



NV, I²C, Stepper Potentiometer

DS3503

General Description

The DS3503 features two synchronized stepping digital potentiometers: one 7-bit potentiometer with RW as its output, and another potentiometer with Y as its output. Both potentiometers reference the RH and RL terminals and feature an output voltage range of up to 15.5V. In addition, both potentiometer outputs can be stepped up and down by configuring the control registers. Programming is accomplished by an I²C-compatible interface that can operate at speeds of up to 400kHz.

Applications

- TFT-LCD VCOM Calibration
- Instrumentation and Industrial Controls
- Mechanical Potentiometer Replacement

Ordering Information

| PART | TEMP RANGE | PIN-PACKAGE |
|-------------|-----------------|-------------|
| DS3503U+ | -40°C to +100°C | 10 μSOP |
| DS3503U+T&R | -40°C to +100°C | 10 μSOP |

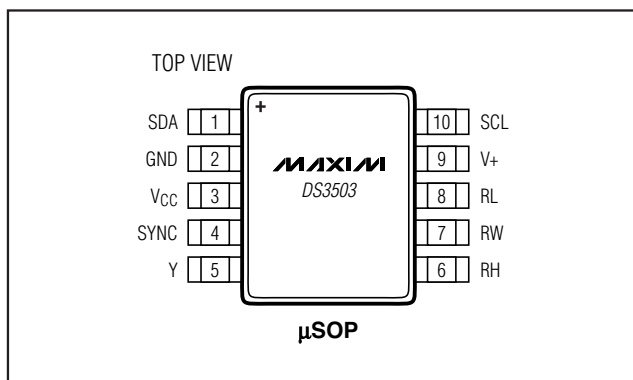
+Denotes a lead(Pb)-free/RoHS-compliant package.
T&R = Tape and reel.

Typical Operating Circuit appears at end of data sheet.

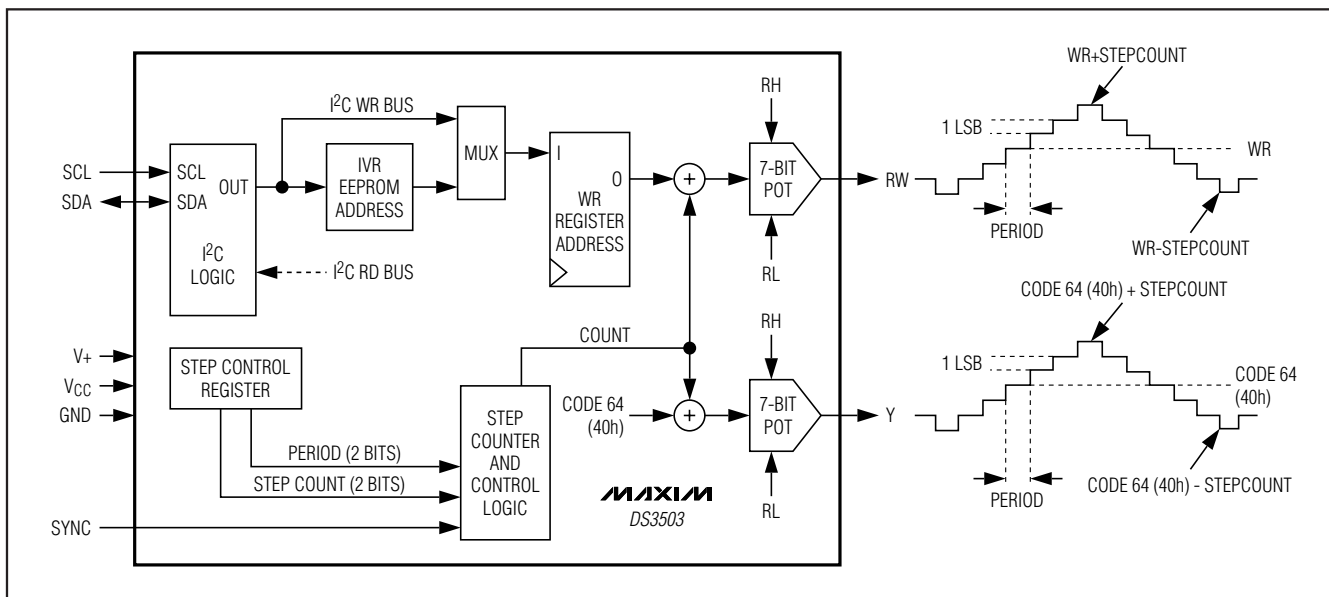
Features

- ◆ 128 Wiper Tap Points
- ◆ Full-Scale Resistance: 5kΩ
- ◆ Programmable Logic Lets WR Step Up and Down with Timing Controlled by SYNC Input
- ◆ Second Potentiometer Output Pin (Y) Centered at Position 40h
- ◆ I²C-Compatible Serial Interface
- ◆ Digital Operating Voltage: 2.7V to 3.6V
- ◆ Analog Operating Voltage: 4.5V to 15.5V
- ◆ Operating Temperature: -40°C to +100°C
- ◆ 10-Pin μSOP Package

Pin Configuration



Functional Diagram



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ABSOLUTE MAXIMUM RATINGS

Voltage Range on V_{CC} Relative to GND-0.5V to +6.0V
 Voltage Range on V+ Relative to GND-0.5V to +17V
 Voltage Range on SDA, SCL, and SYNC
 Relative to V_{CC}.....-0.5V to (V_{CC} + 0.5V), not to exceed 6.0V
 Voltage Range on RH, RL, RW, and Y-0.5V to V+
 Voltage Range Across RH and RL-0.5V to V+

Operating Temperature Range-40°C to +100°C
 Programming Temperature Range0°C to +70°C
 Storage Temperature Range-55°C to +125°C
 Soldering Temperature.....Refer to the IPC/JEDEC
 J-STD-020 Specification.

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.

RECOMMENDED OPERATING CONDITIONS

(T_A = -40°C to +100°C)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|-----------------------------------|-------------------|-------------------------------|--------------------------|-----|--------------------------|-------|
| V _{CC} Supply Voltage | V _{CC} | (Note 1) | +2.7 | | +3.6 | V |
| V+ Voltage | | V+ > V _{CC} (Note 1) | +4.5 | | +15.5 | V |
| Input Logic 0 (SCL, SDA, SYNC) | V _{IL} | (Note 1) | -0.3 | | 0.3 x V _{CC} | V |
| Input Logic 1 (SCL, SDA, SYNC) | V _{IH} | (Note 1) | 0.7 x V _{CC} | | V _{CC} + 0.3 | V |
| Switch Current (All Switches) | I _{SW} | | | | 3 | mA |
| Resistor Current | I _{RES} | | | | 3 | mA |
| SYNC Frequency | f _{SYNC} | | | | 1 | MHz |

ELECTRICAL CHARACTERISTICS

(V_{CC} = +2.7V to +3.6V, T_A = -40°C to +100°C, unless otherwise noted.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--|--------------------|--|-----|-----|------|-------|
| V _{CC} Standby Current | I _{STBY} | V _{CC} = +3.6V, I ² C inactive (Note 2) | | | 10 | μA |
| V _{CC} Supply Current (NV Read or Write) | I _{CC} | f _{SCL} = 400kHz (Note 3) | | | 3 | mA |
| V+ Bias Current | I _{V+} | | | | +1 | μA |
| Input Leakage (SDA, SCL, SYNC) | I _L | | -1 | | +1 | μA |
| Low-Level Output Voltage (SDA) | V _{OL} | 3mA sink current | 0 | | 0.4 | V |
| DCP Wiper Response Time | t _{DCP} | | | | 1 | μs |
| I/O Capacitance | C _{I/O} | | | 5 | 10 | pF |
| Power-Up Recall Voltage | V _{POR} | Min V _{CC} when NV memory is recalled (Note 4) | 1.2 | | 2.6 | V |
| Power-Up Memory Recall Delay | t _D | V _{CC} > V _{POR} to initial memory recall done (Note 5) | | | 3 | ms |
| Wiper Resistance | R _W | V+ = 15.0V | | | 5000 | Ω |
| End-to-End Resistance (RH to RL) | R _{TOTAL} | | | 5 | | kΩ |
| R _{TOTAL} Tolerance | | | -20 | | +20 | % |
| CH, CL, CW Capacitance | C _{POT} | | | 10 | | pF |

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VOLTAGE-DIVIDER CHARACTERISTICS

($V_{CC} = +2.7V$ to $+3.6V$, $T_A = -40^{\circ}C$ to $+100^{\circ}C$, with $R_L = 0V$, $R_H = V_+$, Y , and R_W unloaded, unless otherwise noted.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|------------------------------|--------------------|-------------------|------|-----|------|--------|
| Integral Nonlinearity | INL | (Note 6) | -1 | | +1 | LSB |
| Differential Nonlinearity | DNL | (Note 7) | -0.5 | | +0.5 | LSB |
| Output Matching | | | -1 | | +1 | LSB |
| Zero-Scale Error | Z _{ERROR} | (Note 8) | 0 | 0.5 | 2 | LSB |
| Full-Scale Error | F _{ERROR} | (Note 9) | -2 | -1 | 0 | LSB |
| Ratiometric Temp Coefficient | TCV | WR/IVR set to 40h | | ±4 | | ppm/°C |

I²C AC ELECTRICAL CHARACTERISTICS

($V_{CC} = +2.7V$ to $+3.6V$, $T_A = -40^{\circ}C$ to $+100^{\circ}C$, timing referenced to $V_{IL(MAX)}$ and $V_{IH(MIN)}$. See Figure 2.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--|---------------------|------------|---------------------------|---------------------------|-----|-------|
| SCL Clock Frequency | f _{SCL} | (Note 10) | 0 | | 400 | kHz |
| Bus-Free Time Between STOP and START Conditions | t _{BUF} | | 1.3 | | | μs |
| Hold Time (Repeated) START Condition | t _{HD:STA} | | 0.6 | | | μs |
| Low Period of SCL | t _{LOW} | | 1.3 | | | μs |
| High Period of SCL | t _{HIGH} | | 0.6 | | | μs |
| Data Hold Time | t _{HD:DAT} | | 0 | | 0.9 | μs |
| Data Setup Time | t _{SU:DAT} | | 100 | | | ns |
| START Setup Time | t _{SU:STA} | | 0.6 | | | μs |
| SDA and SCL Rise Time | t _R | (Note 11) | 20 + 0.1C _B | | 300 | ns |
| SDA and SCL Fall Time | t _F | (Note 11) | 20 + 0.1C _B | | 300 | ns |
| STOP Setup Time | t _{SU:STO} | | 0.6 | | | μs |
| SDA and SCL Capacitive Loading | C _B | (Note 11) | | | 400 | pF |
| EEPROM Write Time | t _W | (Note 12) | | 10 | 20 | ms |
| Pulse-Width Suppression Time at SDA and SCL Inputs | t _{IN} | (Note 13) | | 50 | | ns |
| SDA and SCL Input Buffer Hysteresis | | | | 0.05 x V _{CC} | | V |

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NONVOLATILE MEMORY CHARACTERISTICS

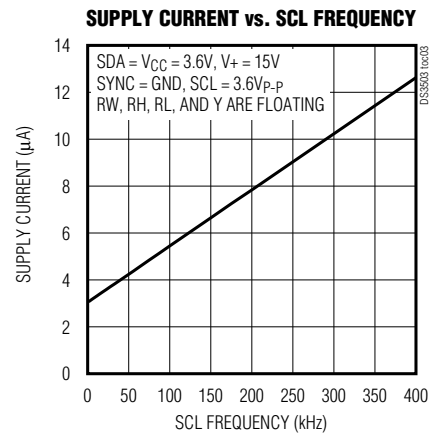
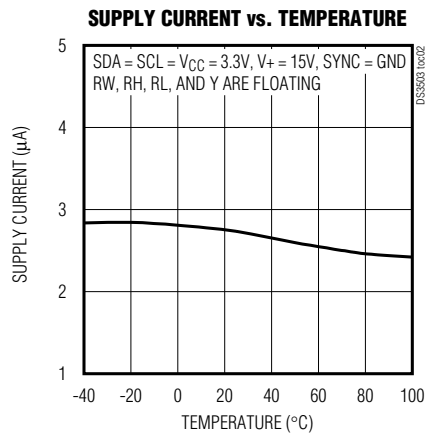
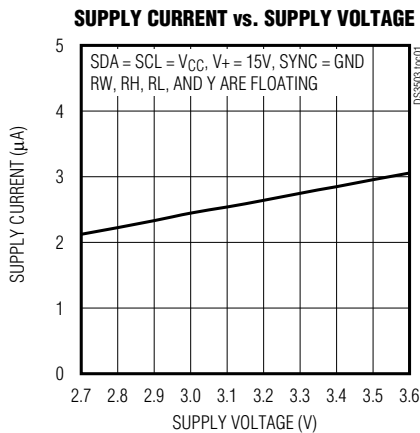
(V_{CC} = +2.7V to +3.6V, unless otherwise noted.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---------------------|--------|------------------------|--------|-----|-----|--------|
| EEPROM Write Cycles | | T _A = +70°C | 30,000 | | | Writes |

- Note 1:** All voltages are referenced to ground. Currents entering the IC are specified positive and currents exiting the IC are negative.
- Note 2:** I_{STBY} is specified with SDA = SCL = V_{CC} and resistor pins floating.
- Note 3:** I_{CC} is specified with the following conditions: SCL = 400kHz, SDA pulled up, and RL, RW, RH, and Y floating.
- Note 4:** This is the minimum V_{CC} voltage that causes NV memory to be recalled.
- Note 5:** This is the time from V_{CC} > V_{POR} until initial memory recall is complete.
- Note 6:** Integral nonlinearity is the deviation of a measured resistor setting value from the expected values at each particular resistor setting. Expected value is calculated by connecting a straight line from the measured minimum setting to the measured maximum setting. $INL = [V(RW)_i - (V(RW)_0)/LSB(ideal) - i]$, for $i = 0...127$.
- Note 7:** Differential nonlinearity is the deviation of the step-size change between two LSB settings from the expected step size. The expected LSB step size is the slope of the straight line from measured minimum position to measured maximum position. $DNL = [V(RW)_{i+1} - (V(RW)_i)/LSB(ideal) - 1]$, for $i = 0...126$.
- Note 8:** Z_{ERROR} = code 0 wiper voltage divided by one LSB (ideal).
- Note 9:** F_{ERROR} = (code 127 wiper voltage - V₊) divided by one LSB (ideal).
- Note 10:** I²C interface timing shown is for fast-mode (400kHz) operation. This device is also backward-compatible with I²C standard mode timing.
- Note 11:** CB—total capacitance of one bus line in picofarads.
- Note 12:** EEPROM write time begins after a STOP condition occurs.
- Note 13:** Pulses narrower than max are suppressed.

Typical Operating Characteristics

(T_A = +25°C, unless otherwise noted.)

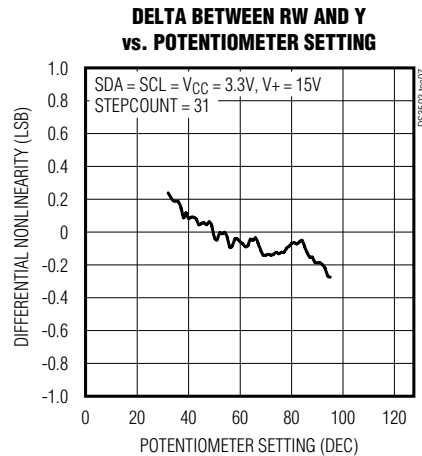
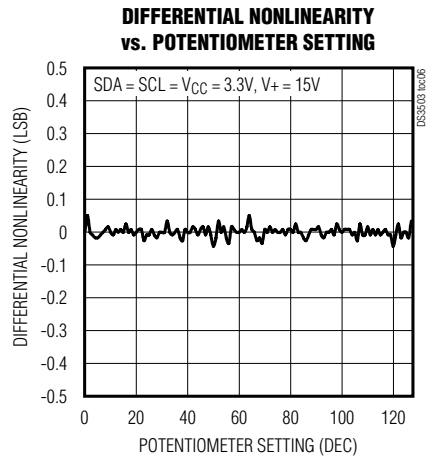
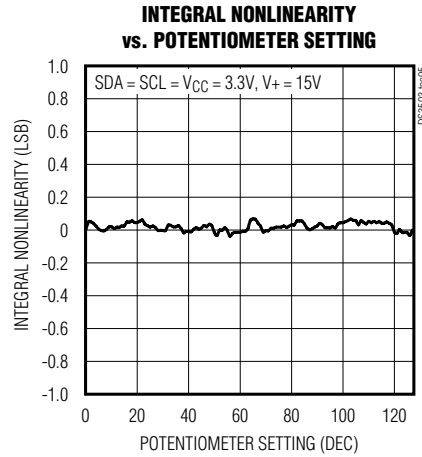
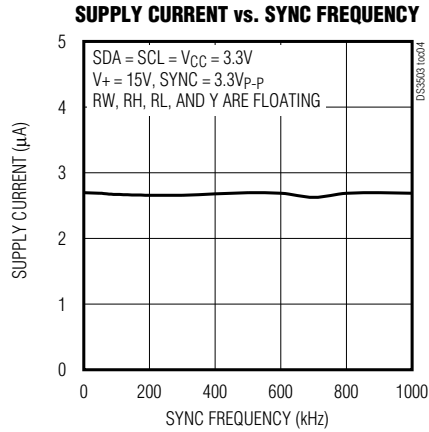


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Typical Operating Characteristics (continued)

(T_A = +25°C, unless otherwise noted.)

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Pin Description

| NAME | PIN | FUNCTION |
|-----------------|-----|---|
| SDA | 1 | I ² C Serial Data. Input/output for I ² C data. |
| GND | 2 | Ground Terminal |
| V _{CC} | 3 | Supply Voltage Terminal |
| SYNC | 4 | Stepping Clock Input. The rising edge updates the outputs. |
| Y | 5 | Code 40h Centered DAC Output |
| RH | 6 | High Terminal of Potentiometer |
| RW | 7 | Wiper Terminal of Potentiometer |
| RL | 8 | Low Terminal of Potentiometer |
| V ₊ | 9 | Wiper Bias Voltage |
| SCL | 10 | I ² C Serial Clock. Input for I ² C clock. |

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Detailed Description

The DS3503 contains two potentiometers whose outputs can be stepped up and down by configuring the control registers. One potentiometer, with output RW, is controlled by the Initial Value Register/Wiper Register (IVR/WR). The other potentiometer is fixed at setting 40h, and its output is on the Y pin. By using the configuration registers and the SYNC pin, the outputs from these two potentiometers can be stepped up and down.

Digital Potentiometers

The RW potentiometer consists of 127 resistors in series connected between the RH and RL pins. Between each resistance and at the two end points, RH and RL, solid-state switches enable RW to be connected within the resistive network. The wiper position and the output on RW are decoded based on the value in WR. If RH, RL, and RW are externally connected in a voltage-divider configuration, the voltage on RW can be easily calculated using the following equation:

$$V_{RW} = V_{RL} + \frac{WR}{127} \times (V_{RH} - V_{RL})$$

Where WR is the wiper position in decimal (0–127). The factory default setting for this potentiometer is 40h.

The Y potentiometer is also referenced to the RH and RL terminals, but is centered at a 40h setting.

Memory Map

The DS3503 contains three registers for controlling the outputs of the two potentiometers, pins RW and Y. Table 1 shows the memory map. IVR/WR is accessed at register address 00h and contains the power-on and current values of the RW potentiometer. The Step Control Register (SCR) controls the stepping function for both potentiometers. The Control Register (CR) controls the write functionality of the IVR/WR.

Initial Value Register/Wiper Register (IVR/WR)

Programming IVR sets the initial power-up value of the RW wiper position. IVR/WR can be visualized as a volatile register (WR) in parallel with a nonvolatile register (IVR). On power-up, the data stored in IVR is loaded into WR, which sets the position of the potentiometer's wiper. The factory default value for IVR is 40h. See the *Stepping* section for information about clamping.

Table 1. Memory Map

| NAME | ADDRESS (HEX) | ACCESS | NONVOLATILE | VOLATILE |
|----------|---------------|--------|--|------------------------------|
| IVR/WR | 00h | R/W | Initial Value Register (IVR), factory setting = 40h | Wiper Register (WR) |
| SCR | 01h | R/W | Step Control Register, factory setting = 00h | — |
| CR | 02h | R/W | Control Register | — |
| Soft-POR | AAh | R/W | — | Soft Power-On Reset Register |

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Step Control Register (SCR)

SCR determines the stepping functionality for the RW and Y potentiometers (see the *Stepping* section). The five LSBs, bits 4:0, control the STEPCOUNT, which is the number of steps up and down the wiper moves when stepping is enabled. Bits 5 and 6 control the PERIOD, which is the number of pulses of the SYNC pin required to perform one step.

Setting STEPCOUNT to all zeros disables stepping for the DS3503. A STEPCOUNT of 1 is an invalid setting. The DS3503 should not be programmed with a STEPCOUNT value of 00001.

Control Register (CR)

CR located at register address 02h determines how I²C data is written to IVR/WR at 00h. When CR is set to a value of 00h, I²C writes to memory address 00h write to both WR and IVR. When CR is set to a value of 80h, I²C writes to memory address 00h write only to WR. Regardless of the CR setting, all I²C reads of address 00h return the contents of WR.

CR is volatile and powers up as 00h, so I²C writes are to both the IVR and WR locations. The data that is stored in EEPROM and SRAM remains unchanged if the value of CR is changed. Table 3 defines CR.

Stepping

The DS3503 can step the RW output up to WR+STEP-COUNT and down to WR-STEP-COUNT when stepping is enabled. Stepping is enabled when a nonzero STEPCOUNT value is programmed into SCR and pulses are applied to the SYNC input pin. Stepping is disabled when STEPCOUNT = 0 or no pulses are applied on the SYNC input pin. STEPCOUNT = 1 is an invalid setting. The falling edge of the SYNC pulse updates the outputs. The Y potentiometer output is created by adding to position 40h (code 64 decimal) the same counter value as is added to WR to form the input to the RW potentiometer.

The WR value is internally limited (clamped) to a minimum of STEPCOUNT and maximum of 127 - STEPCOUNT.

When stepping is enabled, the RW wiper position is controlled by WR plus a counter value (COUNT in the Functional Diagram). COUNT increments or decrements when the number of SYNC pulses received since the last COUNT change is equal to PERIOD. SCR bits 6:5 set PERIOD equal to 32, 64, 128, or 256 SYNC pulses (see Table 2).

After power-up or after any I²C write to IVR/WR, CR, or SCR, stepping is initially disabled until 512 plus

Table 2. Step Control Register Description (01h)

| BIT | NAME | FUNCTION |
|-----|-----------|---|
| 4:0 | STEPCOUNT | Bit 4 is the MSB; bit 0 is the LSB. These 5 bits define the number of steps in an up or down cycle. Maximum is 31, minimum is 2. A STEPCOUNT of zero corresponds to a disabled counter. |
| 6:5 | PERIOD | 0, 0: PERIOD = 32 SYNC pulses |
| | | 0, 1: PERIOD = 64 SYNC pulses |
| | | 1, 0: PERIOD = 128 SYNC pulses |
| | | 1, 1: PERIOD = 256 SYNC pulses |
| 7 | — | Reserved |

Table 3. Control Register Description (02h)

| BIT | NAME | FUNCTION |
|-----|---------------------|--|
| 6:0 | — | Reserved |
| 7 | IVR/WR ADDRESS MODE | 0: Read WR; write IVR and WR at address 00h. 1: Read WR; write WR at address 00h. |

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PERIOD/2 pulses have been applied to the SYNC input. During this disable time, the power-up or new WR value is applied to the RW potentiometer and position 40h (code 64 decimal) is applied to the Y potentiometer. Additionally, the step counter is cleared during this disable time.

After the initialization pulses, stepping is enabled again. The RW potentiometer starts from the power-up or new WR value and the Y potentiometer starts from position 40h (code 64 decimal). The step counter starts from zero in the up direction.

The stepping function is further described as follows:

An internal counter called PERIODCOUNT is set equal to PERIOD.

The input to the RW potentiometer is $WR + COUNT$; the input to the Y potentiometer is $code\ 64 + COUNT$.

When a SYNC pulse is received:

$$PERIODCOUNT = PERIODCOUNT - 1$$

If $PERIODCOUNT = 0$ (underflow), the following actions occur:

If direction is UP:

$$\begin{aligned} COUNT &= \min(COUNT + 1, STEPCOUNT) \\ RW &= \min(127 - STEPCOUNT, WR + COUNT); \\ Y &= 64 + COUNT \\ PERIODCOUNT &\text{ is reset to PERIOD} \end{aligned}$$

If direction is DOWN:

$$\begin{aligned} COUNT &= \max(COUNT - 1, -STEPCOUNT) \\ RW &= \max(STEPCOUNT, WR - COUNT); \\ Y &= 64 - COUNT \\ PERIODCOUNT &\text{ is reset to PERIOD} \end{aligned}$$

If $COUNT = STEPCOUNT$, direction is changed from UP to DOWN.

If $COUNT = -STEPCOUNT$, direction is changed from DOWN to UP.

In this way the RW output steps up to $WR + STEPCOUNT$, then steps down to $WR - STEPCOUNT$, and then repeats the cycle. The outputs of the RW and Y DACs change by one LSB = $(VRH - VRL)/127$ per PERIOD.

STEPCOUNT and PERIOD are programmable from I²C and are stored in the nonvolatile SCR (Table 2).

The STEPCOUNT 5-bit value programmed into SCR<4:0> controls the stepping range reflected in the

Table 4. DAC Stepping Range

| SCR<4:0> (BINARY) | DAC RANGE |
|----------------------|----------------------------------|
| 0 0000 | Stepping disabled; WR is output |
| 0 0001 | Invalid setting. Do not program. |
| 0 0010 | WR-2 to WR+2 |
| 0 0011 | WR-3 to WR+3 |
| 0 0100 | WR-4 to WR+4 |
| 0 0101 | WR-5 to WR+5 |
| ... | ... |
| 1 1110 | WR-30 to WR+30 |
| ... | ... |
| 1 1111 | WR-31 to WR+31 |

RW or Y outputs per Table 4, assuming $STEPCOUNT < IVR < 127 - STEPCOUNT$:

Example 1:

$$\begin{aligned} WR &= 41h\ (65\ \text{decimal});\ SCR<4:0> = STEPCOUNT \\ &= 10000\ (16\ \text{decimal}) \\ RW\ \text{range} &: 49 \leftrightarrow 81\ (\text{decimal}) \\ Y\ \text{range} &: 48 \leftrightarrow 80\ (\text{decimal}) \end{aligned}$$

Example 2:

$$\begin{aligned} WR &= 50h\ (80\ \text{decimal});\ SCR<4:0> = STEPCOUNT \\ &= 11000\ (24\ \text{decimal}) \\ RW\ \text{range} &: 56 \leftrightarrow 104\ (\text{decimal}) \\ Y\ \text{range} &: 40 \leftrightarrow 88\ (\text{decimal}) \end{aligned}$$

Example 3: Clamping at Lower Rail

$$\begin{aligned} WR &= 10h\ (16\ \text{decimal});\ SCR<4:0> = STEPCOUNT \\ &= 11111\ (31\ \text{decimal}) \\ RW\ \text{range} &: 0 \leftrightarrow 62\ (\text{decimal}) \\ Y\ \text{range} &: 33 \leftrightarrow 95\ (\text{decimal}) \end{aligned}$$

Example 4: Clamping at Upper Rail

$$\begin{aligned} WR &= 70h\ (112\ \text{decimal});\ SCR<4:0> = STEPCOUNT \\ &= 11111\ (31\ \text{decimal}) \\ RW\ \text{range} &: 65 \leftrightarrow 127\ (\text{decimal}) \\ Y\ \text{range} &: 33 \leftrightarrow 95\ (\text{decimal}) \end{aligned}$$

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Table 5. Soft Power-On Reset Register Description (AAh)

| BIT | NAME | FUNCTION |
|-----|----------|---|
| 6:0 | — | Reserved |
| 7 | SOFT POR | 0: Default value. 1: Recalls values of IVR, CR, and SCR from EEPROM. |

Soft Power-On Reset Register (Soft-POR)

By writing register AAh's MSB to 1, a soft power-on reset (soft-POR) can be generated. When the MSB is set to 1, the power-up default values of registers 00h, 01h, and 02h are recalled, and the MSB of AAh self-clears. This soft-POR can be used to recall power-on settings without cycling power to the DS3503.

I²C Serial Interface Description

I²C Definitions

The following terminology is commonly used to describe I²C data transfers. (See Figure 2 and the I²C AC Electrical Characteristics table for additional information.)

Master device: The master device controls the slave devices on the bus. The master device generates SCL clock pulses and START and STOP conditions.

Slave devices: Slave devices send and receive data at the master's request.

Bus idle or not busy: Time between STOP and START conditions when both SDA and SCL are inactive and in their logic-high states.

START condition: A START condition is generated by the master to initiate a new data transfer with a slave. Transitioning SDA from high to low while SCL remains high generates a START condition.

STOP condition: A STOP condition is generated by the master to end a data transfer with a slave. Transitioning SDA from low to high while SCL remains high generates a STOP condition.

Repeated START condition: The master can use a repeated START condition at the end of one data transfer to indicate that it will immediately initiate a new data transfer following the current one. Repeated STARTs are commonly used during read operations to identify a specific memory address to begin a data transfer. A repeated START condition is issued identically to a normal START condition.

Bit write: Transitions of SDA must occur during the low state of SCL. The data on SDA must remain valid and unchanged during the entire high pulse of SCL plus the setup and hold time requirements. Data is shifted into the device during the rising edge of the SCL.

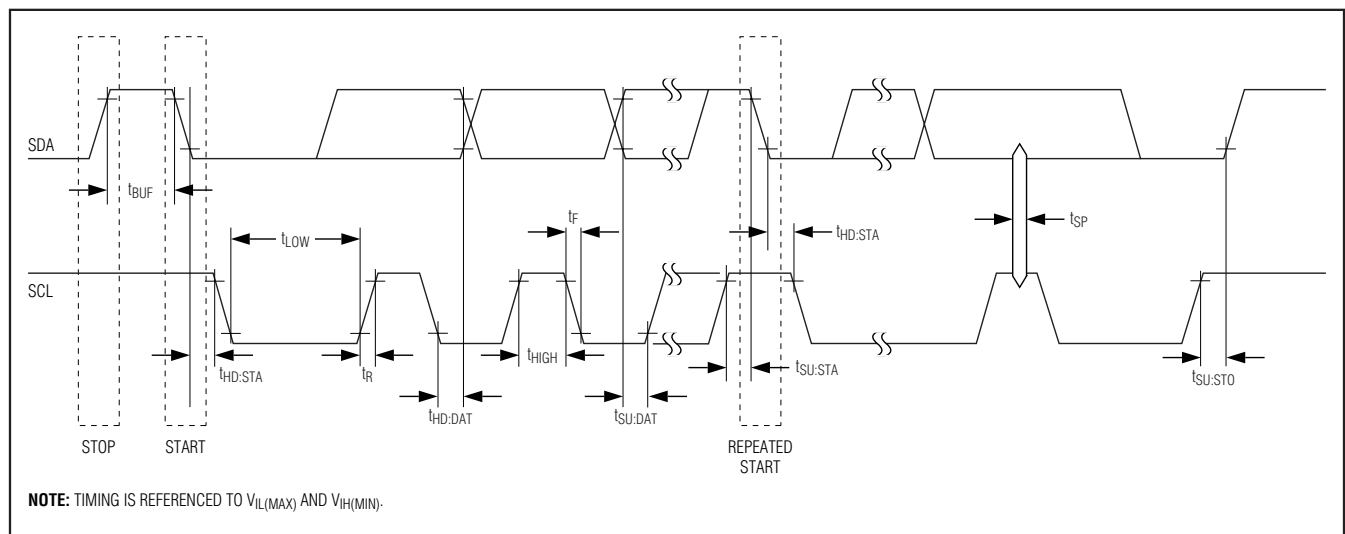


Figure 2. I²C Timing Diagram

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Bit read: At the end of a write operation, the master must release the SDA bus line for the proper amount of setup time before the next rising edge of SCL during a bit read. The device shifts out each bit of data on SDA at the falling edge of the previous SCL pulse and the data bit is valid at the rising edge of the current SCL pulse. Remember that the master generates all SCL clock pulses, including when it is reading bits from the slave.

Acknowledge (ACK and NACK): An Acknowledge (ACK) or Not Acknowledge (NACK) is always the 9th bit transmitted during a byte transfer. The device receiving data (the master during a read or the slave during a write operation) performs an ACK by transmitting a 0 during the 9th bit. A device performs a NACK by transmitting a 1 during the 9th bit. Timing for the ACK and NACK is identical to all other bit writes (Figure 2). An ACK is the acknowledgment that the device is properly receiving data. A NACK is used to terminate a read sequence or indicates that the device is not receiving data.

Byte write: A byte write consists of 8 bits of information transferred from the master to the slave (most significant bit first) plus a 1-bit acknowledgment from the slave to the master. The 8 bits transmitted by the master are done according to the bit-write definition and the acknowledgment is read using the bit-read definition.

Byte read: A byte read is an 8-bit information transfer from the slave to the master plus a 1-bit ACK or NACK from the master to the slave. The 8 bits of information that are transferred (most significant bit first) from the slave to the master are read by the master using the bit-read definition, and the master transmits an ACK using the bit-write definition to receive additional data bytes. The master must NACK the last byte read to terminate communication so the slave returns control of SDA to the master.

Slave address byte: Each slave on the I²C bus responds to a slave address byte sent immediately following a START condition. The slave address byte contains the slave address in the most significant 7 bits and the R/\bar{W} bit in the least significant bit. The DS3503's slave address is 50h (see Figure 1).

When the R/\bar{W} bit is 0 (such as in 50h), the master is indicating it will write data to the slave. If $R/\bar{W} = 1$ (51h in this case), the master is indicating it wants to read from the slave.

If an incorrect slave address is written, the DS3503 assumes the master is communicating with another

I²C device and ignores the communication until the next START condition is sent.

Memory address: During an I²C write operation, the master must transmit a memory address to identify the memory location where the slave is to store the data. The memory address is always the second byte transmitted during a write operation following the slave address byte.

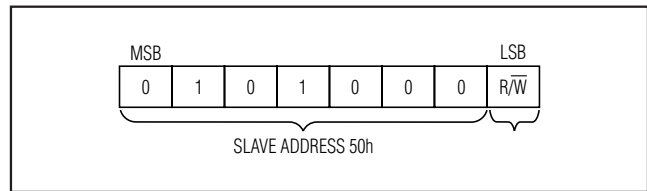


Figure 1. DS3503 Slave Address Byte

I²C Communication

Writing a single byte to a slave: The master must generate a START condition, write the slave address byte ($R/\bar{W} = 0$), write the memory address, write the byte of data, and generate a STOP condition. Remember the master must read the slave's acknowledgment during all byte-write operations.

When writing to the DS3503, the potentiometer adjusts to the new setting once it has acknowledged the new data that is being written, and the EEPROM is written following the STOP condition at the end of the write command. To change the setting without changing the EEPROM, terminate the write with a repeated START condition before the next STOP condition occurs. Using a repeated START condition prevents the t_{W} delay required for the EEPROM write cycle to finish.

Acknowledge polling: Any time a EEPROM byte is written, the DS3503 requires the EEPROM write time (t_{W}) after the STOP condition to write the contents of the byte to EEPROM. During the EEPROM write time, the device will not acknowledge its slave address because it is busy. It is possible to take advantage of this phenomenon by repeatedly addressing the DS3503, which allows communication to continue as soon as the DS3503 is ready. The alternative to acknowledge polling is to wait for a maximum period of t_{W} to elapse before attempting to access the device.

EEPROM write cycles: The DS3503's EEPROM write cycles are specified in the *Nonvolatile Memory Characteristics* table. The specification shown is at the worst-case temperature (hot) as well as at room temperature. Writing to WR/IVR with CR = 80h does not count as a EEPROM write.

NV, I²C, Stepper Potentiometer

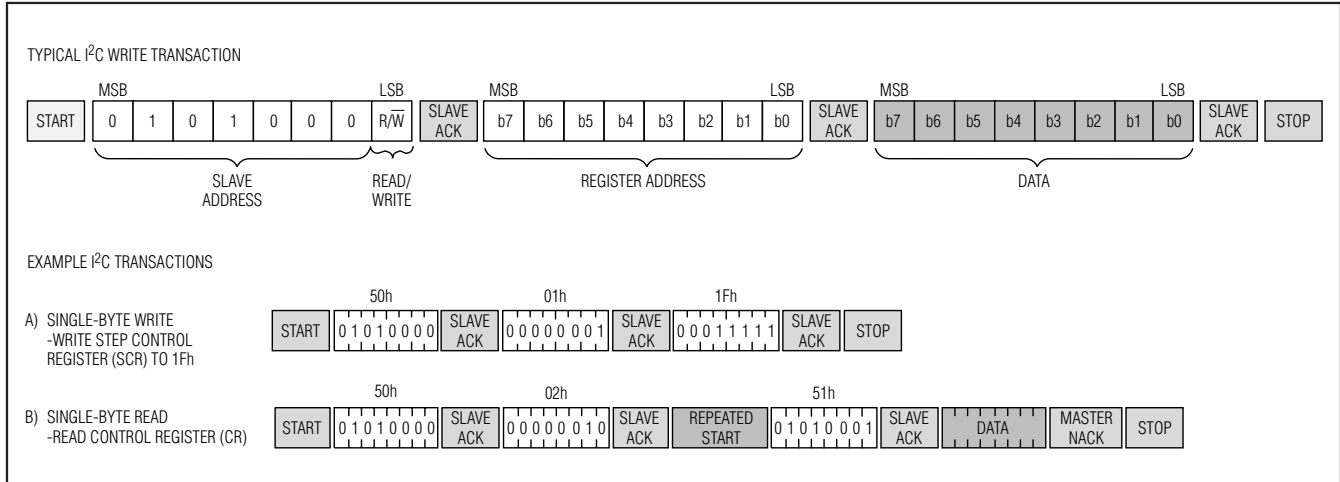


Figure 3. I²C Communication Examples

Reading a single byte from a slave: Unlike the write operation that uses the specified memory address byte to define where the data is to be written, the read operation occurs at the present value of the memory address counter. To read a single byte from the slave, the master generates a START condition, writes the slave address byte with $R/\bar{W} = 1$, reads the data byte with a NACK to indicate the end of the transfer, and generates a STOP condition. However, because requiring the master to keep track of the memory address counter is impractical, the following method should be used to perform reads from a specified memory location.

Manipulating the address counter for reads: A dummy write cycle can be used to force the address counter to a particular value. To do this the master generates a START condition, writes the slave address byte ($R/\bar{W} = 0$), writes the memory address where it desires to read, generates a repeated START condition, writes the slave address byte ($R/\bar{W} = 1$), reads data with ACK or NACK as applicable, and generates a STOP condition.

See Figure 3 for a read example using the repeated START condition to specify the starting memory location.

Applications Information

Power-Supply Decoupling

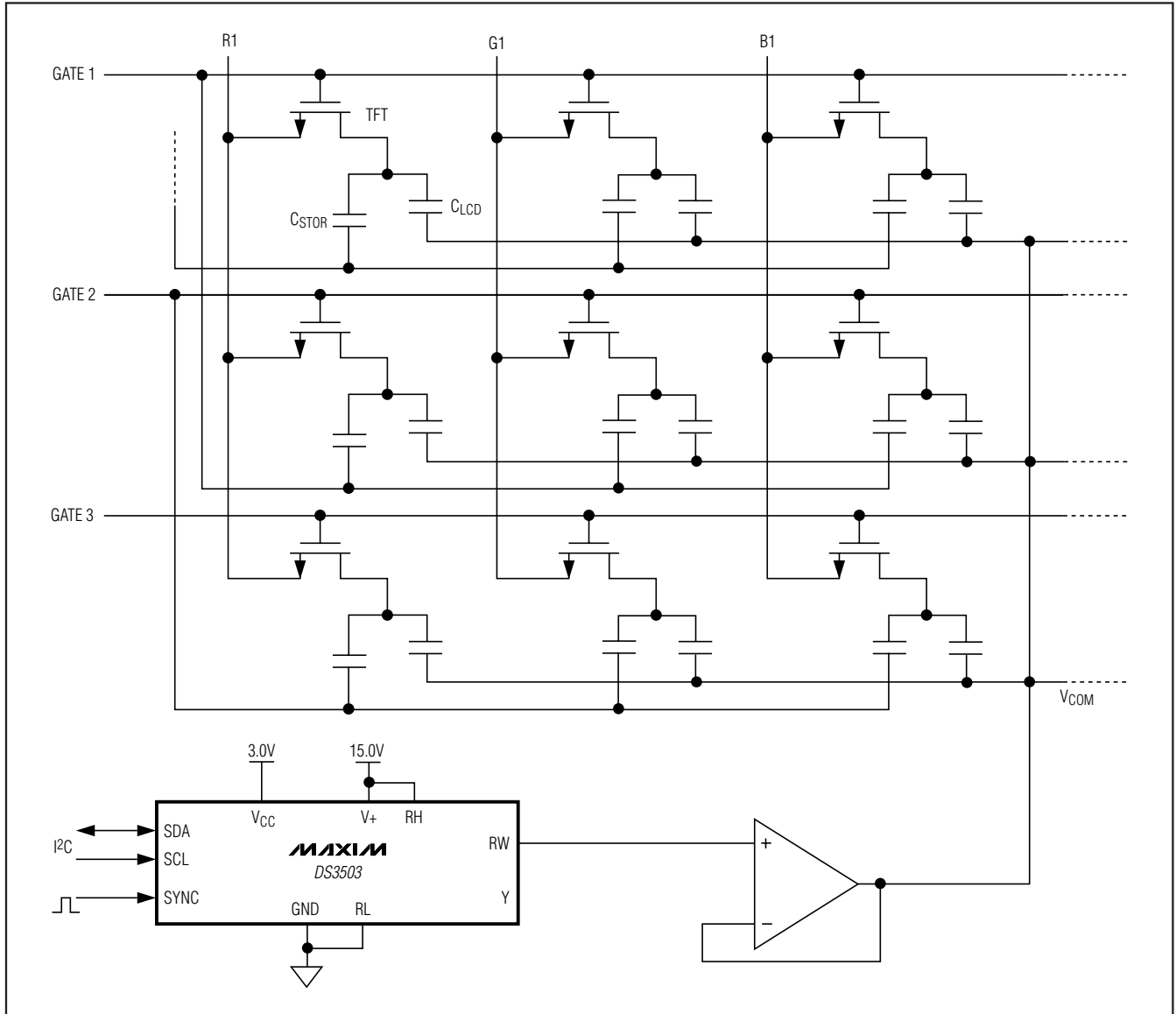
To achieve the best results when using the DS3503, decouple both the power-supply pin (V_{CC}) and the wiper-bias voltage pin ($V+$) with a 0.01 μ F or 0.1 μ F capacitor. Use a high-quality ceramic surface-mount capacitor if possible. Surface-mount components minimize lead inductance, which improves performance, and ceramic capacitors tend to have adequate high-frequency response for decoupling applications.

SDA and SCL Pullup Resistors

SDA is an I/O with an open-collector output that requires a pullup resistor to realize high-logic levels. A master using either an open-collector output with a pullup resistor or a push-pull output driver must be used for SCL. Pullup resistor values should be chosen to ensure that the rise and fall times listed in the I²C AC Electrical Characteristics are within specification. A typical value for the pullup resistors is 4.7k Ω .

NV, I2C, Stepper Potentiometer

Typical Operating Circuit



Package Information

For the latest package outline information and land patterns, go to www.maxim-ic.com/packages.

| PACKAGE TYPE | PACKAGE CODE | DOCUMENT NO. |
|--------------|--------------|-------------------------|
| 10 μ SOP | U10+2 | 21-0061 |

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Revision History

DS3503

| REVISION NUMBER | REVISION DATE | DESCRIPTION | PAGES CHANGED |
|-----------------|---------------|---|---------------|
| 0 | 11/08 | Initial release. | — |
| 1 | 3/09 | <ul style="list-style-type: none">• Added the following sentence to the end of the <i>Step Control Register (SCR)</i> section: “A STEPCOUNT of 1 is an invalid setting. The DS3503 should not be programmed with a STEPCOUNT value of 00001.”• Added the following sentence to the <i>Stepping</i> section: “STEPCOUNT = 1 is an invalid setting.”• Changed the minimum number of steps for the STEPCOUNT bits in the <i>Step Control Register Description (01h)</i> table (Table 2) from 0 to 2.• Changed the 0 0001 DAC range in the <i>DAC Stepping Range</i> table (Table 4) from “WR-1 to WR+1” to “Invalid setting. Do not program.” | 7, 8 |

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