}$ = 3.0V to 3.6V, $V_{EN}$ = 2V, $V_{RS\_+}$ - $V_{RS\_-}$ = 2V, $V_{RS\_-}$ = 0V, $T_A$ = $T_J$ = -40°C to +85°C, unless otherwise specified. Typical values are at $V_{AVDD}$ = $V_{DVDD}$ = 3.3V, $T_A$ = +25°C.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| AVDD/DVDD Operating Voltage Range | | | 3.0 | | 3.6 | V |
| AVDD Undervoltage Lockout (AVDD Rising) | $V_{UVLO}$ | | 2.75 | 2.8 | 2.95 | V |
| AVDD Undervoltage Lockout Hysteresis | $V_{UVLO-HYS}$ | | | 100 | | mV |
| AVDD and DVDD Total Supply Current | | $V_{RS\_+}$ = $V_{RS\_-}$ = 0V | | 12 | 18.5 | mA |
| **OUTPUT-VOLTAGE SENSING** | | | | | | |
| Voltage Regulation Accuracy (2V Range) | | $T_A$ = +25°C, $V_{RS\_+}$ = 1.0V, $V_{RS\_-}$ = 0V | -4 | | +4 | mV |
| | | $T_A$ = -40°C to +85°C, $V_{RS\_+}$ = 1.0V, $V_{RS\_-}$ = 0V | -6 | | +6 | mV |
| Voltage Regulation Accuracy (5.5V Range) | | $T_A$ = +25°C, $V_{RS\_+}$ = 2.5V, $V_{RS\_-}$ = 0V | -11 | | +11 | mV |
| | | $T_A$ = -40°C to +85°C, $V_{RS\_+}$ = 2.5V, $V_{RS\_-}$ = 0V | -16.5 | | +16.5 | mV |
| RS_+, RS_- Differential Mode Range | | | 0 | | 5.5 | V |
| RS_- to AGND Differential Voltage | | | -250 | | +250 | mV |
| RS_+ Input Bias Current | | 2V range, $V_{RS\_+}$ = -0.25V to +2V | -20 | | +20 | µA |
| | | 5.5V range, $V_{RS\_+}$ = -0.25V to +5.5V | -20 | | +100 | |
| RS_- Input Bias Current | | 2V or 5.5V range, $V_{RS\_-}$ = -0.25V to +0.25V | -20 | | 0 | µA |

## ELECTRICAL CHARACTERISTICS (continued)

($V_{AVDD}$ = $V_{DVDD}$ = 3.0V to 3.6V, $V_{EN}$ = 2V, $V_{RS\_+}$ - $V_{RS\_-}$ = 2V, $V_{RS\_-}$ = 0V, $T_A$ = $T_J$ = -40°C to +85°C, unless otherwise specified. Typical values are at $V_{AVDD}$ = $V_{DVDD}$ = 3.3V, $T_A$ = +25°C.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **INTERNAL TEMPERATURE SENSOR** | | | | | | |
| Temperature Sensing Accuracy | | $T_A$ = 0°C to +85°C | | ±3 | | °C |
| **INTERNAL OSCILLATOR** | | | | | | |
| Frequency | | | 7.6 | 8 | 8.4 | MHz |
| **ADC** | | | | | | |
| Resolution | | | | 12 | | Bits |
| **INTERNAL REFERENCE** | | | | | | |
| Reference Voltage | $V_{REF}$ | $T_A$ = +25°C | | 2.048 | | V |
| **DAC** | | | | | | |
| Resolution | | | | 12 | | Bits |
| Differential Nonlinearity | DNL | | -2.5 | | +2.5 | LSB |
| Maximum Output-Voltage Range | | No load | | $V_{REF}$ - 1 LSB | | V |
| Capacitive Load | | | | 200 | | pF |
| Output-Voltage Slew Rate | | | | 0.35 | | V/µs |
| DAC Output Resistance | | | | 10 | | Ω |
| DAC Driving Capability | | DAC output > 100mV; output error < 25mV | -1 | | +1 | mA |
| DAC Output Leakage Current | | DAC output switch open, $V_{DACOUT\_}$ = $V_{REF}$ or 0V | -250 | | +250 | nA |
| **CLKIO** | | | | | | |
| Input Logic-Low Voltage | | | | | 0.8 | V |
| Input Logic-High Voltage | | | 2.1 | | | V |
| Input Bias Current | | $V_{CLKIO}$ = 3.6V or 0V | -1 | | +1 | µA |
| Input Clock Duty Cycle | | | | 50 | | % |
| Output Low Voltage | | CLKIO in output mode, $I_{SINK}$ = 4mA | | | 0.4 | V |
| Output High Leakage | | $V_{CLKIO}$ = 3.6V | -1 | | +1 | µA |
| CLKIO Pullup Voltage | | | | | 3.6 | V |
| CLKIO Input Frequency Range | $f_{EXT\_CLK}$ | | 100 | | 1000 | kHz |
| CLKIO Output Frequency | | | | 1 | | MHz |
| **ENABLE INPUT (EN)** | | | | | | |
| EN Falling Threshold Voltage | $V_{EN\_TH}$ | | 1.17 | 1.21 | 1.23 | V |
| EN Rising Threshold Voltage | | | 1.175 | 1.23 | 1.281 | V |
| EN Input Leakage Current | | | -0.25 | | +0.25 | µA |
| **OUTPUTS (ENOUT_, $\overline{\text{RESET}}$, $\overline{\text{SMBALERT}}$)** | | | | | | |
| Output Low Voltage | $V_{OL}$ | $I_{SINK}$ = 10mA | | | 0.4 | V |
| | | $V_{AVDD}$ = $V_{DVDD}$ = 1.1V, $I_{SINK}$ = 100µA | | | 0.4 | V |
| Output Leakage | | $V_{ENOUT\_}$ = 5V, 0V | -1 | | +1 | µA |

## ELECTRICAL CHARACTERISTICS (continued)

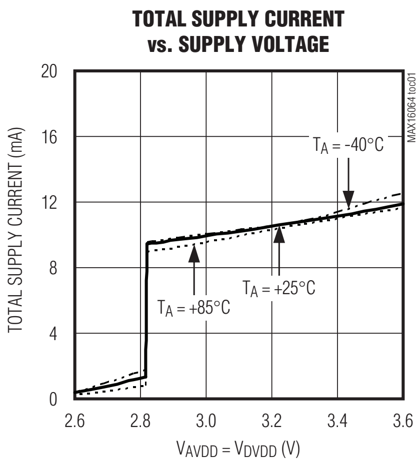
($V_{AVDD}$ = $V_{DVDD}$ = 3.0V to 3.6V, $V_{EN}$ = 2V, $V_{RS\_+}$ - $V_{RS\_-}$ = 2V, $V_{RS\_-}$ = 0V, $T_A$ = $T_J$ = -40°C to +85°C, unless otherwise specified. Typical values are at $V_{AVDD}$ = $V_{DVDD}$ = 3.3V, $T_A$ = +25°C.) (Note 2)

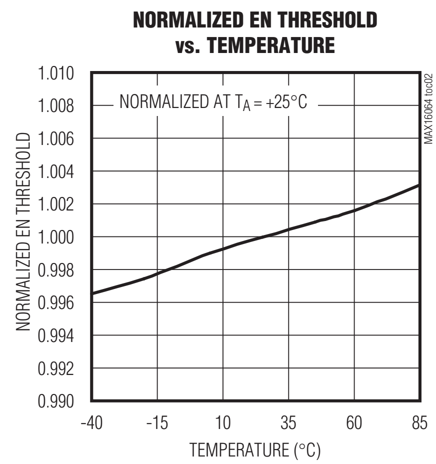
| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **ADDRESS PINS (A1/SCLE, A2/SDAE, A3/CONTROL)** | | | | | | |
| Input Logic-Low Voltage | | | | | 0.3 | V |
| Input Logic-Low Hysteresis | | | | 50 | | mV |
| Input Logic-High Voltage | | | $V_{AVDD}$ - 0.4 | | | V |
| Input Logic-High Hysteresis | | | | 50 | | mV |
| Input Leakage Current | | | -12 | | +12 | µA |
| **SMBus INTERFACE (SCL, SDA) (Note 3)** | | | | | | |
| SCL, SDA Input Low Voltage | $V_{IL}$ | Input voltage falling | | | 0.8 | V |
| SCL, SDA Input High Voltage | $V_{IH}$ | Input voltage rising | 2.1 | | | V |
| SCL, SDA Input Leakage Current (Per Pin) | | Device powered or unpowered, $V_{AVDD}$ = 0 to 3.6V, $V_{SCL}$ = $V_{SDA}$ = 0V or $V_{AVDD}$ | -1 | | +1 | µA |
| Input Capacitance | $C_{IN}$ | | | 10 | | pF |
| SCL, SDA Output Low Voltage | $V_{OL}$ | $I_{SINK}$ = 3mA | | | 0.4 | V |
| **SMBUS TIMING** | | | | | | |
| Serial-Clock Frequency | $f_{SCL}$ | | 10 | | 100 | kHz |
| Bus Free Time Between STOP and START Condition | $t_{BUF}$ | | 4.7 | | | µs |
| START Condition Setup Time | $t_{SU:STA}$ | | 4.7 | | | µs |
| START Condition Hold Time | $t_{HD:STA}$ | | 4.0 | | | µs |
| STOP Condition Setup Time | $t_{SU:STO}$ | | 4.0 | | | µs |
| Clock Low Period | $t_{LOW}$ | | 4.7 | | | µs |
| Clock High Period | $t_{HIGH}$ | | 4.0 | | | µs |
| Data Setup Time | $t_{SU:DAT}$ | | 250 | | | ns |
| Output Fall Time | $t_{OF}$ | $C_{BUS}$ = 10pF to 400pF | | | 300 | ns |
| Data Hold Time | $t_{HD:DAT}$ | From 50% SCL falling to SDA change | 300 | | | ns |
| Pulse Width of Spike Suppressed | $t_{SP}$ | | | 30 | | ns |
| SMBus Timeout | $t_{TIMEOUT}$ | SMBCLK time low for reset | 25 | | 55 | ms |
| **OTHER TIMING PARAMETERS** | | | | | | |
| PMBus Command Response Time | $t_{PMB\_RSP}$ | | | 300 | | µs |
| Fault Response Time | $t_{FAULT\_RSP}$ | | | 5 | | ms |
| Recovery Time After Device Reset | $t_{RST\_WAIT}$ | No external EEPROM | | 15 | | ms |

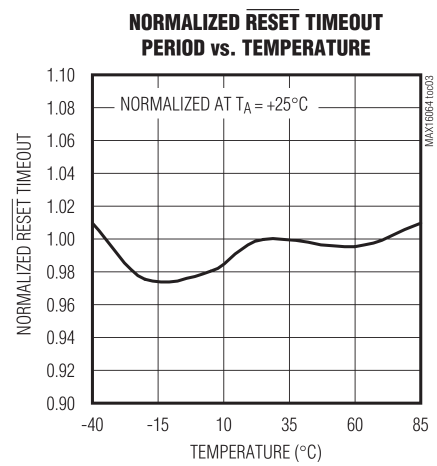
**Note 2:** 100% production tested at $T_A$ = +25°C. Limits over temperature are guaranteed by design.
**Note 3:** The MAX16064 supports SCL clock stretching.

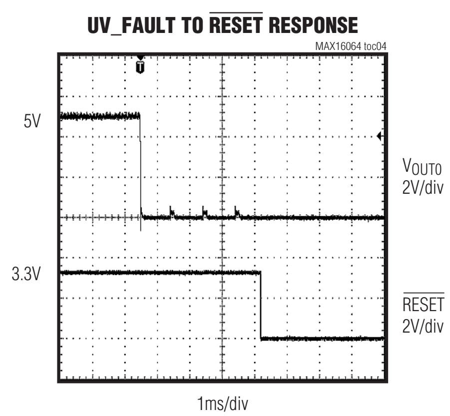
## Typical Operating Characteristics

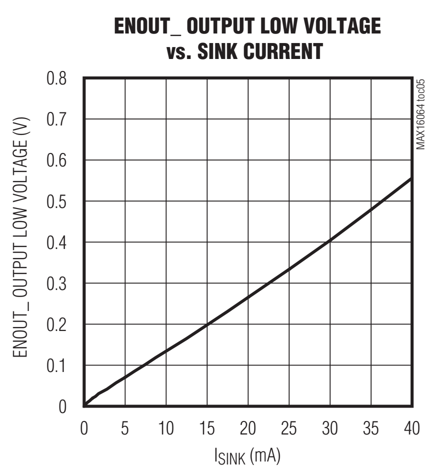
($V_{AVDD}$ = $V_{DVDD}$ = 3.3V, $T_A$ = +25°C, unless otherwise noted.)

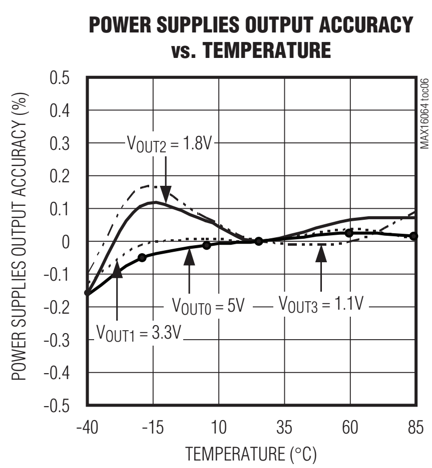


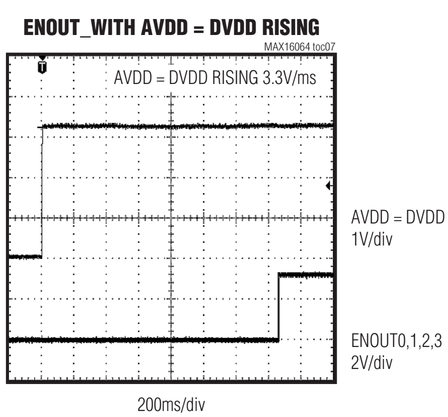



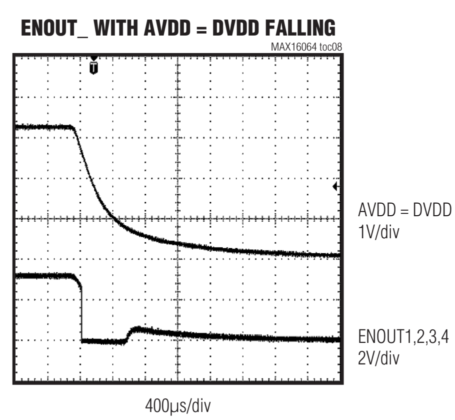



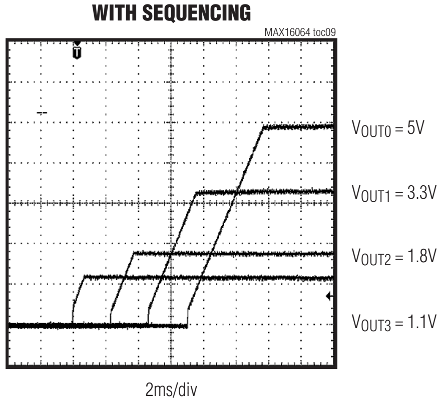



# ±0.3% Accurate, Quad, Power-Supply Controller with Active-Voltage Output Control and PMBus Interface

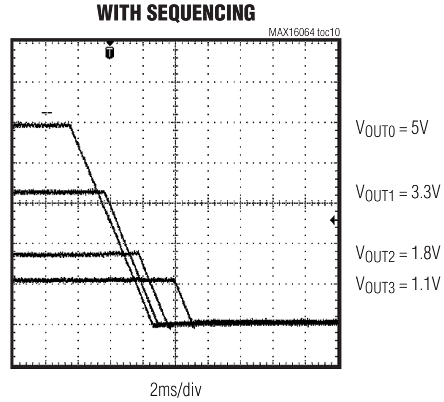
## Typical Operating Characteristics (continued)

($V_{AVDD}$ = $V_{DVDD}$ = 3.3V, $T_A$ = +25°C, unless otherwise noted.)

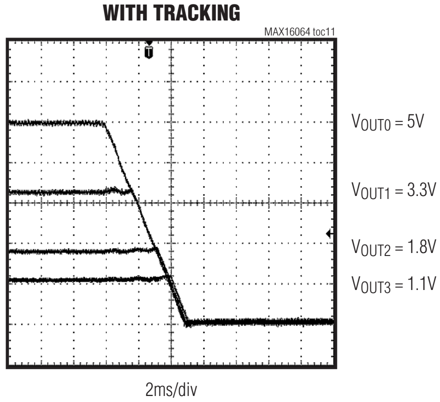
**REFIN MODE SOFT-START WITH SEQUENCING**



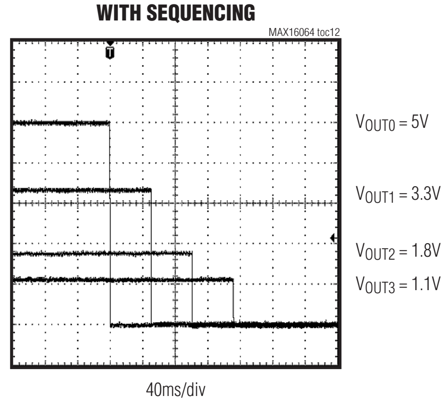

**REFIN MODE SOFT-STOP WITH SEQUENCING**



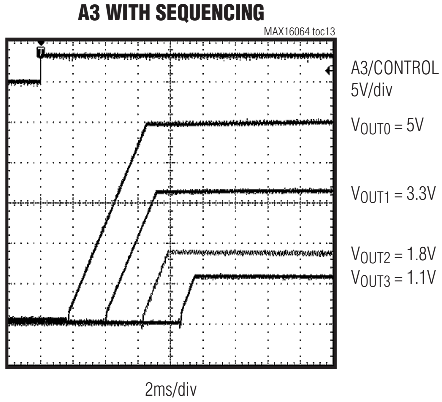

**REFIN MODE SOFT-STOP WITH TRACKING**



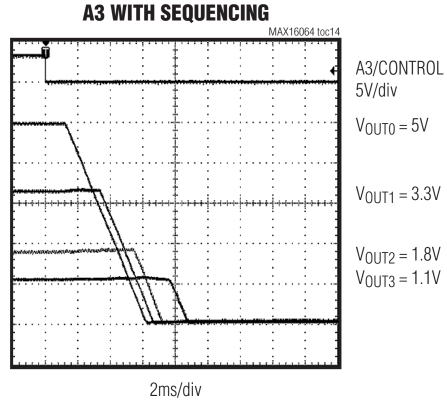

**REFIN MODE OPERATION OFF WITH SEQUENCING**




**REFIN MODE SOFT-START FROM A3 WITH SEQUENCING**

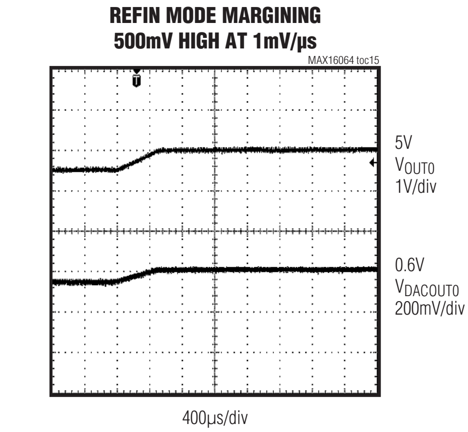


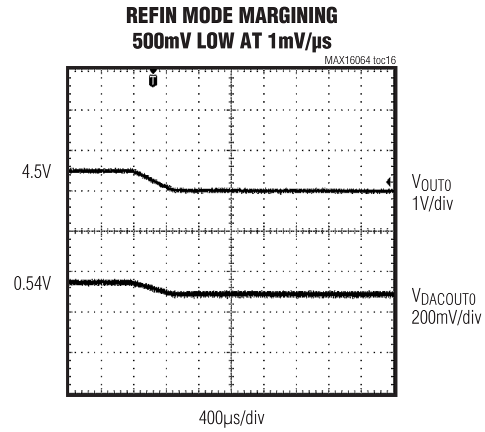

**REFIN MODE SOFT-STOP FROM A3 WITH SEQUENCING**

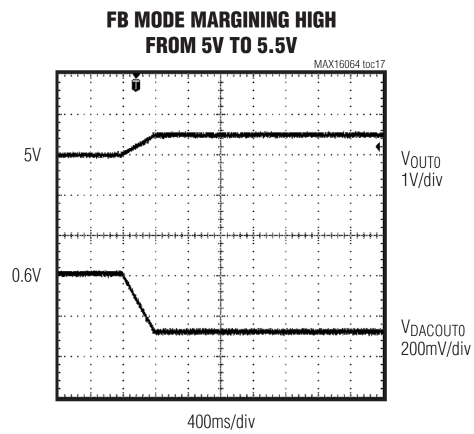


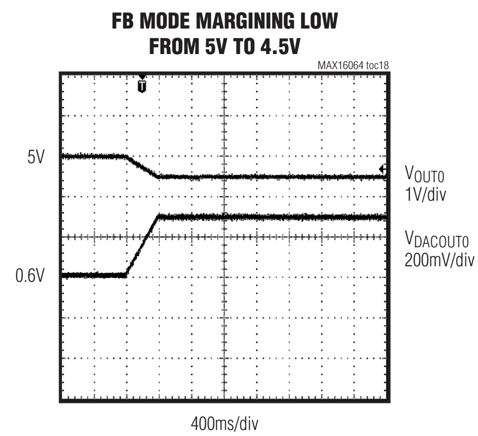
## Typical Operating Characteristics (continued)

($V_{AVDD}$ = $V_{DVDD}$ = 3.3V, $T_A$ = +25°C, unless otherwise noted.)



## Pin Description

| PIN | NAME | FUNCTION |
|---|---|---|
| 1 | RS2- | Differential Remote-Sense Input 2 Return of the DC-DC Output Voltage. Connect to the return terminal at the load. |
| 2 | RS2+ | Differential Remote-Sense Input 2 of DC-DC Output Voltage. Connect to the load terminal where the output must be regulated. |
| 3 | RS3+ | Differential Remote-Sense Input 3 of DC-DC Output Voltage. Connect to the load terminal where the output must be regulated. |
| 4 | RS3- | Differential Remote-Sense Input 3 Return of the DC-DC Output Voltage. Connect to the return terminal at the load. |
| 5 | RS3C | Filter Capacitor for $V_{SENSE}$ Amplifier 3. Connect a 1µF capacitor from RS3C to AGND. |
| 6 | EN | Enable Input. All ENOUT_ are deasserted when the voltage on EN is below 1.2V (typ). Used to turn on/off the controlled power supplies in conjunction with the PMBus OPERATION command. |
| 7 | DACOUT1 | Analog Voltage Output of Internal 12-Bit DAC 1. Connect to TRIM, REFIN, or FB of a DC-DC module or an LDO to adjust the power-supply output voltage. High impedance in shutdown. |
| 8 | AGND | Analog Ground. Connect AGND to AGND1 and to DGND externally close to the device. |
| 9 | ENOUT0 | On/Off Signal Output 0. Typically used to turn on/off a power supply. Controlled by the PMBus OPERATION command or the sequencer. Can be configured as either an active-high or an active-low open-drain output. See the *ENOUT_ Operation* section. |
| 10 | ENOUT1 | On/Off Signal Output 1. Typically used to turn on/off a power supply. Controlled by the PMBus OPERATION command or the sequencer. Can be configured as either an active-high or an active-low open-drain output. See the *ENOUT_ Operation* section. |
| 11 | ENOUT2 | On/Off Signal Output 2. Typically used to turn on/off a power supply. Controlled by the PMBus OPERATION command or the sequencer. Can be configured as either an active-high or an active-low open-drain output. See the *ENOUT_ Operation* section. |
| 12 | ENOUT3 | On/Off Signal Output 3. Typically used to turn on/off a power supply. Controlled by the PMBus OPERATION command or the sequencer. Can be configured as either an active-high or an active-low open-drain output. See the *ENOUT_ Operation* section. |
| 13 | CLKIO | Clock Input/Output. User-configurable clock input/output signal. The system controller can provide a clock input to synchronize the time bases of multiple MAX16064 devices. Alternatively, a MAX16064 can provide a 1MHz output clock to other MAX16064s for synchronization. See the *MFR_MODE (D1h)* section. When configured as an output, CLKIO is an open-drain output and a pullup resistor is required. |
| 14 | A1/SCLE | Dual-Functioned MAX16064 Slave Address Identifier (LSB) and EEPROM $I^2C$ Clock Output. See the *MAX16064 Address Assignment* and *External EEPROM Interface* sections. |
| 15 | A2/SDAE | Dual-Functioned MAX16064 Slave Address Identifier and EEPROM $I^2C$ Data Input/Output. See the *MAX16064 Address Assignment* and *External EEPROM Interface* sections. |
| 16 | A3/CONTROL | Dual-Functioned MAX16064 Slave Address Identifier (MSB) and Power-Supply On/Off Control Using the MFR_MODE Command. See the *MAX16064 Address Assignment* and *A3/CONTROL Operation* sections. |
| 17 | $\overline{RESET}$ | Active-Low, Open-Drain Reset Output |

## Pin Description (continued)

| PIN | NAME | FUNCTION |
|---|---|---|
| 18 | $\overline{\text{SMBALERT}}$ | Active-Low, Open-Drain Fault-Detection Interrupt Output |
| 19 | SCL | SMBus Serial-Clock Input/Output |
| 20 | SDA | SMBus Serial-Data Input/Output |
| 21 | DGND | Digital Ground. Connect DGND to AGND and AGND1 externally close to the device. |
| 22 | DVDD | Digital Power-Supply Input. Connect a 1µF capacitor from DVDD to DGND. |
| 23 | RSVD | Reserved. Connect to DVDD externally. |
| 24 | DACOUT3 | Analog Voltage Output of Internal 12-Bit DAC 3. Connect to TRIM, REFIN, or FB of a DC-DC module or an LDO to adjust the power-supply output voltage. High impedance in shutdown. |
| 25 | AGND1 | Analog Ground. Connect to AGND and DGND externally close to the device. |
| 26 | AVDD | Analog Power-Supply Input. Connect a 1µF capacitor from AVDD to AGND. |
| 27 | DACOUT2 | Analog Voltage Output of Internal 12-Bit DAC 2. Connect to TRIM, REFIN, or FB of a DC-DC module or an LDO to adjust the power-supply output voltage. High impedance in shutdown. |
| 28 | RS1- | Differential Remote-Sense Input 1 Return of the DC-DC Output Voltage. Connect to the return terminal at the load. |
| 29 | RS1+ | Differential Remote-Sense Input 1 of DC-DC Output Voltage. Connect to the load terminal where the output must be regulated. |
| 30 | RS1C | Filter Capacitor for $V_{SENSE}$ Amplifier 1. Connect a 1µF capacitor from RS1C to AGND. |
| 31 | REFO | Reference Output. Connect a 1µF capacitor from REFO to AGND. |
| 32 | RS0+ | Differential Remote-Sense Input 0 of DC-DC Output Voltage. Connect to the load terminal where the output must be regulated. |
| 33 | RS0C | Filter Capacitor for $V_{SENSE}$ Amplifier 0. Connect a 1µF capacitor from RS0C to AGND. |
| 34 | RS0- | Differential Remote-Sense Input 0 Return of the DC-DC Output Voltage. Connect to the return terminal at the load. |
| 35 | DACOUT0 | Analog Voltage Output of Internal 12-Bit DAC 0. Connect to TRIM, REFIN, or FB of a DC-DC module or an LDO to adjust the power-supply output voltage. High impedance in shutdown. |
| 36 | RS2C | Filter Capacitor for $V_{SENSE}$ Amplifier 2. Connect a 1µF capacitor from RS2C to AGND. |
| — | EP | Exposed Pad. Internally connected to AGND. Connect EP to the ground plane of the power supplies for best temperature measurement performance. |

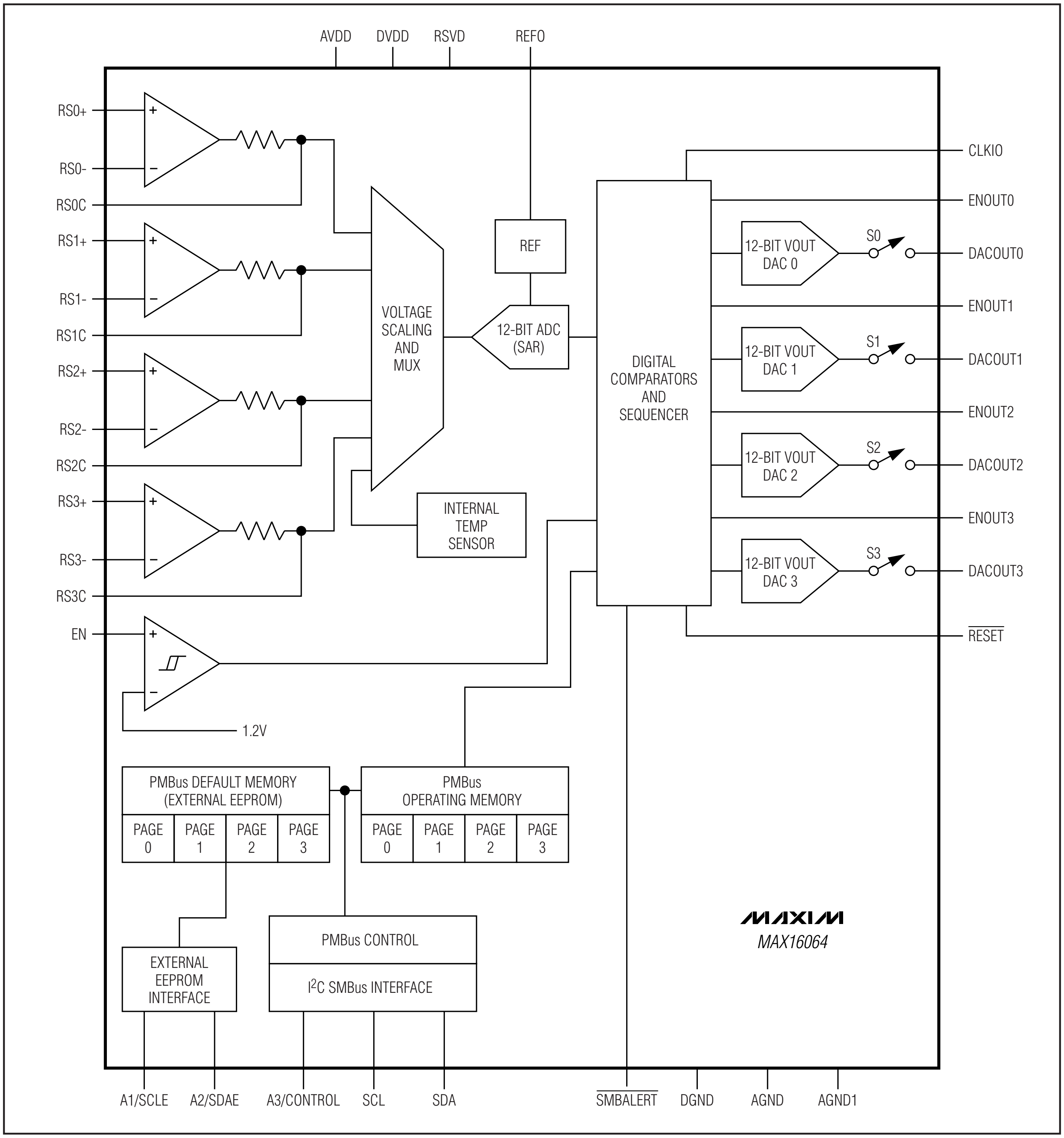



*Figure 1. MAX16064 Functional Diagram*

## Detailed Description

The MAX16064 adds digital control functionality to four power supplies. Using a closed-loop control system, the MAX16064 can continuously adjust the power-supply output voltages to maintain ±0.3% output-voltage accuracy. The MAX16064 can also be programmed to sequence, track, and margin each power supply.

A PMBus-compliant interface bus provides access to configuration parameters of the MAX16064, including monitoring thresholds, sequence delays, soft-start and soft-stop slew rates, output-voltage settings, an on-chip temperature sensor, and more.

Up to 114 MAX16064s can reside on the same PMBus bus, each controlling its own power supplies, under commands from the PMBus system controller, as shown in Figure 2. The MAX16064s can be placed close to the power supplies they control so that all sensitive analog traces are short and less susceptible to noise. The power supplies can also be placed close to the load where they provide the best transient response and lowest losses with short power plane runs.

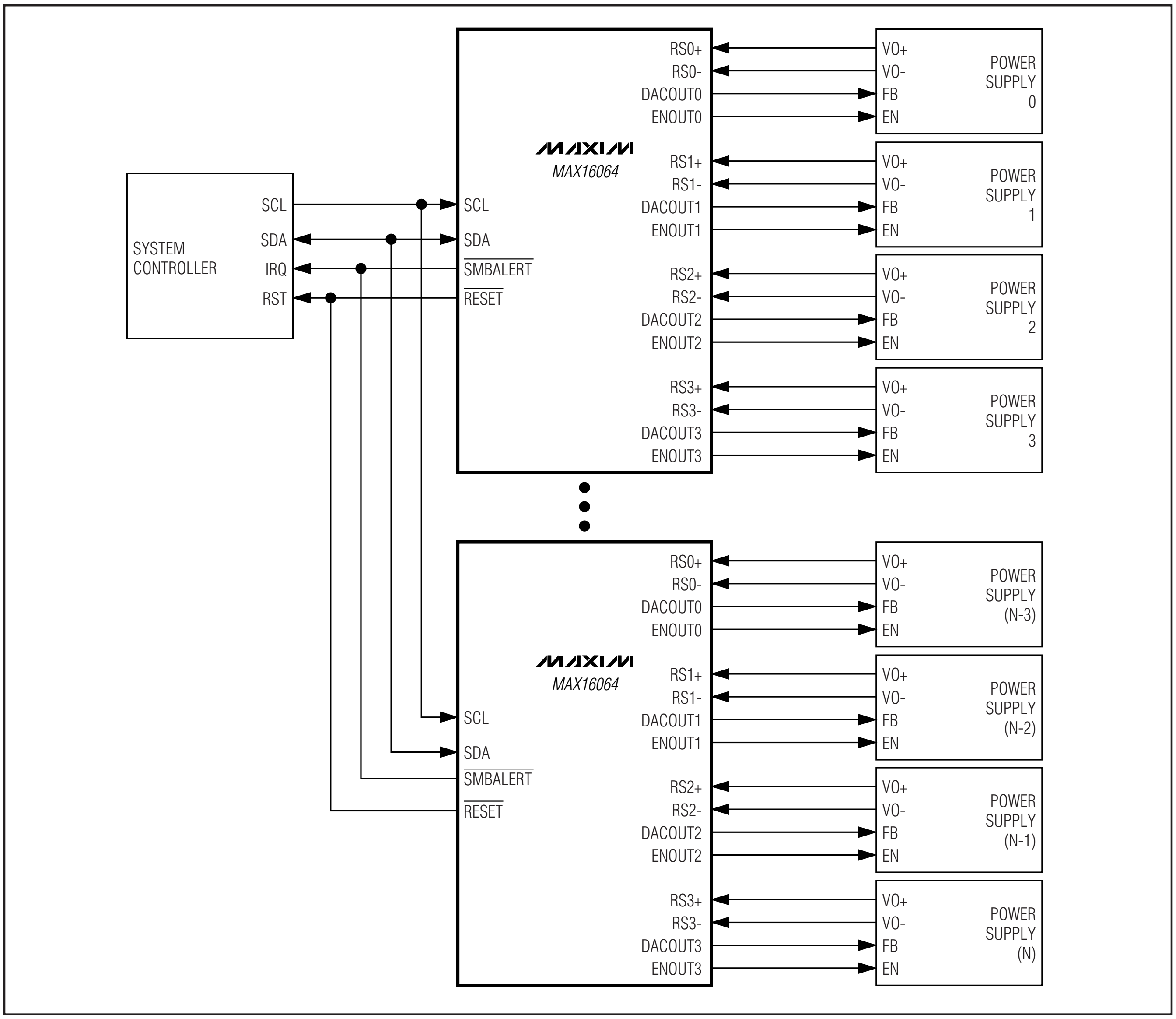



*Figure 2. System Application Showing Multiple MAX16064s Controlling Power Supplies*

### MAX16064 Operating Modes

#### Reference Input (REFIN) Mode

Figure 3 shows how to connect a MAX16064 to the reference voltage input of a typical power supply, allowing the MAX16064 to fully control the power-supply output voltage. Connect a DACOUT_ of the MAX16064 to the REFIN input of the power supply and connect the output-voltage terminals of the power supply to the RS_+ and RS_- sense inputs of the MAX16064. The sensed voltage on RS_+ and RS_- is filtered by an internal 200Ω resistor and an external capacitor connected to RS_C, and is digitized by a 12-bit ADC that uses an accurate internal reference voltage.

Normal operation begins as follows: upon receiving an OPERATION ON command or a turn-on signal from A3/CONTROL, the MAX16064 waits the programmed $t_{ON\_DELAY}$ time, then switches on the associated ENOUT_ output and ramps up the power-supply output voltage to its target VOUT_COMMAND value precisely in the programmed $t_{ON\_RISE}$ time. This facilitates easy implementation of tracking of multiple output rails. On reaching the target output voltage, the MAX16064 continuously monitors the power-supply output voltage obtained at the RS_+ and RS_- inputs, and regulates it to within ±0.3% by incrementing or decrementing the DACOUT_ output 1 LSB (0.5mV) at a time. The MAX16064 output-voltage correction rate is controlled by MFR_MODE.1, MFR_VLTO, and MFR_DAC_ACT_CNT, as discussed in the *ADC Conversion, Monitoring, and AVOC Adjustment Rates* section.

Once the requested target power-supply voltage is reached, it can be margined up or down at a slew rate programmed by the VOUT_TRANSITION_RATE parameter. To achieve this, the MAX16064 increments or decrements the DACOUT_ output in a suitable number of steps that depend on the programmed transition rate. The number of steps is calculated from the VOUT_SCALE_LOOP parameter, which must be set to the ratio of the power-supply output voltage to the power-supply reference voltage. This ratio is the same as the voltage-divider ratio implemented on the power supply from its output voltage node to the inverting input of its error amplifier. This allows the MAX16064 to correctly calculate the number of DACOUT_ steps and voltage increments/decrements per step and thus achieve the programmed rise time and transition time.

Since the reference voltage input is provided by the MAX16064, the REFIN mode provides complete control of the power supply in terms of soft-start, soft-stop, and margining transitions.

Upon receiving an OPERATION OFF command or a turn-off signal from A3/CONTROL, the MAX16064 waits the programmed $t_{OFF\_DELAY}$ time, ramps the output voltage down to zero in the programmed $t_{OFF\_FALL}$ time, then deasserts the ENOUT_ output. Each of the four power-supply converters has its own set of delay parameters, so sequencing is accomplished by loading different delay times for each power supply.

#### Feedback (FB) Mode

Some power-supply converters do not provide a reference input. In these applications, the feedback node can be used instead. Connect a DACOUT_ output of the MAX16064 to the feedback node (FB) through a resistor $R_{FB}$ as shown in Figure 5. In steady-state operation, the MAX16064 controls the power-supply voltage as measured between RS_+ and RS_- to ±0.3% accuracy by adjusting DACOUT_ 1 LSB at a time (0.5mV), up and down as required. This mode of operation is termed FB mode. Since the MAX16064 does not have control over the power-supply error-amplifier reference voltage, this mode relies on the power-supply soft-start setting to implement the required soft-start time.

Upon receiving an OPERATION ON command or a turn-on signal from A3/CONTROL, the MAX16064 waits the programmed $t_{ON\_DELAY}$ time, turns on the ENOUT_ output, causing the power supply to ramp up its output voltage to its target value. The soft-start time taken by the power supply to ramp from zero to its commanded output voltage should be entered into the MAX16064 with the $t_{ON\_RISE}$ parameter.

During $t_{ON\_RISE}$, the MAX16064 maintains DACOUT_ in a high-impedance state by keeping the S_ switches open. This allows the voltage at DACOUT_ to equal that of the FB node of the power supply. At the end of the $t_{ON\_RISE}$ delay time, the internal DAC output voltage is set to match the external voltage measured on DACOUT_, and then the DACOUT_ switch S_ is closed. The voltages on either side of the resistor $R_{FB}$ should be equal, or very close to equal. Under these conditions, little or no current flows into the FB node from DACOUT_ and no perturbations are introduced to the output voltage. From this point on, the MAX16064 adjusts the voltage at DACOUT_ to provide accurate output-voltage control. In FB mode, the user must supply $t_{ON\_DELAY}$ and $t_{ON\_RISE}$. If those parameters are not set (the default values are zero), S_ closes prematurely and causes the supply voltage to overshoot or undershoot.

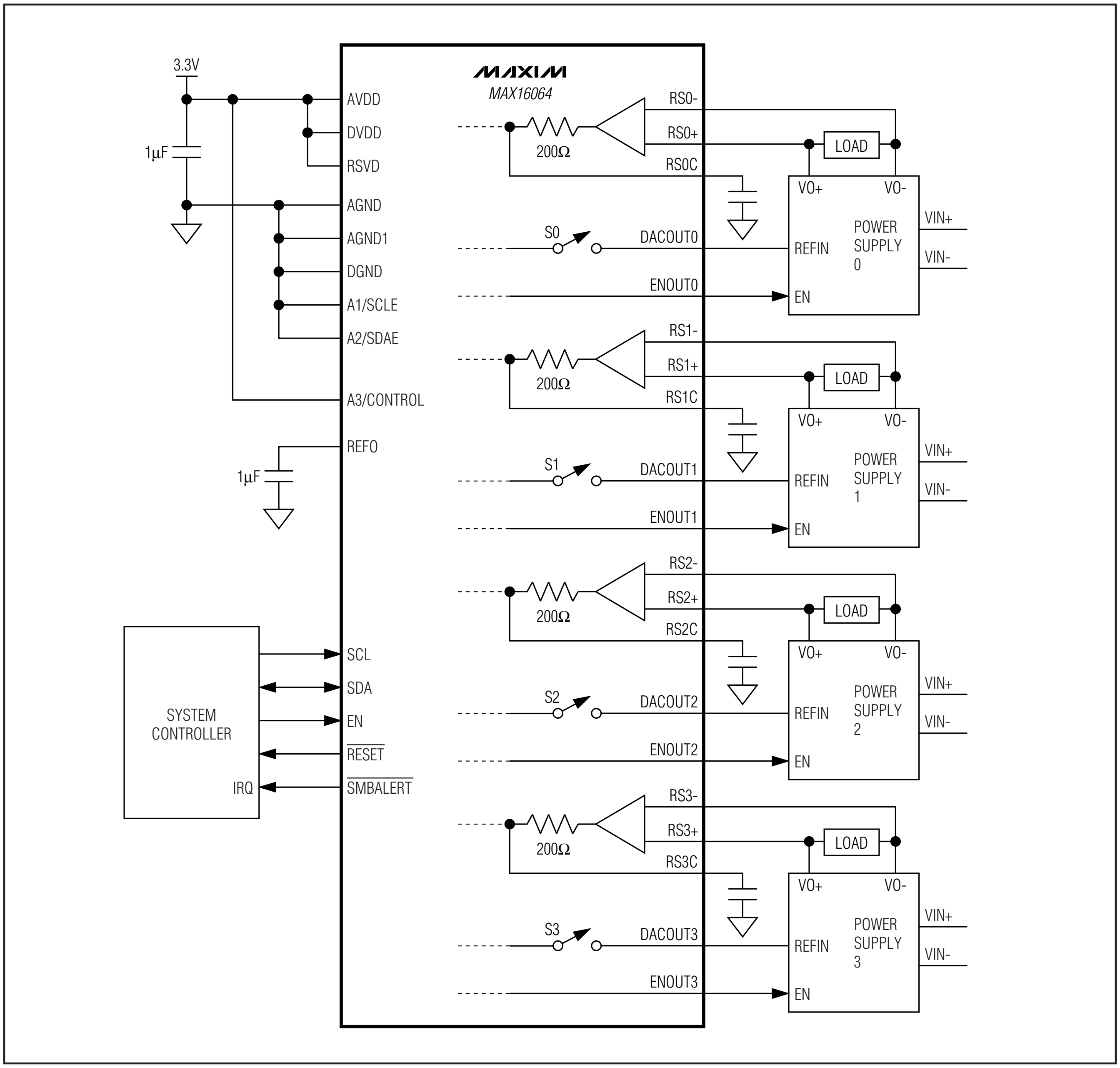



*Figure 3. Typical System Application—REFIN Mode*

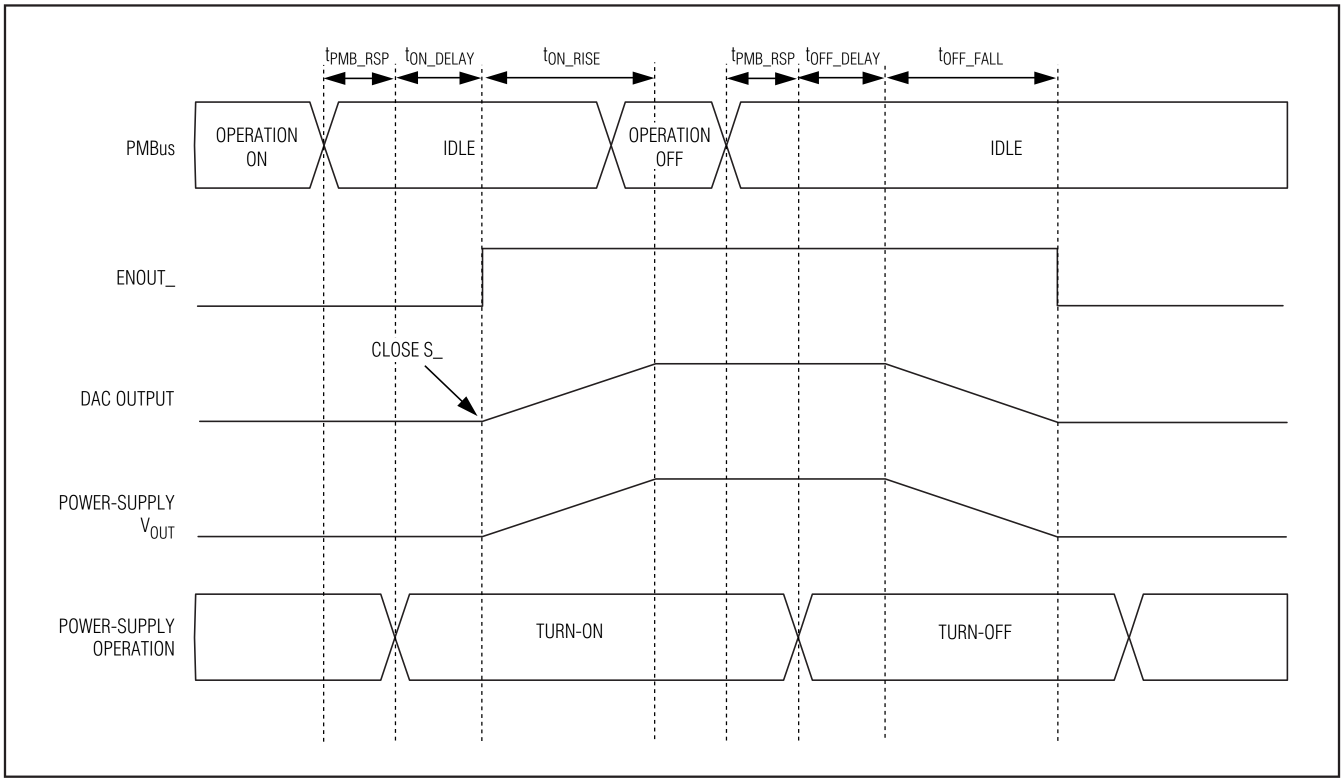



*Figure 4. REFIN Mode Timing*

After receiving an OPERATION OFF command or a turn-off signal from A3/CONTROL, the MAX16064 waits the programmed $t_{OFF\_DELAY}$ time, deasserts the ENOUT_ output, and turns off the power supply.

For the FB mode, use the following formula to calculate the value of $R_{FB}$:

$$R_{FB} = R_1 \times \frac{\Delta V_{DAC}}{\Delta V_O}$$

Where $R_1$ is the upper feedback divider resistor, $\Delta V_O$ is the required change in output voltage, and $\Delta V_{DAC}$ is the DACOUT_ output-voltage change that the user allows. The recommended operating range for the DACOUT_ voltage for power-supply output voltage adjustment is between 30mV and 2V. Note that $\Delta V_{DAC}$ is the difference between the steady-state power-supply FB node voltage, $V_{FB}$, and the voltage limits on DACOUT_. This is best illustrated with an example as follows:

Consider an application involving a power supply with $V_{FB}$ = 0.6V. Let the desired margining be ±10% for a power-supply output voltage of 1V. For a power supply with an upper voltage divider resistor $R_1$ = 10kΩ, $R_{FB}$ is calculated as follows:

$$R_{FB} = 10k\Omega \times \frac{(0.6V - 0.03V)}{0.1V} = 57k\Omega$$

This value of $R_{FB}$ allows the MAX16064 to margin the power-supply output voltage up by 10%. It is useful to check the margin low condition by using the formula:

$$\Delta V_O = R_1 \times \frac{\Delta V_{DAC}}{R_{FB}} = 10k\Omega \times \frac{(2.0V - 0.6V)}{57k\Omega} = 0.245V$$

The effective margining range for the 57kΩ resistor therefore turns out to be between +10% and -24.5%.

Note that the VOUT_TRANSITION_RATE parameter has no effect on FB mode. The transition time for margining in the FB mode of operation is a function of the update rate ($f_{AVOC}$), see the *MFR_DAC_ACT_CNT (E0h)* section for the calculation of $f_{AVOC}$. $R_{FB}$ and $R_1$, and $t_{FB}$ is given by the following formula:

$$t_{FB} = \left(\frac{R_{FB} \times \Delta V_O \times 2000}{f_{AVOC} \times R_1}\right)$$

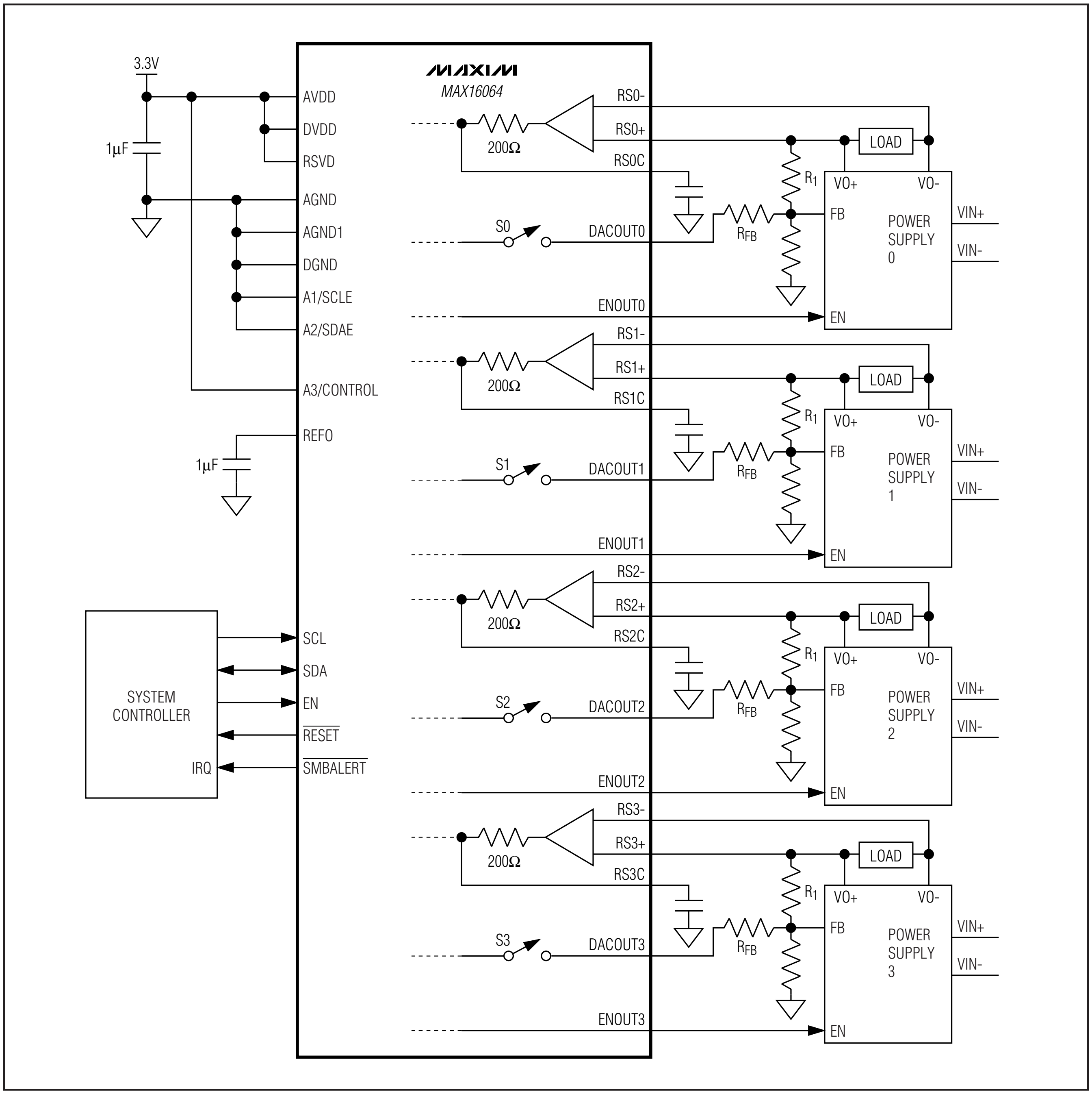



*Figure 5. Typical System Application—Feedback Mode*

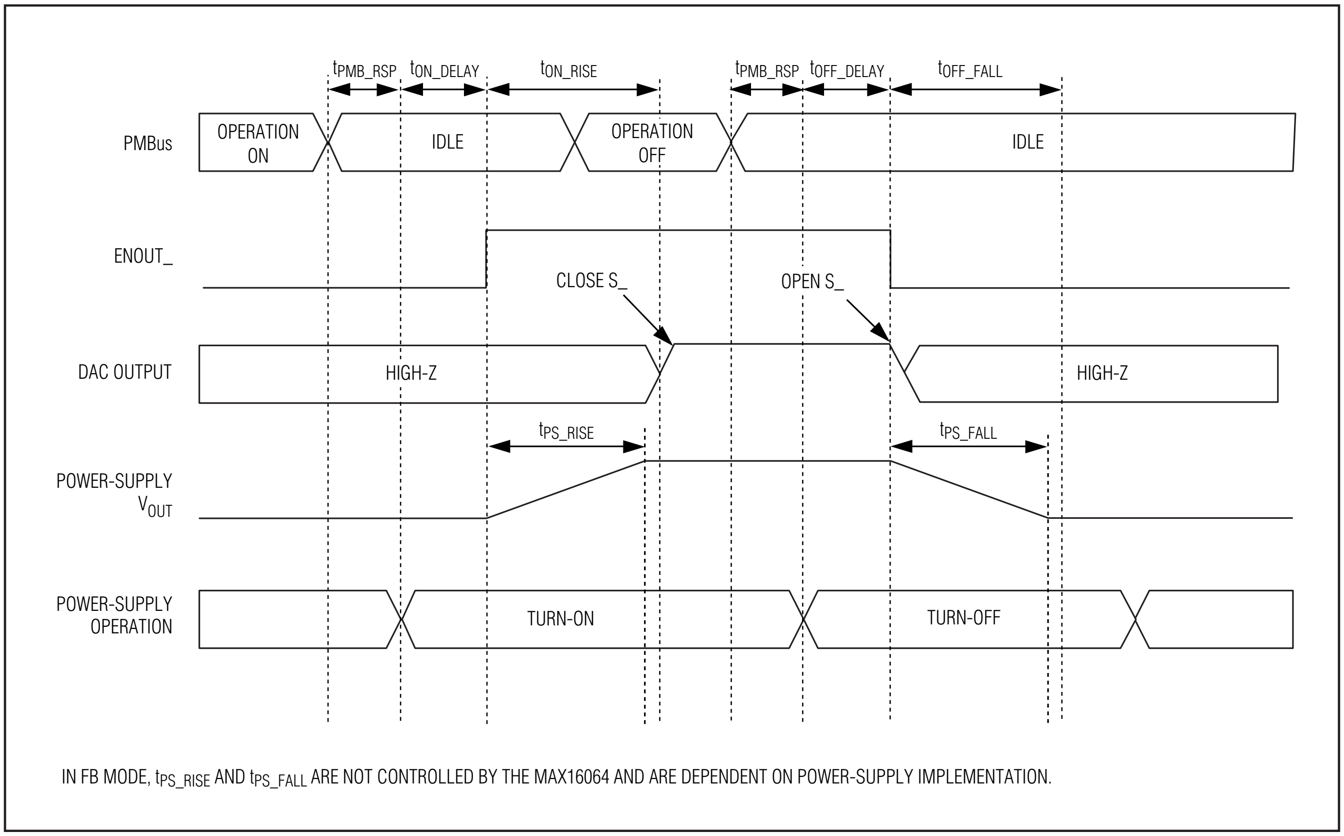



*Figure 6. Feedback Mode Timing*

### Temperature Sensing

To obtain useful temperature readings, place the MAX16064 in close proximity to the power supplies. The on-chip temperature sensor on the MAX16064 senses the temperature of the die, which is related to the exposed pad temperature of the MAX16064 by the junction-to-case thermal resistance. The exposed pad of the MAX16064 can connect to the heat dissipating ground plane of the power supplies, and the power supplies' boards can be characterized to obtain the relationship between the power supplies' temperature and temperature as measured by the MAX16064. This information can be used to set overtemperature fault settings in the MAX16064.

### ADC Conversion, Monitoring, and AVOC Adjustment Rates

Several timing parameters control the rate at which the MAX16064 monitors voltages and temperatures and the rate at which the MAX16064 adjusts the power-supply output voltages. Each of the four voltage input channels and the single temperature channel conversions are performed round-robin fashion. If the input filter is turned on by setting register MFR_MODE.1 to 0, then four conversions are performed for each channel instead of just one. A small programmable delay is inserted in between each conversion, determined by the MFR_VLTO register. This establishes the total conversion rate of the voltages and temperature. Smaller values of MFR_VLTO results in a higher sampling rate, and larger values of MFR_VLTO allow for more ADC settling time.

The ADC conversion result registers are compared to the fault threshold registers at a rate that is independent of the total conversion rate. The value of register MFR_SAMPLE_RATE determines how frequently this comparison occurs. Using higher fault comparison rates increases glitch sensitivity, but slows the response time of the MAX16064 to PMBus commands. Using lower fault comparison rates makes the MAX16064 less sensitive to power-supply output voltage glitches.

Finally, the AVOC system uses a separate control loop rate that is related to the total ADC conversion rate. The value of register MFR_DAC_ACT_CNT sets the number of total ADC conversion cycles (one cycle is a complete set of ADC conversions for 4 voltages and 1 temperature) that must occur before AVOC changes the DAC output voltage. Smaller values of MFR_DAC_ACT_CNT shorten the adjustment time. Larger values of MFR_DAC_ACT_CNT adjust the output voltage at much slower rates, reducing possible negative effects on the power-supply control loop.

### External EEPROM Interface

The MAX16064 can communicate with an EEPROM attached to the A1/SCLE and A2/SDAE. The MAX16064 communicates to the EEPROM with an address byte of 1010 0000 for writing and 1010 0001 for reading. For the data values of 2 bytes, the most significant byte is stored in the lower address of the EEPROM, whereas the least significant byte is stored in the higher address of the EEPROM.

Upon reset, the MAX16064 tests for the presence of a configuration EEPROM. It searches for the SIGNATURE bytes in the attached EEPROM. If the SIGNATURE bytes are present, it concludes that it has a valid configuration EEPROM and starts reading configuration information from the attached EEPROM. If the slave address (MFR_SET_ADDRESS) is a value other than 0xFF, this overrides the slave address information previously set by the address A3:A1 pins.

Table 1b shows the contents and addresses of the configuration information expected by the MAX16064. This information is for reference only. It is recommended to use a properly configured, working MAX16064 to save its state to the EEPROM and limit direct modifications to as few fields as possible (such as the slave address).

Temperature and voltage values are stored in an internal representation, which is not the same as the format used by the corresponding PMBus commands. For details on the EEPROM internal representation, see Conversion Rules (Table 1a).

For example, to store to the EEPROM PAGE 2 VOUT_COMMAND = 3.0V, m = 19995, b = 0, R = -1. First calculate the PMBus command value, which is 5998. If the voltage range is 2V, no conversion is required. Hence write 17h to address 28 and 6Eh to address 29. If the voltage range is 5.5V, the stored EEPROM value = 5998/2.75 = 2181. So write 08h to address 28 and write 85h to address 29.

Note that the conversion is automatically handled by the MAX16064 when it stores and loads configuration information.

### Table 1a. Conversion Rules

| | READ (INTERNAL TO PMBus) | WRITE (PMBus TO INTERNAL) |
|---|---|---|
| **TEMPERATURE** | Subtract 3010 (decimal) from the PMBus value | Add 3010 (decimal) to the PMBus value |
| **VOLTAGE** | No conversion in 2V mode;<br>multiply by 2.75 in 5.5V mode | No conversion in 2V mode;<br>divide by 2.75 in 5.5V mode |

### Table 1b. 16-Bit Words Stored in EEPROM

| EEPROM ADDRESS | NAME | PAGE | PMBus COMMAND | NOTES |
|---|---|---|---|---|
| 0 | MFR_FAULT_REASON | — | 0E2h | — |
| 2 | MFR_MODE | — | 0D1h | Must also match MFR_TICK_RELOAD |
| 4 | MFR_TEMPERATURE_PEAK | — | 0D6h | Internal representation (temperature) |
| 6 | MFR_FAULT_TEMP | — | 0E4h | Internal representation (temperature) |
| 8 | MFR_VOUT_PEAK | 0 | 0D4h | Internal representation (voltage) |
| 10 | MFR_VOUT_PEAK | 1 | | |
| 12 | MFR_VOUT_PEAK | 2 | | |
| 14 | MFR_VOUT_PEAK | 3 | | |

### Table 1b. 16-Bit Words Stored in EEPROM (continued)

| EEPROM ADDRESS | NAME | PAGE | PMBus COMMAND | NOTES |
|---|---|---|---|---|
| 16 | MFR_FAULT_VOUT | 0 | 0E3h | Internal representation (voltage) |
| 18 | MFR_FAULT_VOUT | 1 | | |
| 20 | MFR_FAULT_VOUT | 2 | | |
| 22 | MFR_FAULT_VOUT | 3 | | |
| 24 | VOUT_COMMAND | 0 | 21h | Internal representation (voltage) |
| 26 | VOUT_COMMAND | 1 | | |
| 28 | VOUT_COMMAND | 2 | | |
| 30 | VOUT_COMMAND | 3 | | |
| 32 | TON_RISE | 0 | 61h | — |
| 34 | TON_RISE | 1 | | |
| 36 | TON_RISE | 2 | | |
| 38 | TON_RISE | 3 | | |
| 40 | TON_DELAY | 0 | 60h | — |
| 42 | TON_DELAY | 1 | | |
| 44 | TON_DELAY | 2 | | |
| 46 | TON_DELAY | 3 | | |
| 48 | VOUT_MARGIN_HIGH | 0 | 25h | Internal representation (voltage) |
| 50 | VOUT_MARGIN_HIGH | 1 | | |
| 52 | VOUT_MARGIN_HIGH | 2 | | |
| 54 | VOUT_MARGIN_HIGH | 3 | | |
| 56 | VOUT_MARGIN_LOW | 0 | 26h | Internal representation (voltage) |
| 58 | VOUT_MARGIN_LOW | 1 | | |
| 60 | VOUT_MARGIN_LOW | 2 | | |
| 62 | VOUT_MARGIN_LOW | 3 | | |
| 64 | TOFF_FALL | 0 | 65h | — |
| 66 | TOFF_FALL | 1 | | |
| 68 | TOFF_FALL | 2 | | |
| 70 | TOFF_FALL | 3 | | |
| 72 | OT_FAULT_LIMIT | — | 4Fh | Internal representation |
| 74 | MFR_SAMPLE_RATE | — | 0D3h | — |
| 76–87 | Reserved (set to 0) | — | — | — |
| 88 | MFR_FAULT_RESPONSE | 0 | 0D9h | — |
| 90 | MFR_FAULT_RESPONSE | 1 | | |
| 92 | MFR_FAULT_RESPONSE | 2 | | |
| 94 | MFR_FAULT_RESPONSE | 3 | | |
| 96 | MFR_FAULT_RETRY | 0 | 0DAh | — |
| 98 | MFR_FAULT_RETRY | 1 | | |
| 100 | MFR_FAULT_RETRY | 2 | | |
| 102 | MFR_FAULT_RETRY | 3 | | |

## Table 1b. 16-Bit Words Stored in EEPROM (continued)

| EEPROM ADDRESS | NAME | PAGE | PMBus COMMAND | NOTES |
|---|---|---|---|---|
| 104–115 | MFR_DATE | — | 9Dh | — |
| 116 | MFR_STATUS_WORD | — | 0D8h | Set to 0 |
| 118 | WRITE_PROTECT | — | 10h | — |
| 120 | ON_OFF_CONFIG | 0 | 02h | — |
| 122 | ON_OFF_CONFIG | 1 | 02h | — |
| 124 | ON_OFF_CONFIG | 2 | 02h | — |
| 126 | ON_OFF_CONFIG | 3 | 02h | — |
| 128 | VOUT_SCALE_LOOP | 0 | 29h | — |
| 130 | VOUT_SCALE_LOOP | 1 | 29h | — |
| 132 | VOUT_SCALE_LOOP | 2 | 29h | — |
| 134 | VOUT_SCALE_LOOP | 3 | 29h | — |
| 136 | OT_WARN_LIMIT | — | 51h | Internal representation (temperature) |
| 138 | Reserved (set to 0) | — | — | — |
| 140 | MFR_SET_ADDRESS | — | 0DBh | Low byte: $I^2C$ address, high byte: reserved |
| 142 | Reserved (set to 0) | — | — | — |
| 144 | TOFF_DELAY | 0 | 64h | — |
| 146 | TOFF_DELAY | 1 | 64h | — |
| 148 | TOFF_DELAY | 2 | 64h | — |
| 150 | TOFF_DELAY | 3 | 64h | — |
| 152 | VOUT_TRANSITION_RATE | 0 | 27h | — |
| 154 | VOUT_TRANSITION_RATE | 1 | 27h | — |
| 156 | VOUT_TRANSITION_RATE | 2 | 27h | — |
| 158 | VOUT_TRANSITION_RATE | 3 | 27h | — |
| 160–175 | Reserved (set to 0) | 0 | — | — |
| 176 | MFR_MODE_OUTPUT | 0 | 0DEh | — |
| 178 | MFR_MODE_OUTPUT | 1 | 0DEh | — |
| 180 | MFR_MODE_OUTPUT | 2 | 0DEh | — |
| 182 | MFR_MODE_OUTPUT | 3 | 0DEh | — |
| 184–199 | Reserved (set to 0) | — | — | — |
| 200 | MFR_RESET_DELAY | — | 0DDh | — |
| 202 | MFR_RESET_OUTPUT | — | 0E1h | — |
| 204 | Reserved (set to 0) | — | — | — |
| 206 | MFR_TICK_RELOAD | — | 0D1h | — |
| 208 | MFR_STATUS_WORD | 0 | 0D8h | Set to 0 |
| 210 | MFR_STATUS_WORD | 1 | 0D8h | Set to 0 |
| 212 | MFR_STATUS_WORD | 2 | 0D8h | Set to 0 |
| 214 | MFR_STATUS_WORD | 3 | 0D8h | Set to 0 |

## Table 1b. 16-Bit Words Stored in EEPROM (continued)

| EEPROM ADDRESS | NAME | PAGE | PMBus COMMAND | NOTES |
|---|---|---|---|---|
| 216–237 | MFR_LOCATION | — | 9Ch | — |
| 238–255 | MFR_SERIAL | — | 9Eh | — |
| 256–297 | MFR_USER_DATA_00 | — | 0B0h | — |
| 298 | VOUT_OV_FAULT_LIMIT | 0 | 40h | Internal representation (voltage) |
| 300 | VOUT_UV_FAULT_LIMIT | 0 | 44h | Internal representation (voltage) |
| 302 | VOUT_OV_WARN_LIMIT | 0 | 42h | Internal representation (voltage) |
| 304 | VOUT_UV_WARN_LIMIT | 0 | 43h | Internal representation (voltage) |
| 306 | VOUT_OV_FAULT_LIMIT | 1 | 40h | Internal representation (voltage) |
| 308 | VOUT_UV_FAULT_LIMIT | 1 | 44h | Internal representation (voltage) |
| 310 | VOUT_OV_WARN_LIMIT | 1 | 42h | Internal representation (voltage) |
| 312 | VOUT_UV_WARN_LIMIT | 1 | 43h | Internal representation (voltage) |
| 314 | VOUT_OV_FAULT_LIMIT | 2 | 40h | Internal representation (voltage) |
| 316 | VOUT_UV_FAULT_LIMIT | 2 | 44h | Internal representation (voltage) |
| 318 | VOUT_OV_WARN_LIMIT | 2 | 42h | Internal representation (voltage) |
| 320 | VOUT_UV_WARN_LIMIT | 2 | 43h | Internal representation (voltage) |
| 322 | VOUT_OV_FAULT_LIMIT | 3 | 40h | Internal representation (voltage) |
| 324 | VOUT_UV_FAULT_LIMIT | 3 | 44h | Internal representation (voltage) |
| 326 | VOUT_OV_WARN_LIMIT | 3 | 42h | Internal representation (voltage) |
| 328 | VOUT_UV_WARN_LIMIT | 3 | 43h | Internal representation (voltage) |
| 330–509 | Unused (set to 0) | — | — | — |
| 510 | SIGNATURE (set to 4432h) | — | N/A | — |

Figure 7 shows how the MAX16064 interfaces to an external serial EEPROM using the A1/SCLE and A2/SDAE in applications where a master controller does not exist or is not required. Using the GUI, the user can select each MAX16064 device and configure all the required output-voltage settings and sequencing/tracking information. Once the configuration is complete, the results can be saved to the external EEPROM by using the STORE_DEFAULT_ALL command and configuration restored on the MAX16064 power-on reset. The EEPROM can also be preprogrammed prior to board assembly in the manufacturing environment. A3/CONTROL can be used as a control signal to turn on/off the power supply in a similar fashion as the OPERATION command.

Use a serial EEPROM IC with a minimum of 4kb of storage to ensure proper device operation.

### MAX16064 Operation

On power-up reset, the MAX16064 goes through an initialization process as shown in Figure 8.

After initialization, the MAX16064 monitors the PMBus and executes the PMBus commands accordingly. In addition, if the power supply has been commanded to turn on, the MAX16064 also monitors the power-supply output voltage and temperature at the MFR_SAMPLE_RATE. The PMBus system controller can monitor the power-supply health by issuing various inquiries and status commands to the MAX16064.

### $\overline{\text{RESET}}$ Output Operation

$\overline{\text{RESET}}$ is an active-low, open-drain output that is low when the device is powering on. $\overline{\text{RESET}}$ is assigned to one of the power supplies using the MFR_RESET_OUTPUT command. When that power-supply output is at the target voltage, $\overline{\text{RESET}}$ goes high after the reset timeout period (see Figure 9). The reset timeout period ($t_{RP}$) is set by the MFR_RESET_DELAY command.

The MFR_RESET_OUTPUT value defines which power-supply output affects $\overline{\text{RESET}}$. If MFR_RESET_OUTPUT is set to 0, 1, 2, or 3, then $\overline{\text{RESET}}$ goes high $t_{RP}$ after that output has reached its target value. If MFR_RESET_OUTPUT is any other value, $\overline{\text{RESET}}$ is permanently low.

If the power-supply output selected by MFR_RESET_OUTPUT is later disabled for any reason (either due to a fault condition, or an OPERATION OFF command), then $\overline{\text{RESET}}$ goes low immediately. To enable faults on any power supply to cause $\overline{\text{RESET}}$ to go low, set the MFR_MODE_OUTPUT.GLOBALFAULTS bit to a 1 for all the supplies.

$\overline{\text{RESET}}$ requires an external pullup resistor.

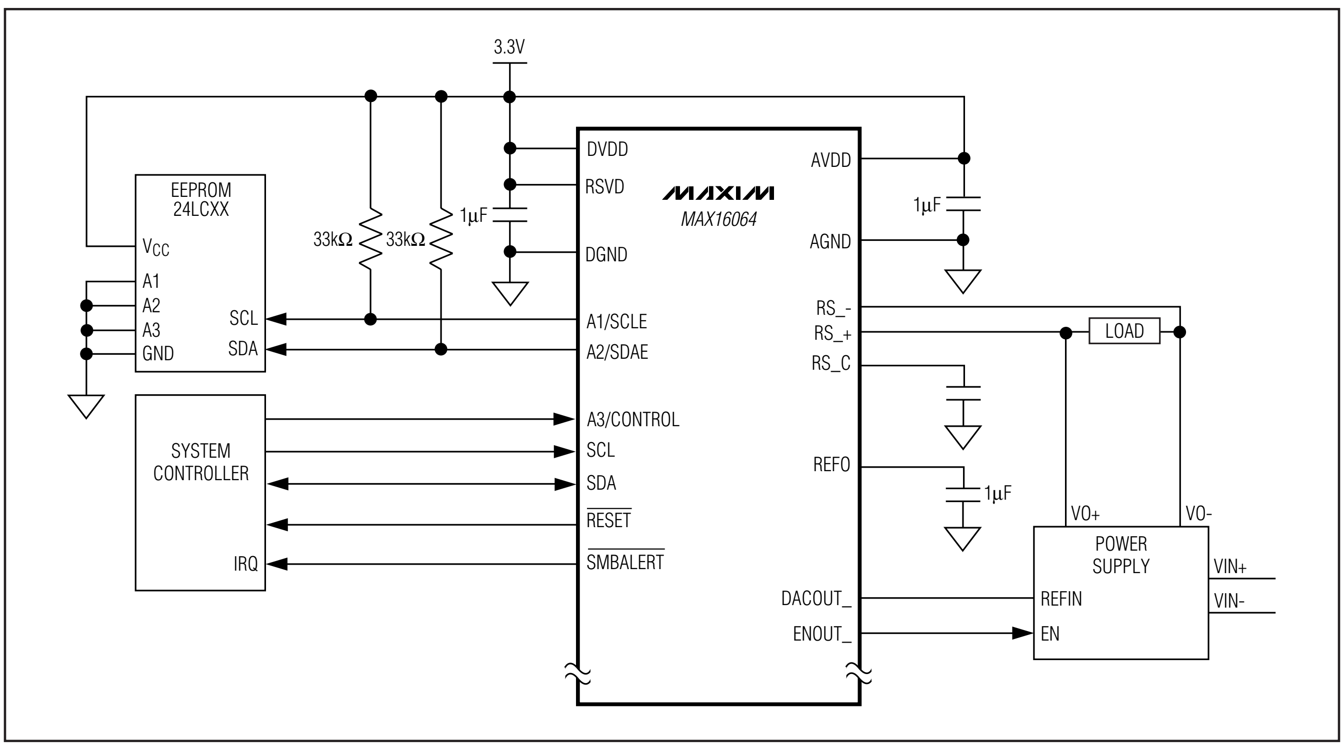



*Figure 7. Typical System Application with External EEPROM*

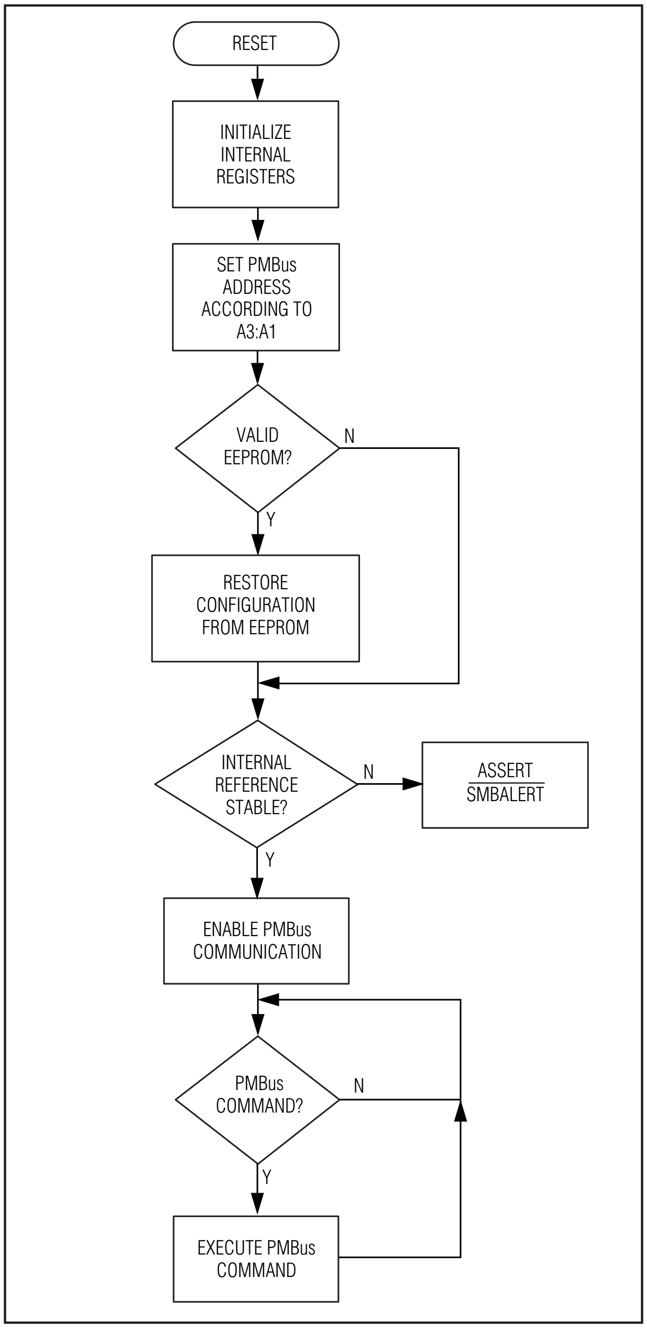



*Figure 8. MAX16064 Initialization*

### SMBALERT Output Operation

SMBALERT is an optional interrupt signal defined in Appendix A of the SMBus specification. The MAX16064 provides an output SMBALERT as this interrupt signal. SMBALERT is an active-low, open-drain output and it asserts to signal the PMBus master if any of the voltage or temperature fault has occurred. Typically, SMBALERT is connected to all other SMBALERT open-drain signals in the system, creating a wired-OR function with all SMBALERT outputs. When the master is interrupted by its SMBALERT input, it stops or finishes the current bus transfer and places an alert response address (ARA) on the bus. The slave that pulled the SMBALERT signal low acknowledges the ARA and places its own address on the bus, identifying itself to the master as the slave that caused the interrupt.

SMBALERT deasserts when the MAX16064 responds to the ARA. SMBALERT deasserts when all the fault conditions are removed. SMBALERT is also cleared by the CLEAR_FAULTS command.

### ENOUT_ Operation

When power is applied, all ENOUT_ are held low. Upon receiving a command to turn on the power supply, ENOUT_ goes high. The polarity can be changed by the ENOUT_POL bit of the MFR_MODE_OUTPUT command. Setting the bit to a 1 makes the ENOUT_ active low. If the bit in the external EEPROM is set to 1, upon power-up, the ENOUT_ is held low until the bit is copied from the EEPROM to the on-chip register at which time the ENOUT_ goes high. Upon receiving a command to turn on the power supply, ENOUT_ goes low. It takes 1.60ms (typ) to copy the configuration bits from the EEPROM to the on-chip registers.

## Table 2. ENOUT_ Active State

| ENOUT_ DEFAULT STARTUP STATE | MFR_MODE_OUTPUT. ENOUT_POL | ENOUT_ ACTIVE STATE |
|---|---|---|
| Low | 0 | Active high |
| Low | 1 | Active low |

### EN Operation

The MAX16064 includes an enable input (EN) that controls all ENOUT_ signals in conjunction with the MFR_MODE command. Unless MFR_MODE.IGNORE_EN is set, a below-threshold level on EN prevents any ENOUT_ from turning on. Additionally, if the voltage at EN falls below the 1.2V (typ) threshold during OPERATION ON, the MAX16064 follows the fault action in MFR_FAULT_RESPONSE.EN. Figure 9 shows a typical sequencing with MFR_MODE.IGNORE_EN = 0.

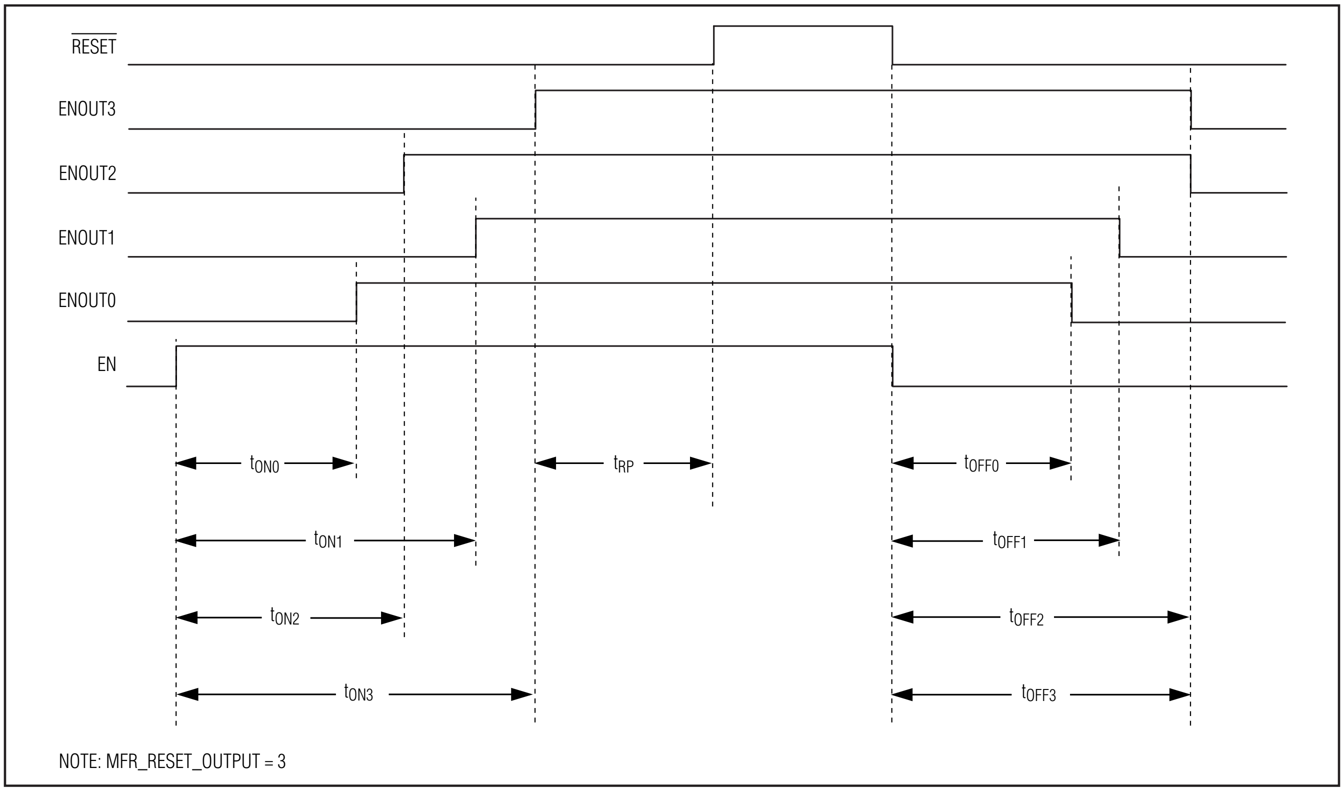



*Figure 9. MAX16064 Typical Sequencing Timing*

### MAX16064 Address Assignment

The MAX16064 picks a slave address in one of the two ways described below:

1) Hardwired by A3:A2:A1.
2) Restored from EEPROM at power-on.

Address assignment order is shown in Figure 10.

The MAX16064 reads A3:A2:A1 address pins upon device reset and determines its address according to Table 3.

## Table 3. MAX16064 A3:A1 Slave Address Assignment

| A3/CONTROL | A2/SDAE | A1/SCLE | ADDRESS (BITS 7–1) |
|---|---|---|---|
| L | L | L | 40h |
| L | L | Z | 01h* |
| L | Z | L | 02h |
| L | Z | Z | 03h |
| Z | L | L | 04h |
| Z | L | Z | 05h |
| Z | Z | L | 06h |
| Z | Z | Z | 07h |
| L | L | H | 09h |
| L | Z | H | 0Bh |
| Z | L | H | 0Dh |

# ±0.3% Accurate, Quad, Power-Supply Controller with Active-Voltage Output Control and PMBus Interface

### Table 3. MAX16064 A3:A1 Slave Address Assignment (continued)

| A3/CONTROL | A2/SDAE | A1/SCLE | ADDRESS (BITS 7–1) |
|---|---|---|---|
| Z | Z | H | 0Fh |
| L | H | L | 12h |
| L | H | Z | 13h |
| Z | H | L | 16h |
| Z | H | Z | 17h |
| L | H | H | 1Bh |
| Z | H | H | 1Fh |
| H | L | L | 24h |
| H | L | Z | 25h |
| H | Z | L | 26h |
| H | Z | Z | 27h |
| H | L | H | 2Dh |
| H | Z | H | 2Fh |
| H | H | L | 36h |
| H | H | Z | 37h |
| H | H | H | 3Fh |

**The shaded addresses are not available if external EEPROM is attached.*

The hardwired address pins give $3^3$ = 27 address options. For example, to configure the MAX16064 to have a slave address of 010 0101 (25h), set A3:A2:A1 = H:L:Z. The MAX16064 also responds to the broadcast address (00h).

If an EEPROM with valid SIGNATURE bytes is attached to the MAX16064, the MAX16064 tries to restore its slave address from the EEPROM. This overrides the address set by the address pins. This gives a total of 128 possible slave addresses. Note that there are 14 reserved addresses that are restricted by the PMBus specification and may not be used in PMBus systems. If the address bit 7 from the EEPROM is set to 1, this is an invalid address and the MAX16064 continues using the address set by the address pins. When an EEPROM is attached to A2/SDAE and A1/SCLE, these pins assume either a logic-high or a logic-low level, therefore, the resulting number of possible addresses set by the A3:A2:A1 pins in this scenario is $2^3$ = 8.

In addition, for the MAX16064 with an EEPROM attached, the system controller can change the MAX16064 slave address by sending the new address with the MFR_SET_ADDRESS command. However, the new address is not immediately effective. The new address must be stored to the EEPROM first using the STORE_DEFAULT_ALL command. Then, the MAX16064 power must be cycled to start the address assignment procedure and recalls the new address from the EEPROM.

### *A3/CONTROL Operation*

The A3/CONTROL input is utilized in combination with the A2 and A1 inputs to set the PMBus address when power is applied to the device. After the PMBus address detection, the A3/CONTROL input functions as the PMBus CONTROL input.

The ON_OFF_CONFIG command determines whether the A3/CONTROL input affects the on/off behavior of the power supply. When A3/CONTROL is enabled by the ON_OFF_CONFIG command, a transition of A3/CONTROL from low to high turns the power supply on, as if the MAX16064 has received an OPERATION ON command. A transition of A3/CONTROL from high to low initiates a soft-off to the power supply, as if the MAX16064 has received an OPERATION OFF command (soft-off, with sequencing). The MAX16064 still responds to the PMBus OPERATION command while A3/CONTROL is enabled. To detect the A3/CONTROL input, the A3/CONTROL signal pulse width has to satisfy the $t_{A3\_LOW}$ and $t_{A3\_HIGH}$ requirements to be detected. See the *ON_OFF_CONFIG (02h)* section and Table 6 for more information.

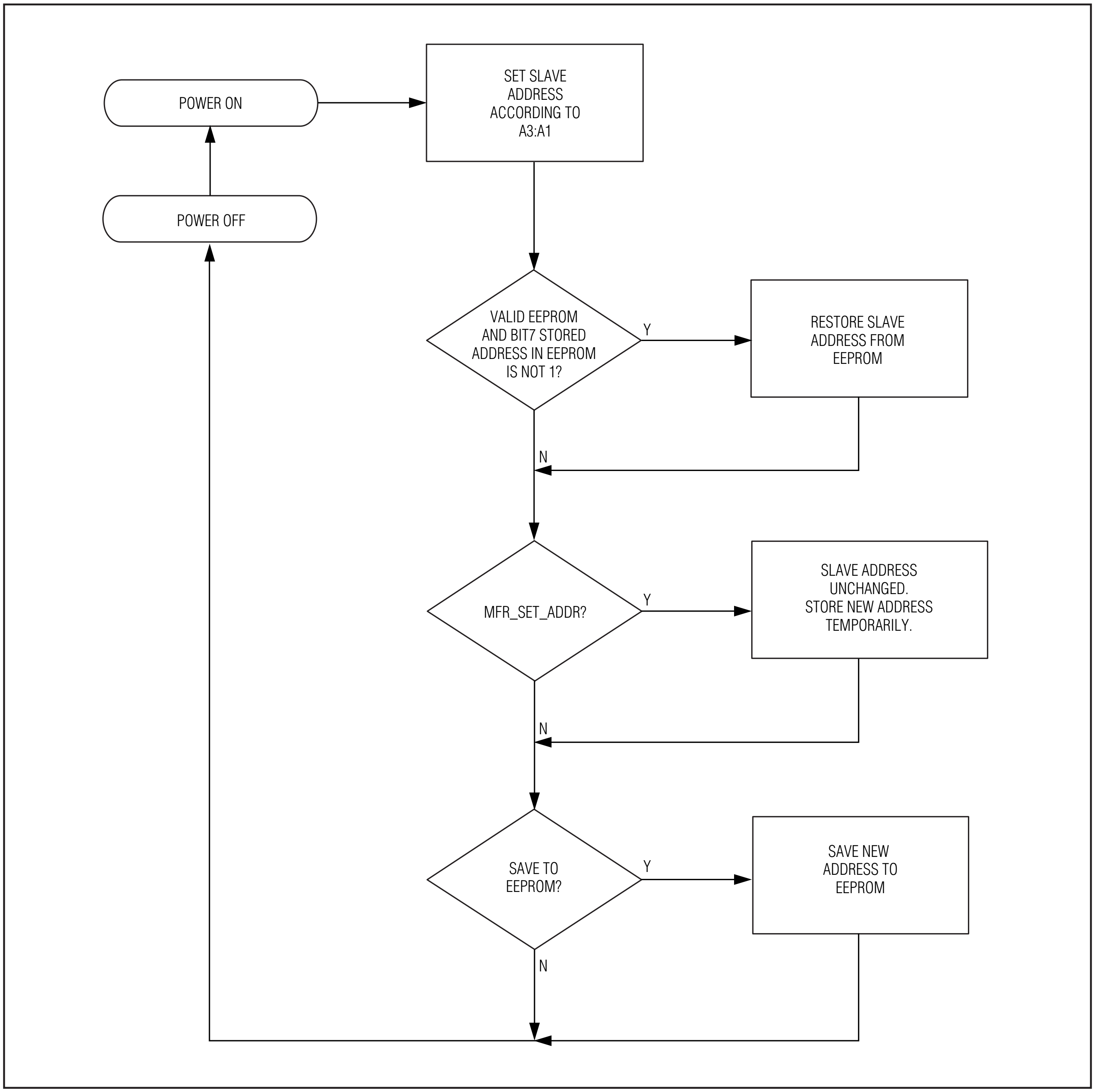



*Figure 10. MAX16064 Address Assignment*