TD24C128-C
128-Kbit I²C Serial EEPROM 4-Ball WLCSP

GENERAL DESCRIPTION

The TD24C128-C is a 128-Kbit I²C-compatible serial EEPROM device. The device is designed to operate in a supply voltage range of 1.7V to 5.5V, with a maximum of 1MHz transfer rate. The operating temperature range is from -40℃ to +125℃. The device address is software programmable by using the Device Address Configuration feature. A Software Write Protection feature is used for selective Write Protection on partial or the whole memory array.

The TD24C128-C offers an additional 64-byte Identification Page for users to store sensitive application parameters. The Identification Page can be locked permanently in Read-only mode after the data is written into this page. The device also offers a separate memory block containing a factory programmed 128-bit Unique ID. This block is in Read-only mode and can be accessed by sending a specific Read command.

The TD24C128-C is delivered in a WLCSP-0.63×0.74-4B package.

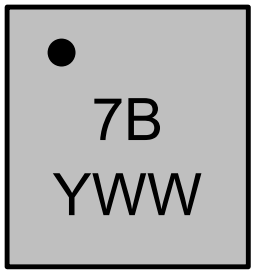
FEATURES

- **Supply Voltage Range: 1.7V to 5.5V**
- **2-Wire Serial Interface I²C Compatible**
  - **400kHz and High Speed Transfer Rate 1MHz Compatibility**
- **Page (up to 64 bytes) Write Mode**
  - **Partial Page Write Allowed**
- **Software Write Protection on Partial or Whole Memory Array**
  - **Upper Quarter Memory Array**
  - **Upper Half Memory Array**
  - **Upper 3/4 Memory Array**
  - **Whole Memory Array**
- **Software Programmable Device Address Configuration**
- **Additional 64-byte Write Lockable Page and 128-bit Unique ID**
- **Self-timed Write Cycle (5ms MAX)**
- **Schmitt Trigger, Filtered Inputs for Noise Suppression**
- **High Reliability**
  - **Endurance: 1,000,000 Write Cycles at T_A = +25℃**
  - **Data Retention: 100 Years at T_A = +25℃**
- **Low Operating Current**
  - **Write Current: 1mA (MAX)**
  - **Read Current: 0.5mA (MAX)**
- **Operating Temperature Range: -40℃ to +125℃**
- **RoHS Compliant and Halogen Free**
- **Available in a Green WLCSP-0.63×0.74-4B Package**

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
TD24C128-C	WLCSP-0.63×0.74-4B	-40℃ to +125℃	TD24C128-C2LPTR	7B YWW	Tape and Reel, 4000

MARKING INFORMATION



7B: TD24C128-C2LPTR
YWW: Date Code, Y = year, WW = week
Example: 919 = year 2019, week 19

Green (RoHS & HSF): SG Micro Corp defines "Green" to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your SGMICRO representative directly.

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, V_{CC} ..... -0.5V to 6V
Voltage on Input Pins, V_{IN} ..... -0.5V to 6V
Ambient Temperature with Power Applied ... -55℃ to +130℃
Storage Temperature Range ..... -65℃ to +150℃
ESD Susceptibility
HBM..... 6000V

RECOMMENDED OPERATING CONDITIONS

Operating Ambient Temperature Range..... -40℃ to +125℃

OVERSTRESS CAUTION

Stresses beyond those listed in Absolute Maximum Ratings may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect reliability. Functional operation of the device at any conditions beyond those indicated in the Recommended Operating Conditions section is not implied.

ESD SENSITIVITY CAUTION

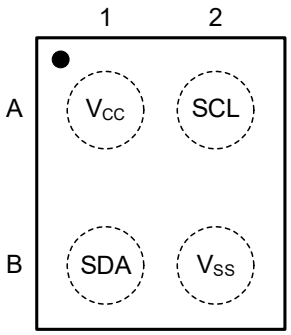
This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because even small parametric changes could cause the device not to meet the published specifications.

DISCLAIMER

SG Micro Corp reserves the right to make any change in circuit design, or specifications without prior notice.

PIN CONFIGURATION

(TOP VIEW)



WLCSP-0.63×0.74-4B

PIN DESCRIPTION

NAME	TYPE	FUNCTION
SDA	Input/Output	Serial Data. The SDA pin is an open-drain bidirectional input/output pin used to serially transfer data to and from the device.
SCL	Input	Serial Clock. The SCL pin is used to provide a clock to the device and is used to control the flow of data to and from the device. Command and input data present on the SDA pin is always latched in on the rising edge of SCL, while output data on the SDA pin is always clocked out on the falling edge of SCL.
V_{CC}	Power	Device Power Supply. The V_{CC} pin is used to supply the source voltage to the device. Operations at invalid V_{CC} voltages may produce spurious results and should not be attempted.
V_{SS}	Ground	Ground. The ground reference for the power supply. V_{SS} should be connected to the system ground.

ELECTRICAL CHARACTERISTICS

DC Characteristics

(Operating range: T_A = -40℃ to +125℃, V_{CC} = 1.7V to 5.5V, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	MAX	UNITS
Supply Voltage	V_{CC}		1.7	5.5	V
Supply Current (Read)	I_{CC1}	V_{CC} = 1.7V, Read at 1MHz		0.1	mA
		V_{CC} = 1.8V, Read at 400kHz		0.1	mA
		V_{CC} = 5.5V, Read at 400kHz		0.4	mA
		V_{CC} = 5.5V, Read at 1MHz		0.5	mA
Supply Current (Write)	I_{CC2}	V_{CC} = 1.8V, Write at 400kHz		0.4	mA
		V_{CC} = 5.5V, Write at 400kHz		1	mA
Standby Current	I_{SB}	V_{CC} = 1.7V, V_{IN} = V_{CC} or V_{SS}		0.5	μA
		V_{CC} = 5.5V, V_{IN} = V_{CC} or V_{SS}		1	μA
Input Leakage Current	I_{LI}	V_{IN} = V_{CC} or V_{SS}		1	μA
Output Leakage Current	I_{LO}	V_{OUT} = V_{CC} or V_{SS}		1	μA
Input Low-Level Voltage (SDA, SCL)	V_{IL}		-0.5	0.3 × V_{CC}	V
Input High-Level Voltage (SDA, SCL)	V_{IH}		0.7 × V_{CC}	V_{CC} + 0.5	V
Low-Level Output Voltage	V_{OL1}	V_{CC} > 2V, I_{OL} = 3mA		0.4	V
Low-Level Output Voltage	V_{OL2}	V_{CC} ≤ 2V, I_{OL} = 2mA		0.2	V

AC Characteristics

(Operating range: T_A = -40℃ to +125℃, V_{CC} = 1.7V to 5.5V, C_L = 100pF. Measurement conditions: input rise and fall time ≤ 50ns, input pulse voltages: 0.2 × V_{CC} to 0.8 × V_{CC}; input and output timing reference voltages: 0.3 × V_{CC} to 0.7 × V_{CC}, unless otherwise noted.)

PARAMETER	SYMBOL	FAST MODE V_{CC} = 1.7V to 5.5V		HIGH SPEED MODE V_{CC} = 1.7V to 5.5V		UNIT
		MIN	MAX	MIN	MAX	
Clock Frequency, SCL	f_{SCL}		400		1000	kHz
Clock Pulse Width Low	t_{LOW}	1300		600		ns
Clock Pulse Width High	t_{HIGH}	600		260		ns
SDA Rise Time	t_R (1)		300		300	ns
SDA (Out) Fall Time	t_F (1)		300		100	ns
Start Hold Time	$t_{HD.STA}$	600		250		ns
Start Setup Time	$t_{SU.STA}$	600		250		ns
Stop Setup Time	$t_{SU.STO}$	600		250		ns
Bus Free Time between Stop and Next Start	t_{BUF}	1300		500		ns
Data In Hold Time	$t_{HD.DI}$	0		0		ns
Data In Setup Time	$t_{SU.DAT}$	100		50		ns
Data Out Hold Time	$t_{HD.DAT}$	50		50		ns
SCL Low to Data Out Valid	t_{AA}	100	900	50	500	ns
Write Cycle Time	t_{WR}		5		5	ms
Noise Suppression Time	t_I		50		50	ns

NOTE: 1.This parameter is ensured by characterization only.

ELECTRICAL CHARACTERISTICS (continued)

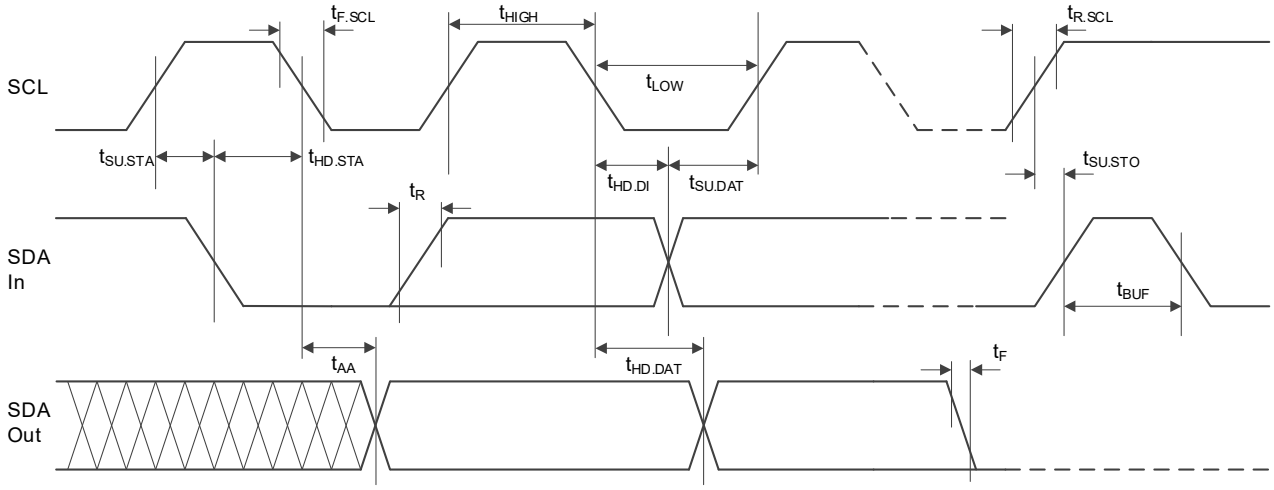


Figure 1. Bus Timing

Pin Capacitance

(Operating range for pin capacitance: T_A = +25℃, f_C = 1MHz, V_{CC} = 1.7V to 5.5V.)

PARAMETER (1)	SYMBOL	CONDITIONS	MAX	UNITS
Input/output Capacitance (SDA)	$C_{I/O}$	$V_{I/O}$ = 0V	8	pF
Input Capacitance (SCL)	C_{IN}	V_{IN} = 0V	6	pF

NOTE: 1. These parameters are ensured by characterization only.

Reliability Characteristics

PARAMETER	SYMBOL	CONDITIONS	MIN	UNITS
Write Cycle Endurance	N_W	T_A = +25℃, Page mode	1×10^6	cycle
		T_A = +125℃, Page mode	1×10^5	
Data Retention	D_R	T_A = +25℃	100	year

FUNCTIONAL BLOCK DIAGRAM

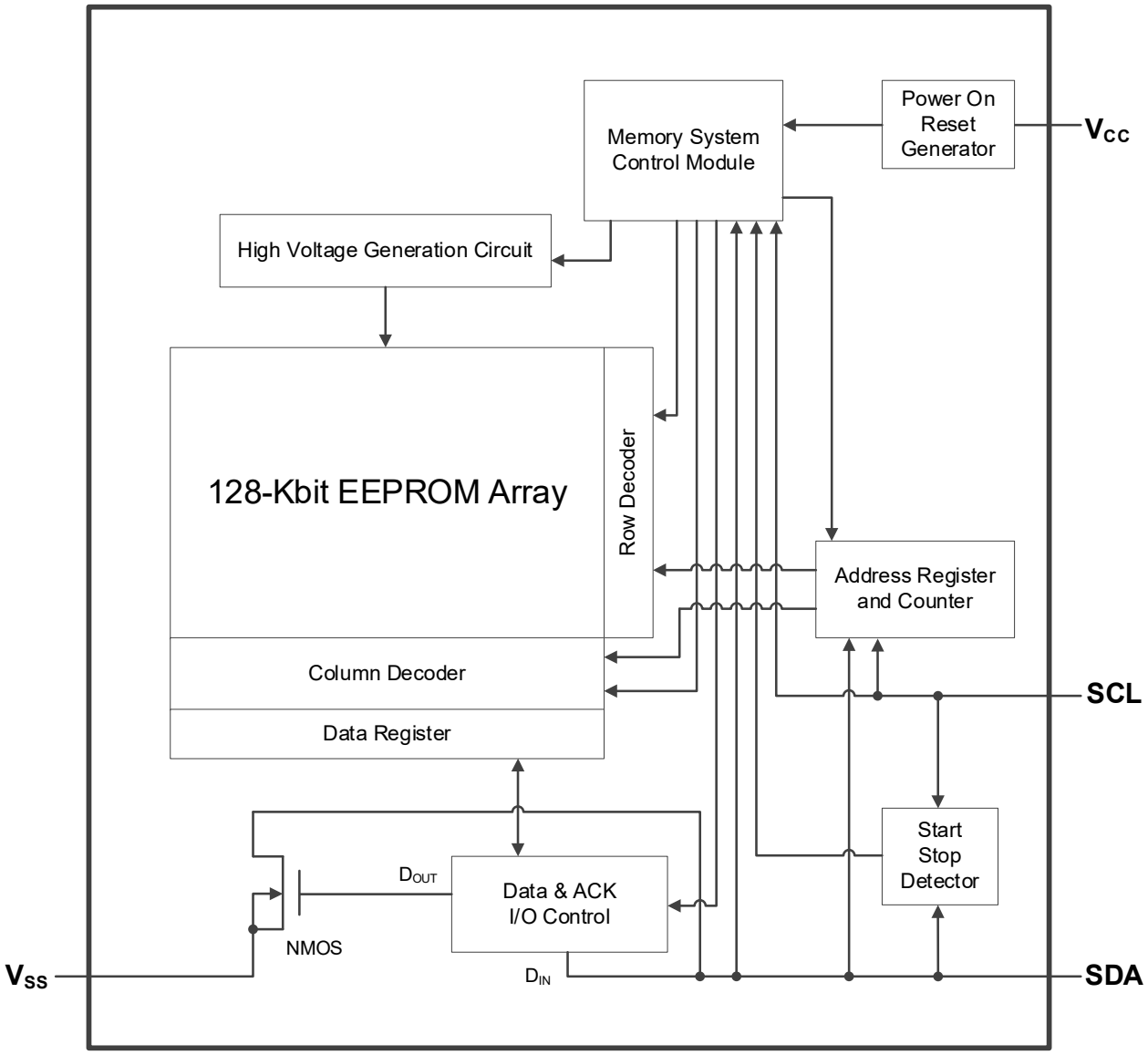


Figure 2. Block Diagram

DEVICE COMMUNICATION

The TD24C128-C operates as a slave device and utilizes a 2-Wire serial interface to communicate with the Master. The Master initiates and controls all Read and Write operations to the slave devices on the serial bus, and both the Master and the slave devices can transmit and receive data on the bus.

The serial interface is comprised of just two signal lines: the Serial Clock (SCL) and the Serial Data (SDA). Data is always latched into the TD24C128-C on the rising edge of SCL and is always output from the device on the falling edge of SCL. Both the SCL pin and SDA pin incorporate integrated spike suppression filters and Schmitt Triggers to minimize the effects of input spikes and bus noise.

All command and data information is transferred with the Most Significant Bit (MSB) first. During the bus communication, one data bit is transmitted every clock cycle, and after eight bits of data has been transferred, the receiving device must respond with an acknowledge or a no-acknowledge response bit during a ninth clock cycle generated by the Master. Therefore, nine clock cycles are required for every one byte of data transferred. There is no unused clock cycle during any Read or Write operation, so there must not be any interruptions or breaks during the data stream.

During data transfers, data on the SDA pin must only change while SCL is low, and the data must remain stable while SCL is high. If data on the SDA pin changes while SCL is high, then either a Start or a Stop condition will occur. The number of data bytes transferred between a Start and a Stop condition is not limited and is determined by the Master.

Start Condition

A Start condition occurs when there is a high-to-low transition on the SDA pin while the SCL pin is stable in Logic 1 state. The Start condition must precede any command as the Master uses a Start condition to initiate any data transfer sequence (see Figure 3). The TD24C128-C will continuously monitor the SDA and SCL pins for a Start condition, and the device will not respond unless one is given.

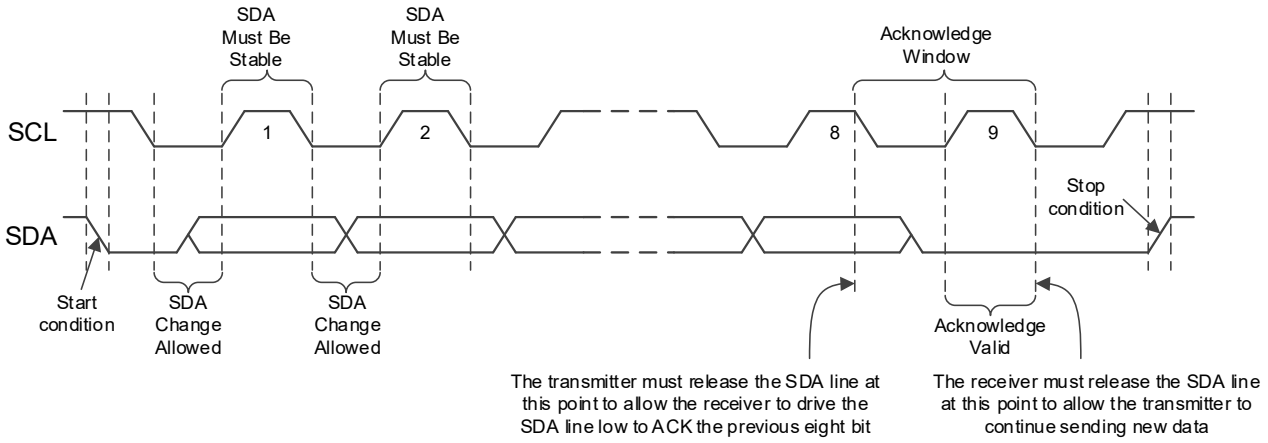


Figure 3. Start, Stop, and ACK

Stop Condition

A Stop condition occurs when there is a low-to-high transition on the SDA pin while the SCL pin is stable in Logic 1 state (see Figure 3). A stop condition terminates communication between the TD24C128-C and the Master. A Stop condition at the end of a Write command triggers the EEPROM internal write cycle. Otherwise, the TD24C128-C subsequently returns to Standby mode after receiving a Stop condition.

Acknowledge (ACK)

After each byte of data is received, the TD24C128-C should acknowledge to the Master that it has received the data byte successfully. This is accomplished by the Master first releasing the SDA line and providing the ACK/NACK clock cycle (a ninth clock cycle for every byte). During the ACK/NACK clock cycle, the TD24C128-C must output Logic 0 as ACK for the entire clock cycle so that the SDA line must be stable in Logic 0 state during the entire high period of the clock cycle (see Figure 3).

DEVICE COMMUNICATION (continued)

Standby Mode

The TD24C128-C features a low-power Standby mode which is enabled:

(1) Upon power-up;

(2) After the receipt of a Stop condition in Read operation;

(3) The completion of any internal operations.

Software Reset

After an interruption in protocol, power loss, or system reset, any 2-Wire part can be reset by following these steps: (1) Create a Start condition; (2) Clock nine cycles; (3) Create another Start condition followed by a Stop condition (see Figure 4).

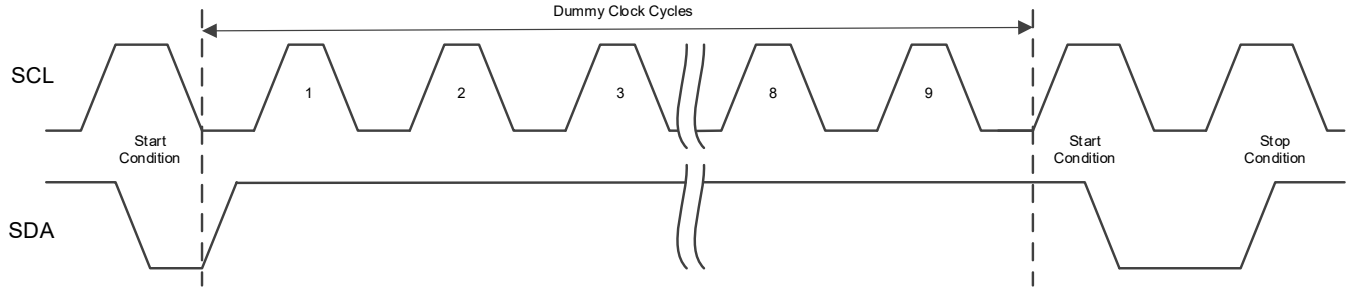


Figure 4. 2-Wire Software Reset

DEVICE COMMUNICATION (continued)

Device Reset and Initialization

The TD24C128-C incorporates a Power-On Reset (POR) circuit to prevent inadvertent operations during power-up. On a cold power-up, the device does not respond to any instructions until the supply voltage reaches the internal power-on reset threshold voltage (V_{POR}). The supply voltage must rise continuously between V_{POR} and V_{CC} (MIN) without any ring back to ensure a proper power-up. Once the supply voltage passes V_{POR}, the device is reset and enters Standby mode. However, no protocol should be issued to the device until a valid and stable supply voltage is applied for the time specified by the t_{INIT} parameter. The supply voltage must remain stable and valid until the end of the protocol transmission, and for a Write instruction, until the end of the internal write cycle (see Figure 5).

This POR behavior is bi-directional. It protects the TD24C128-C against brown-out failure caused by a temporary loss of power. In a similar way, as soon as the supply voltage drops below the internal brown-out reset threshold voltage (V_{BOR}), the device is reset and stops responding to any instructions. The V_{BOR} level is set below the V_{POR} level.

Parameters related to power-up and power-down conditions are listed in Table 1.

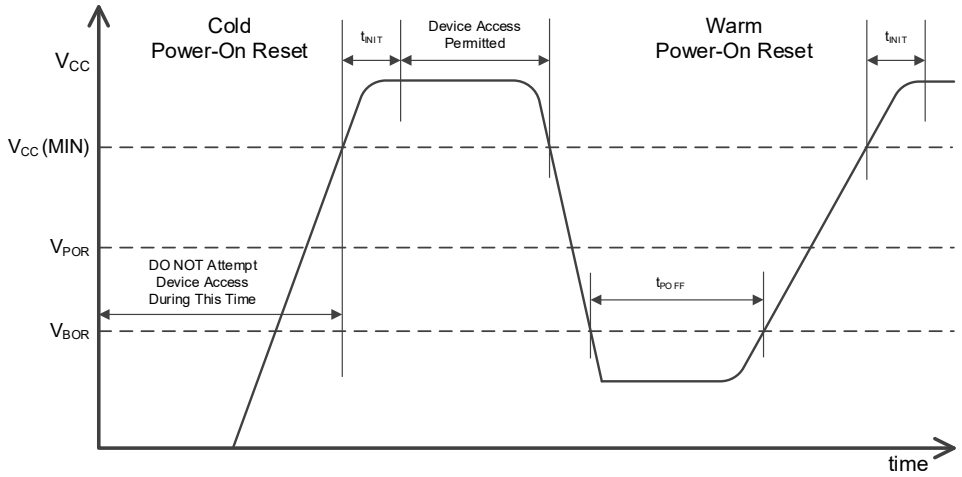


Figure 5. Power-Up and Power-Down Timing

Table 1. Power-Up and Power-Down Conditions

PARAMETER	SYMBOL	MIN	MAX	UNITS
Power-On Reset Voltage	V_{POR}		1.5	V
Brown-Out Reset Voltage	V_{BOR}	1.2		V
Time from V_{CC} (MIN) to First Command	t_{INIT}	100		μs
Warm Power Cycle Off Time	t_{POFF}	100		μs

Data Security

The TD24C128-C incorporates a Software Write Protection (SWP) feature that allows the user to write protect the memory array by blocks (see ***Write Software Write Protection (SWP) Register*** section for details).

DEVICE ADDRESSING

The TD24C128-C requires a 7-bit device address and a Read/Write select bit following a Start condition from the Master to initiate communication with the serial EEPROM. The device address byte is comprised of a 4-bit device type identifier followed by three device address bits (E2, E1, and E0) and a R/$\overline{W}$ select bit and is clocked by the Master on the SDA pin with the most significant bit (bit 7) first.

The TD24C128-C responds to two unique device type identifiers. The device type identifier of '1010' is necessary to select the device memory for normal Read or Write operation. The device type identifier of '1010' is also used to select the Software Write Protection register and Device Address Configuration register for Read or Write operation. The device type identifier of '1011' is used to select the Identification Page for Read or Write / Lock operation. The device type identifier of '1011' is also used for Read Unique ID operation (see Table 2).

The software device address bits (E2, E1 and E0) must match the corresponding device address data stored in the Device Address Configuration register, allowing up to eight devices on the bus at the same time. The eighth bit of the address byte is the R/$\overline{W}$ operation selection bit. A Read operation is selected if this bit is Logic 1, and a Write operation is selected if this bit is Logic 0. Upon a compare of the device address byte, the TD24C128-C outputs an ACK or an NACK during the ninth clock cycle if the compare is true or not true, respectively. The device will return to the low-power Standby mode after an NACK.

Once the TD24C128-C has acknowledged the device address byte, the device waits for the Master to send two word address bytes (first word address byte sent first, followed by the second word address byte) for a certain Read or Write instruction according to Table 3. The TD24C128-C responds to each address byte with an ACK.

Table 2. TD24C128-C Device Address Byte

FUNCTION	DEVICE TYPE IDENTIFIER				DEVICE ADDRESS			READ/WRITE
	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
When accessing the 128-Kbit memory array	1	0	1	0	E2	E1	E0	R/W
When accessing the Software Write Protection register	1	0	1	0	E2	E1	E0	R/W
When accessing the Device Address Configuration register	1	0	1	0	E2	E1	E0	R/W
When accessing the Identification Page	1	0	1	1	E2	E1	E0	R/W
When accessing the Lock Identification Page bit	1	0	1	1	E2	E1	E0	0
When accessing the Unique ID	1	0	1	1	E2	E1	E0	1

Table 3. TD24C128-C Word Address Bits

FUNCTION	FIRST WORD ADDRESS BYTE								SECOND WORD ADDRESS BYTE							
	BIT 15	BIT 14	BIT 13	BIT 12	BIT 11	BIT 10	BIT 9	BIT 8	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
Random Read	0	X (1)	A13 (2)	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
Byte/Page Write	0	X	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
Write Software Write Protection Register	1	0	1	X	X	X	X	X	X	X	X	X	X	X	X	X
Read SWP Register	1	0	1	X	X	X	X	X	X	X	X	X	X	X	X	X
Write Device Address Configuration Register	1	1	0	X	X	X	X	X	X	X	X	X	X	X	X	X
Read DAC Register	1	1	0	X	X	X	X	X	X	X	X	X	X	X	X	X
Read Identification Page	X	X	X	X	X	0	0	X	X	X	A5	A4	A3	A2	A1	A0
Write Identification Page	X	X	X	X	X	0	0	X	X	X	A5	A4	A3	A2	A1	A0
Lock Identification Page	X	X	X	X	X	1	0	X	X	X	X	X	X	X	X	X
Read Lock Status	X	X	X	X	X	0	0	X	X	X	X	X	X	X	X	X
Read Unique ID	X	X	X	X	X	0	1	X	X	X	X	X	A3	A2	A1	A0

NOTES:

1. A = Significant address bit.
2. X = Bit is Don't Care.

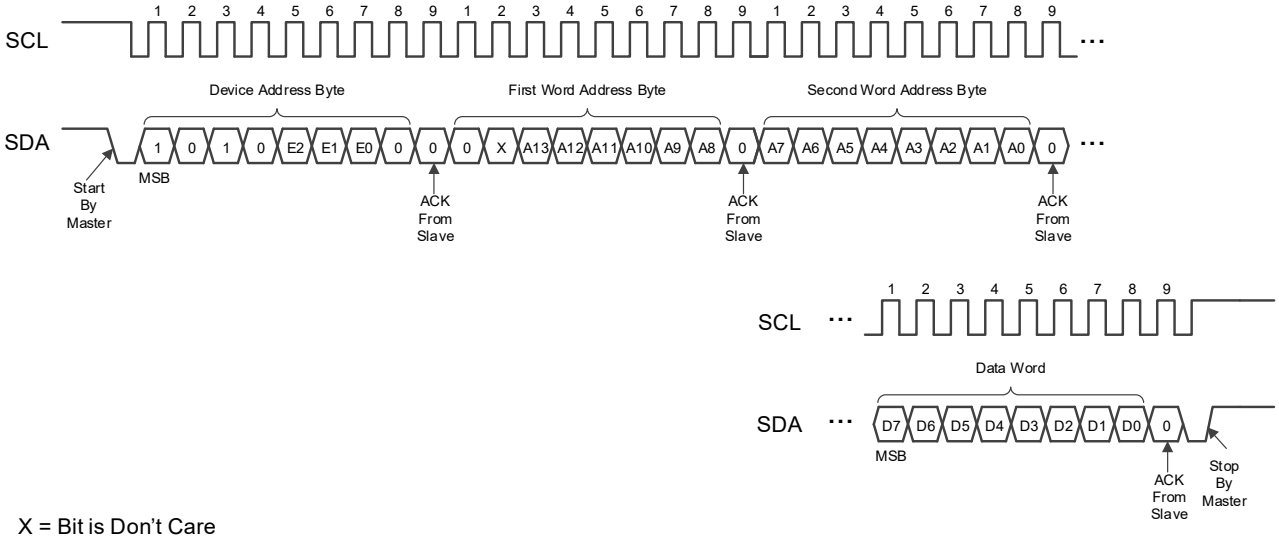
READ AND WRITE OPERATIONS

Write Operations

Byte Write

For a Byte Write operation, the Master sends a Start condition followed by the device type identifier of '1010', the device address bits and the R/$\overline{W}$ select bit set to Logic 0. The TD24C128-C responds with an ACK during the ninth clock cycle and waits for the Master to send two word address bytes (first word address byte and second word address byte). Then the device responds to each word address byte with an ACK. After receiving ACKs from the device, the Master transmits one data byte. If the addressed location has been Write-protected, the device responds with an NACK, and the addressed location will not be modified. If the addressed location is not Write-protected, the device responds with an ACK. The Master ends the Byte Write sequence with a Stop condition during the 10th clock cycle to initiate the internally self-timed write cycle (see Figure 6). A Stop condition issued during any other clock cycle during the Write operation will not trigger the internal write cycle.

Once the write cycle begins, the preloaded data word will be programmed in the amount of time not to exceed the t_{WR} specification (see Figure 8). During the time, the Master should wait a fixed time by the t_{WR} specification, or for time sensitive applications, an ACK polling routine can be implemented. All inputs are ignored by the device during the write cycle and the device will not respond until the write cycle is completed. The serial EEPROM will increment its internal address counter each time a byte is written.



X = Bit is Don't Care

Figure 6. Byte Write

READ AND WRITE OPERATIONS (continued)

Page Write

The 128-Kbit serial EEPROM is capable of writing up to 64 data bytes at a time by executing the Page Write protocol sequence. A partial or full Page Write operation is initiated the same as a Byte Write operation except that the Master does not send a Stop condition after the first data word is clocked in. Instead, after the device has acknowledged to the first data word, the Master can transmit up to sixty-three more data words. The device responds with an ACK after each data word is received if the addressed locations are not Write-protected. If the addressed locations have been Write-protected, the device responds with an NACK to each data word and the addressed locations will not be modified. After the device acknowledges to the last data word, the Master should terminate the Page Write sequence with a Stop condition to start the internal write cycle (see Figure 7). A Stop condition issued at any other clock cycle will not initiate the internally self-timed write cycle and the Write sequence will have to be repeated again. Once the write cycle begins, the data words should be programmed in the amount of time not exceeding the t_{WR} specification (see Figure 8). During this time, the Master should wait a fixed time by the t_{WR} specification, or for time sensitive applications, an ACK polling routine can be implemented.

The lower six bits of the word address are internally incremented following the receipt of each data word. The higher word address bits are not incremented, retaining the memory page row location. When the internally generated word address reaches the page boundary, the following data word will be placed at the beginning of the same page. If more than sixty-four data words are transmitted to the device, the data word address will roll over and the previous data will be overwritten. The address roll-over during a Write sequence is from the last byte of the current page to the first byte of the same page.

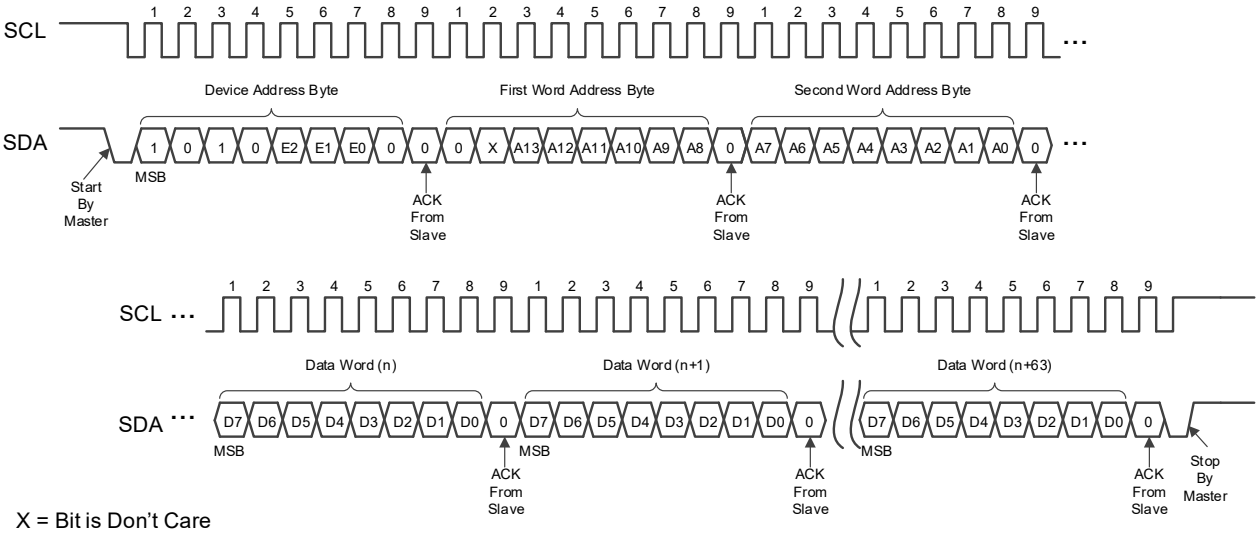


Figure 7. Page Write

Write Cycle Timing

The length of the self-timed write cycle, or t_{WR}, is defined as the amount of time from a valid Stop condition that begins the internal write sequence to the Start condition of the first device address byte sent to the TD24C128-C that it subsequently responds to with an ACK (see Figure 8).

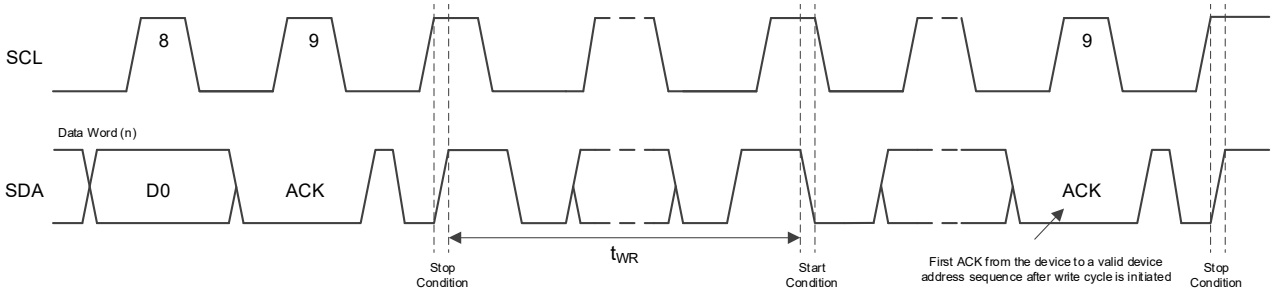


Figure 8. Write Cycle Timing

READ AND WRITE OPERATIONS (continued)

Acknowledge (ACK) Polling

An ACK polling routine can be implemented to optimize time sensitive applications that would not prefer to wait the fixed maximum write cycle time but would prefer to know immediately when the serial EEPROM write cycle has completed to start a subsequent operation. Once the internally self-timed write cycle has started, the device inputs are disabled and ACK polling can be initiated. An ACK polling routine involves sending a valid Start condition followed by the device address byte. While the write cycle is in progress, the device will not respond with an ACK, indicating the device is busy writing data. Once completed, the device returns an ACK and the next device operation can be started (see Figure 9).

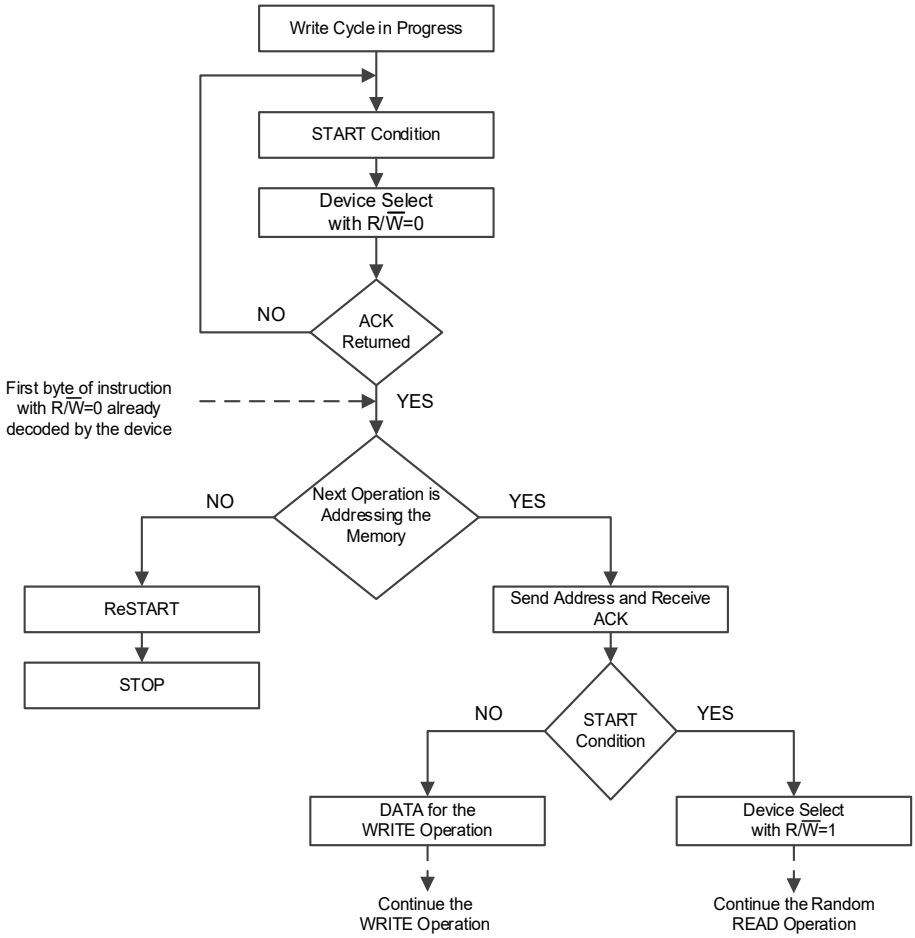


Figure 9. Acknowledge Polling Flow Chart

READ AND WRITE OPERATIONS (continued)

Write Identification Page

The TD24C128-C offers a 64-byte Identification Page (ID Page) in addition to the 128-Kbit memory array for storage of specific application data. This Identification Page can be written and permanently locked in Read-only mode after the data is written into this Page. The Identification Page is written by issuing the Write Identification Page instruction (see Figure 10), which uses the same protocol and format as Page Write, except that:

- The device type identifier is defined as '1011';
- The word address bits A10:A9 must be '00', bits A15:A11 and A8:A6 are Don't Care;
- The word address bits A5:A0 define the byte locations inside the ID Page (see Table 3).

If the Identification Page has been locked, the data bytes transferred during the Write Identification Page instruction will not be acknowledged.

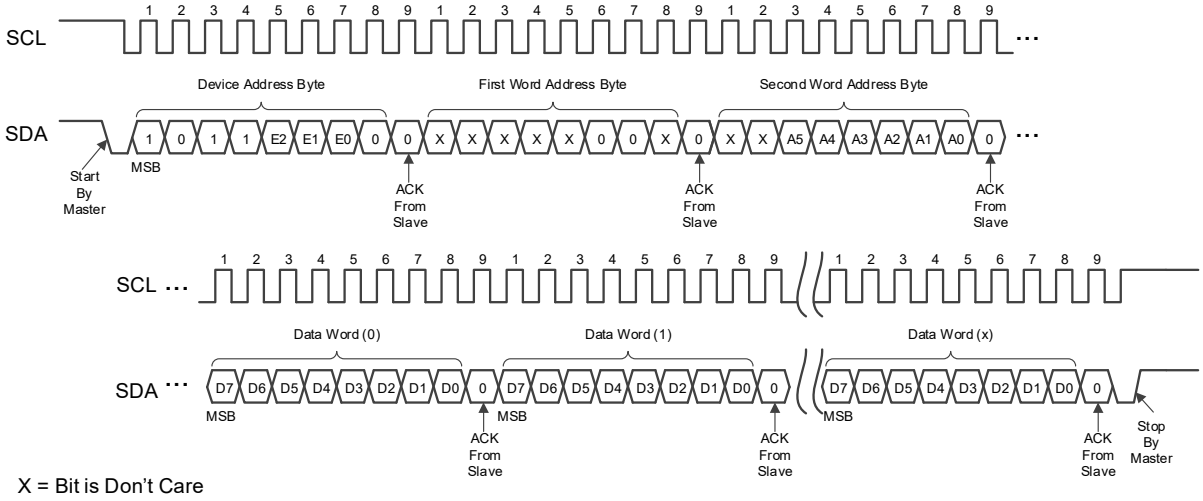


Figure 10. Write Identification Page

Lock Identification Page

The Lock Identification Page (Lock ID) instruction permanently locks the Identification Page in Read-only mode. The Lock ID instruction is similar to Byte Write, except the following specific conditions:

- The device type identifier is defined as '1011';
- The word address bits A10:A9 must be '10' and other word address bits are Don't Care;
- The data byte must be equal to the binary value xxxx_xx1x, where 'x' is Don't Care (see Figure 11).

Once a valid Lock ID instruction has been executed, if another Lock ID instruction is issued, the device will respond with an NACK to the data word byte.

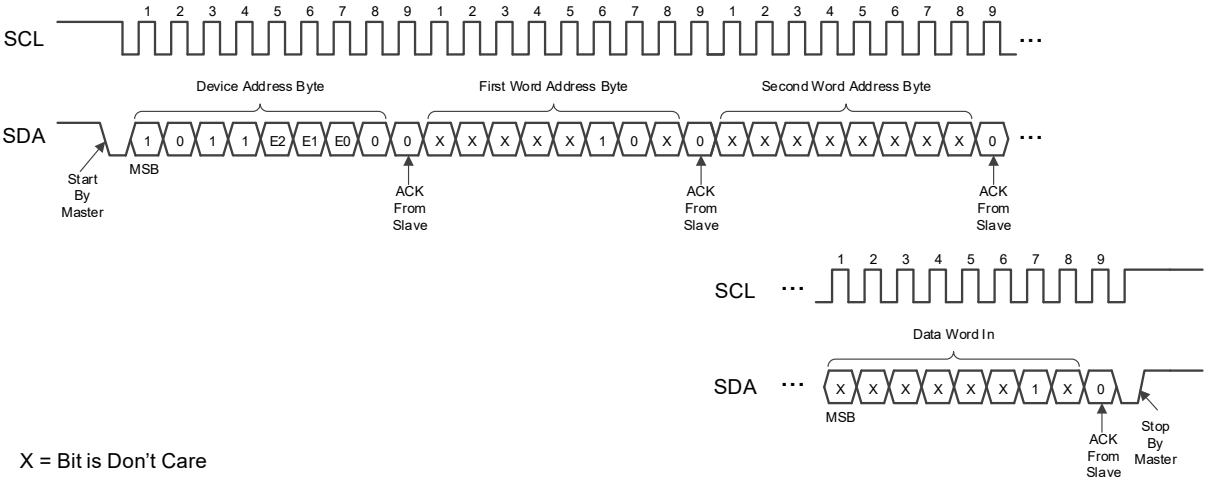


Figure 11. Lock Identification Page

READ AND WRITE OPERATIONS (continued)

Write Software Write Protection (SWP) Register

By writing specific values in a register located at address 101x_xxxx_xxxx_xxxxb (where 'x' is Don't Care), the 128-Kbit memory array can be Write-protected by blocks, which size can be defined as:

- The upper quarter memory array (memory address: 3000h to 3FFFh);
- The upper half memory array (memory address: 2000h to 3FFFh);
- The upper 3/4 memory array (memory address: 1000h to 3FFFh);
- The whole memory array (memory address: 0000h to 3FFFh).

Writing in the Software Write Protection register is performed with a Write SWP Register instruction. The Write SWP Register instruction is similar to Byte Write, except that the word address bits A15:A13 must be '101' and other word address bits are Don't Care (see Figure 12). The higher four bits of the data word byte are Don't Care; bit 3 enables or disables the Software Write Protection feature; bit 2 and bit 1 define the size of Write-protected memory block to be against Write instructions; bit 0 locks or unlocks the SWP status (see Table 4). If the value of bit 0 is '1', bit 3 to bit 1 cannot be modified by the Write SWP Register instruction and the data byte transferred during the instruction will not be acknowledged. Under the SWP locked status (bit 0 is '1'), a Write SWP Register instruction with a data byte of xxxx_xxxD0b (where 'x' is Don't Care and D0 is '0') can be issued to unlock the SWP register, but other bits in the SWP register will not be modified during this unlock operation. Writing more than one byte will discard the write cycle and the content in the SWP register will not be changed.

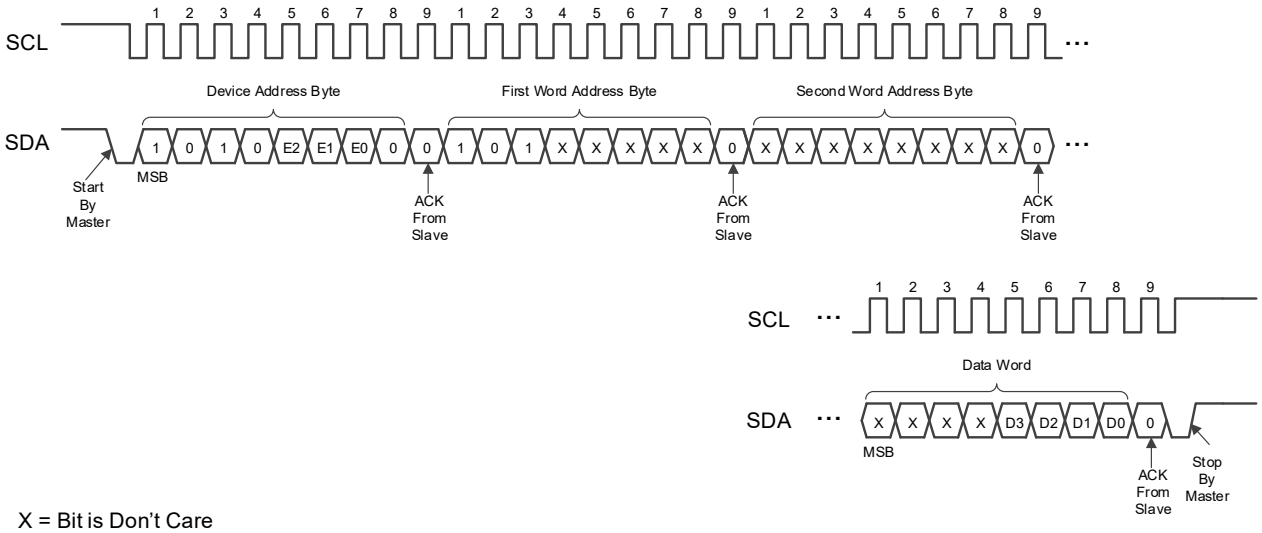


Figure 12. Write Software Write Protection Register

Table 4. Software Write Protection Register (Address 101x_xxxx_xxxx_xxxxb)

	REGISTER DATA BYTE							
	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
Write	X (1)	X	X	X	Write Protect Activation 0: the whole memory can be written (no Write protection) 1: the concerned block is write-protected	Size of Write-protected Block 00: the upper quarter memory is write-protected 01: the upper half memory is write-protected 10: the upper 3/4 memory is write-protected 11: the whole memory is write-protected		Write Protect Lock 0: bit 3 to bit 0 can be modified 1: bit 3 to bit 1 cannot be modified and the write protection is frozen
Read	0	0	0	0				

NOTE: 1. X = Bit is Don't Care.

READ AND WRITE OPERATIONS (continued)

Write Device Address Configuration (DAC) Register

The three-bit Device Address of TD24C128-C is defined by the value stored in a register located at address 110x_xxxx_xxxx_xxxxb (where 'x' is Don't Care) and is software programmable. Writing in the Device Address Configuration register is performed with a Write DAC Register instruction. The Write DAC Register instruction is similar to Byte Write, except that the word address bits A15:A13 must be '110' and other word address bits are Don't Care (see Figure 13). The higher four bits of the data word byte are Don't Care; bit 3 defines whether the device is selected by the Device Address Configuration; bit 2, bit 1 and bit 0 define the Device Address E2, E1 and E0 (see Table 5).

Note that the software device address bits (E2, E1 and E0) must match the corresponding address data (bit 2, bit 1 and bit 0) when the value of bit 3 in the DAC register is '0' (which means the device is selected by Device Address Configuration). After a valid Write DAC Register instruction is executed and the values of bit 2, bit 1 and bit 0 in the DAC register are reconfigured, the Master should send new device address bits for the subsequent instructions, otherwise the device responds with an NACK.

If the value of bit 0 in the SWP register is '1' (see Table 4), the DAC register is also locked as the SWP register, and the data word byte transferred during the Write DAC Register instruction will not be acknowledged. To unlock the DAC register, a Write SWP Register instruction with a specific data byte of xxxx_xxx0b (where 'x' is Don't Care) is needed (see ***Write Software Write Protection (SWP) Register*** section).

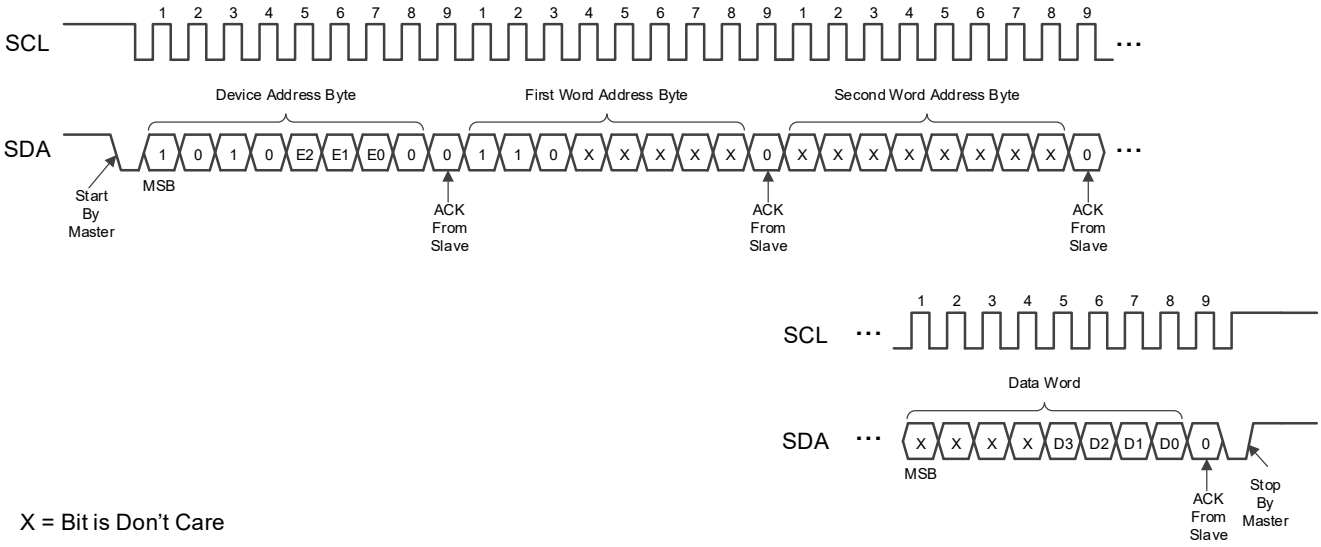


Figure 13. Write Device Address Configuration Register

Table 5. Device Address Configuration Register (Address 110x_xxxx_xxxx_xxxxb)

	REGISTER DATA BYTE							
	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
Write	X (1)	X	X	X	Device Address Exclusion 0: the device can be selected by DAC (bit 2 to bit 0) 1: the device can be selected by any device address	Device Address E2, E1, E0		
Read	0	0	0	0				

NOTE: 1. X = Bit is Don't Care.

READ AND WRITE OPERATIONS (continued)

Read Operations

All Read operations are initiated by the Master transmitting a Start condition, a device type identifier of '1010' or '1011', three software device address bits (E2, E1, E0) that match corresponding Device Address Configuration, and the R/W select bit with Logic 1 state. In the following clock cycle, the TD24C128-C should respond with an ACK. The subsequent protocol depends on the type of Read operation desired. There are three Read operations for memory array: Current Address Read, Random Address Read, and Sequential Read with the device type identifier of '1010'; three Read operations for Identification Page and Unique ID: Read Identification Page, Read the Lock Status, and Read Unique ID with the device type identifier of '1011'; two Read operations for functional registers: Read SWP register and Read DAC register with the device type identifier of '1010'.

Current Address Read

For a Current Address Read operation, the Master sends a Start condition followed by transmitting the device address byte with the R/W bit set to Logic 1 (see Figure 14). The TD24C128-C should respond with an ACK and then serially transmits the data word addressed by the internal address counter. This address maintained by the internal address counter is the last address accessed during the last Read or Write operation. The counter is then incremented by one and the address will stay valid between operations as long as power to the device is supplied. The address roll-over during a Read operation is from the last byte of the last page to the first byte of the first page. To end the command, the Master responds with an NACK followed by a Stop condition.

Note that the address counter value is defined by instructions accessing the memory or the Identification Page or the Unique ID or the SWP/DAC register. For example, when accessing the ID Page, the counter value is loaded with the byte location in the ID Page. Therefore the next Current Address Read in the memory uses this new address counter value. When accessing the memory, it is recommended to always use the Random Read instruction (see ***Random Read*** section) instead of the Current Address Read instruction.

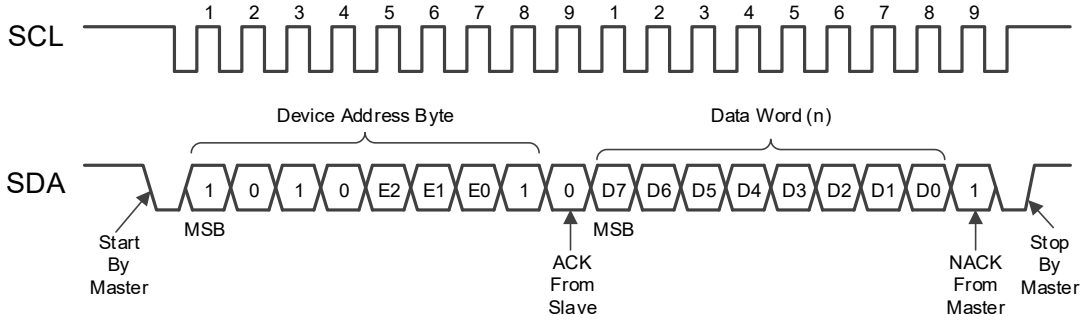


Figure 14. Current Address Read

READ AND WRITE OPERATIONS (continued)

Random Read

A Random Read operation allows the Master to access any memory location in a random manner and requires a dummy write sequence to preload the starting data word address. To perform a Random Read, the device address byte and the word address bytes are transmitted to the TD24C128-C as part of the dummy write sequence (see Figure 15). Once the device address byte and word address bytes are clocked in and acknowledged by the TD24C128-C, the Master must generate another Start condition. The Master initiates a Current Address Read by sending another device address byte with the R/$\overline{W}$ bit set to Logic 1. The TD24C128-C responds with an ACK to the device address byte and serially clocks out the first data word and increments its internal address counter. The device will continue to transmit sequential data words as long as the Master continues to acknowledge each data word. To end the sequence, the Master responds with an NACK followed by a Stop condition.

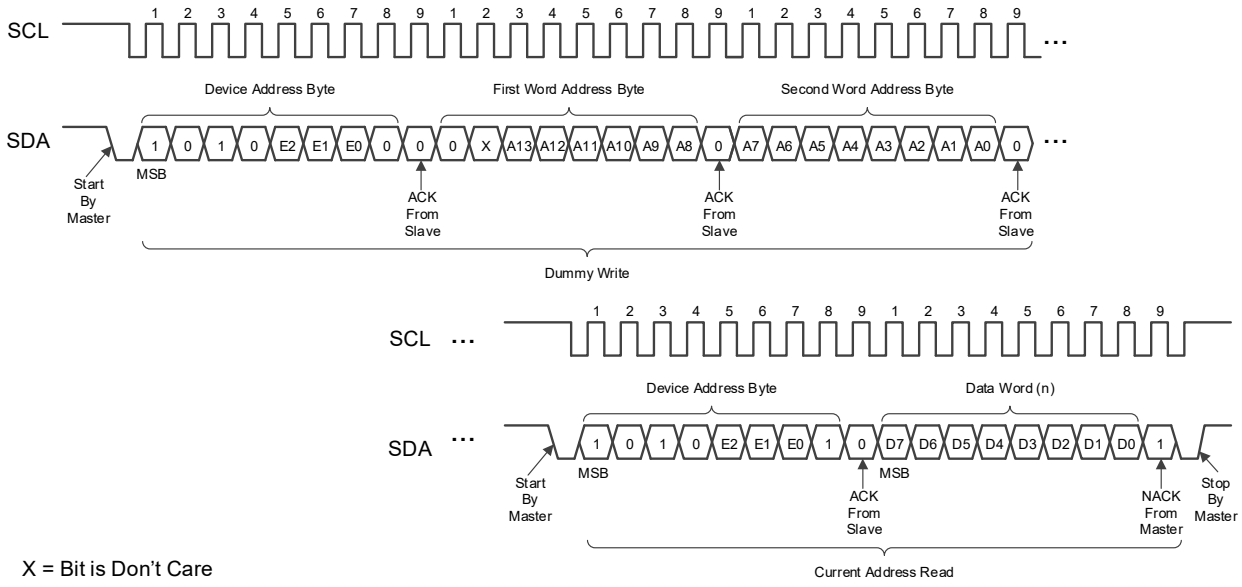


Figure 15. Random Read

Sequential Read

A Sequential Read operation is initiated in the same way as either a Current Address Read or a Random Read, except that after the TD24C128-C transmitting the first data word, the Master responds with an ACK instead of an NACK. As long as the TD24C128-C receives an ACK, it will continue to increment the data word address and serially clock out the sequential data words (see Figure 16). When the internal address counter is at the last byte of the last page, the word address will roll over to the beginning of the memory array and the Sequential Read operation will continue. The Sequential Read operation is terminated by the Master responding with an NACK followed by a Stop condition.

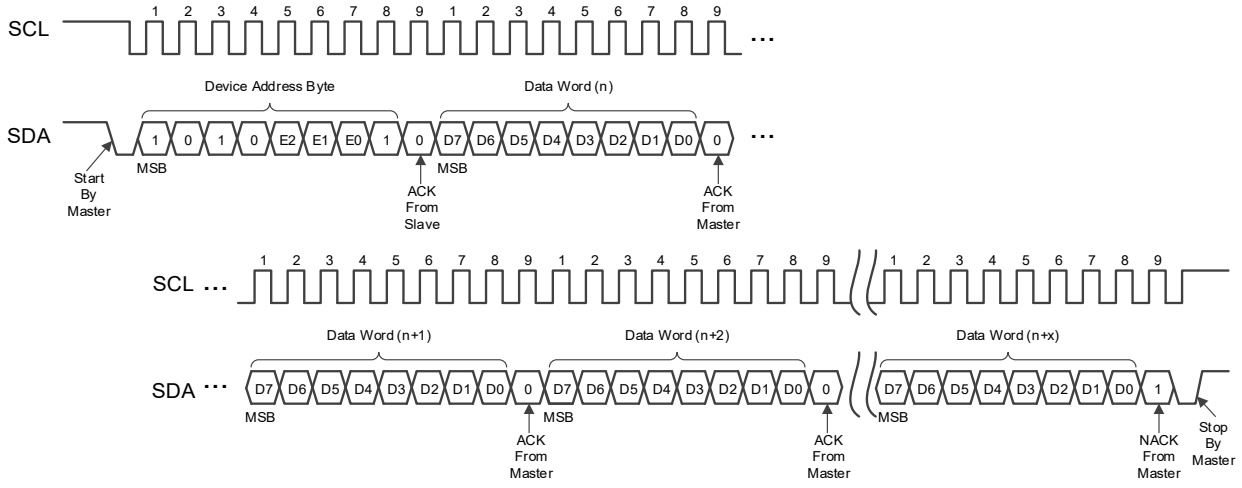


Figure 16. Sequential Read

READ AND WRITE OPERATIONS (continued)

Read Identification Page

The Identification Page can be read by issuing a Read Identification Page instruction. This instruction uses the same protocol and format as Random Read, except that:

- The device type identifier is defined as '1011';
- The word address bits A10:A9 must be '00', bits A15:A11 and A8:A6 are Don't Care;
- The word address bits A5:A0 define the byte locations inside the ID Page (see Table 3).

When the end of Identification Page is reached, the word address will roll over to the beginning of the Identification Page. The Read Identification Page operation is terminated by the Master responding with an NACK followed by a Stop condition (see Figure 17).

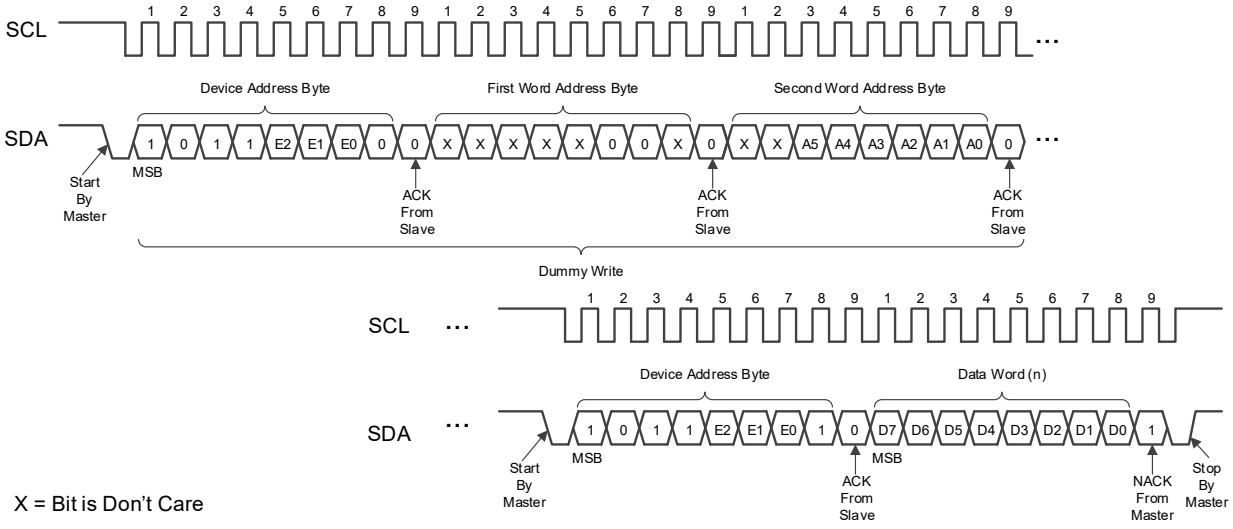


Figure 17. Read Identification Page

Read Lock Status

The locked/unlocked status of the Identification Page can be checked by transmitting a specific truncated command, Write Identification Page instruction and one data byte to the device. The device responds with an ACK to the data byte if the Identification Page is unlocked, or responds with an NACK if the Identification Page has been locked. Right after this, it is recommended to transmit a Start condition to the device followed by a Stop condition (see Figure 18), so that the truncated Write command will not be executed because the Start condition resets the device internal logic, and the device is then set back into Standby mode by the Stop condition.

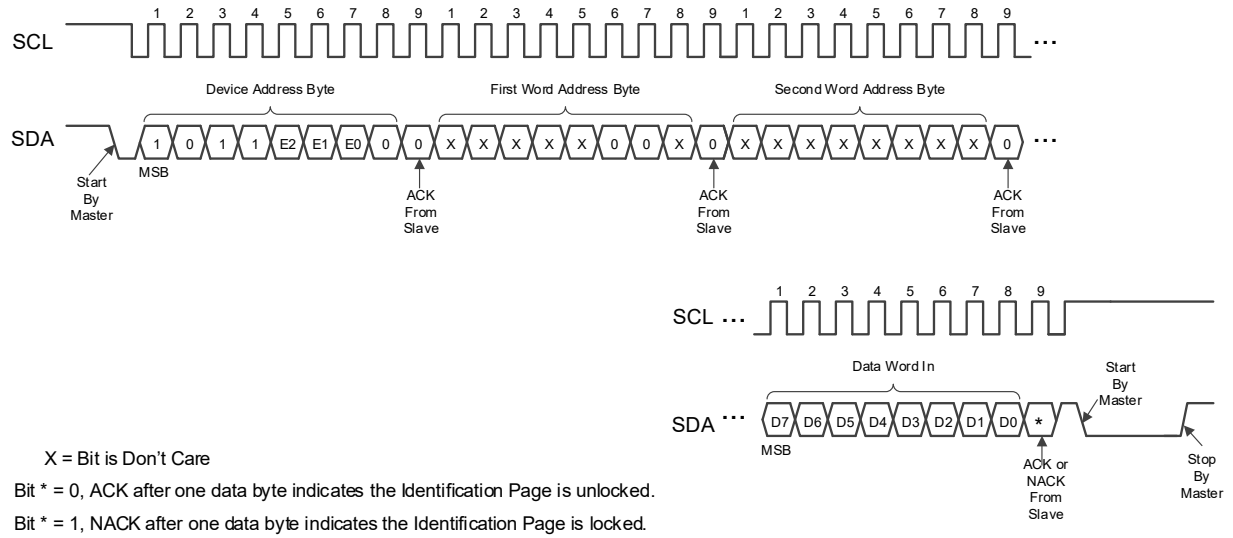


Figure 18. Read Lock Status

READ AND WRITE OPERATIONS (continued)

Read Unique ID

The TD24C128-C offers a separate memory block containing a factory programmed 128-bit Unique ID (UID), or Serial Number. Reading the Serial Number is similar to Sequential Read, except that:

- The device type identifier is defined as ‘1011’;
- The word address bits A10:A9 must be ‘01’, bits A15:A11 and A8:A4 are Don't Care;
- The word address bits A3:A0 define the byte locations inside the Unique ID (see Table 3).

In order to guarantee a unique number, the entire 128-bit value must be read from the starting address of the Serial Number block. To read the first byte of the Serial Number, the word address bits A3:A0 need to be ‘0000’. Writing or altering the 128-bit Unique ID is not allowed. When the end of the 128-bit UID block is reached (16 bytes of data), the word address will roll over to the beginning of the 128-bit UID block. The Read Unique ID operation is terminated when the Master responds with an NACK to the data byte followed by a Stop condition (see Figure 19).

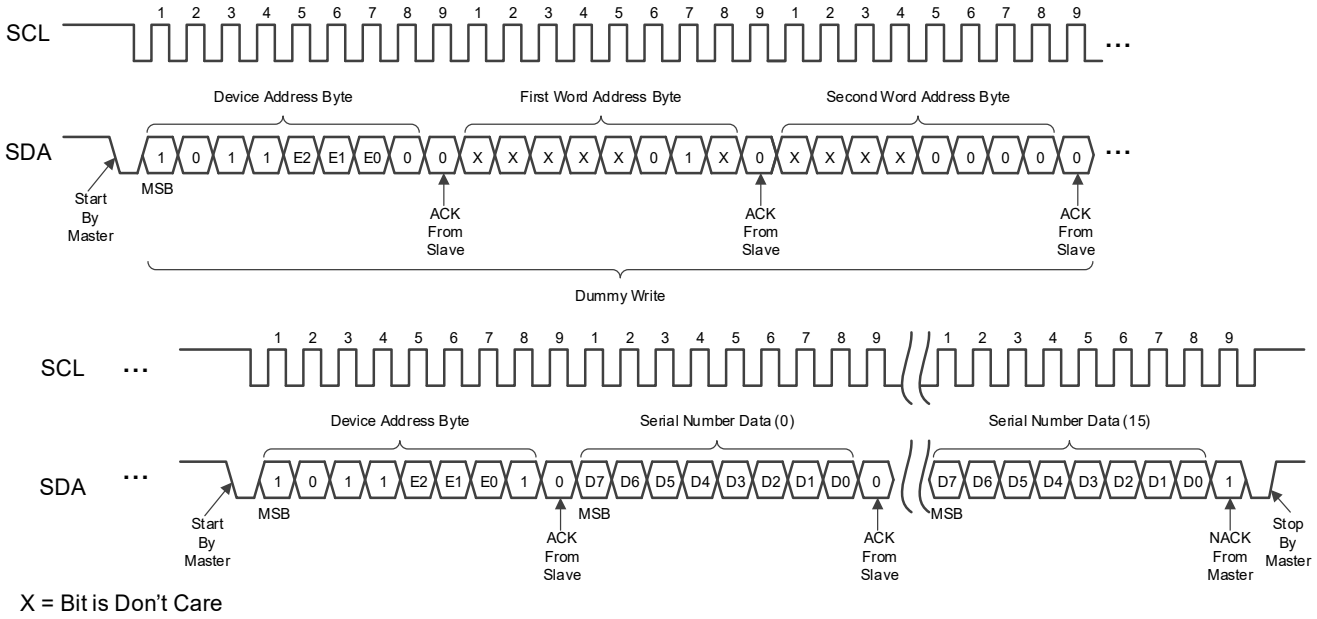


Figure 19. Read Unique ID

READ AND WRITE OPERATIONS (continued)

Read SWP Register

Reading the Software Write Protection register is performed with a Read SWP Register instruction, which is similar to Random Read except that the word address bits A15:A13 must be '101' and other word address bits are Don't Care (see Figure 20). The higher four bits of the SWP register content are read as '0000'. The lower four bits (bit 3, bit 2, bit 1, and bit 0) are defined in ***Write Software Write Protection (SWP) Register*** section. Reading more than one byte will loop on reading the SWP register value.

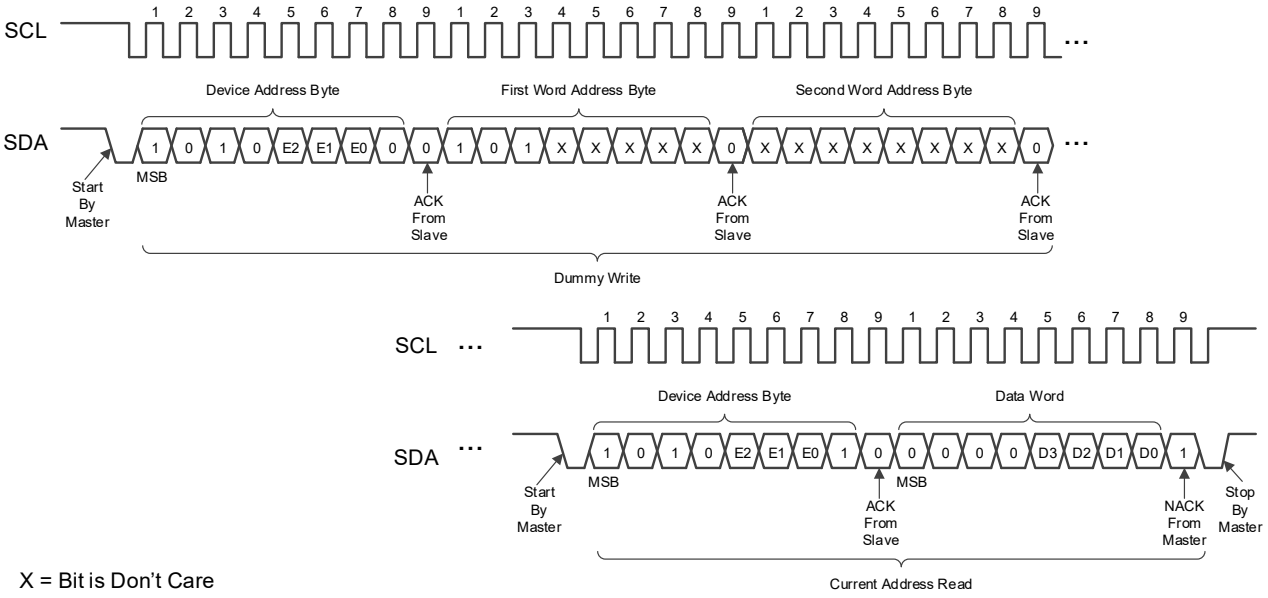


Figure 20. Read SWP Register

Read DAC Register

Reading the Device Address Configuration register is performed with a Read DAC Register instruction, which is similar to Random Read except that the word address bits A15:A13 must be '110' and other word address bits are Don't Care (see Figure 21). The higher four bits of the DAC register content are read as '0000'. The lower four bits (bit 3, bit 2, bit 1, and bit 0) are defined in ***Write Device Address Configuration (DAC) Register*** section. Bit 2, bit 1 and bit 0 are expected to be the same with the three-bit Device Address if the value of bit 3 is '0'. Reading more than one byte will loop on reading the DAC register value.

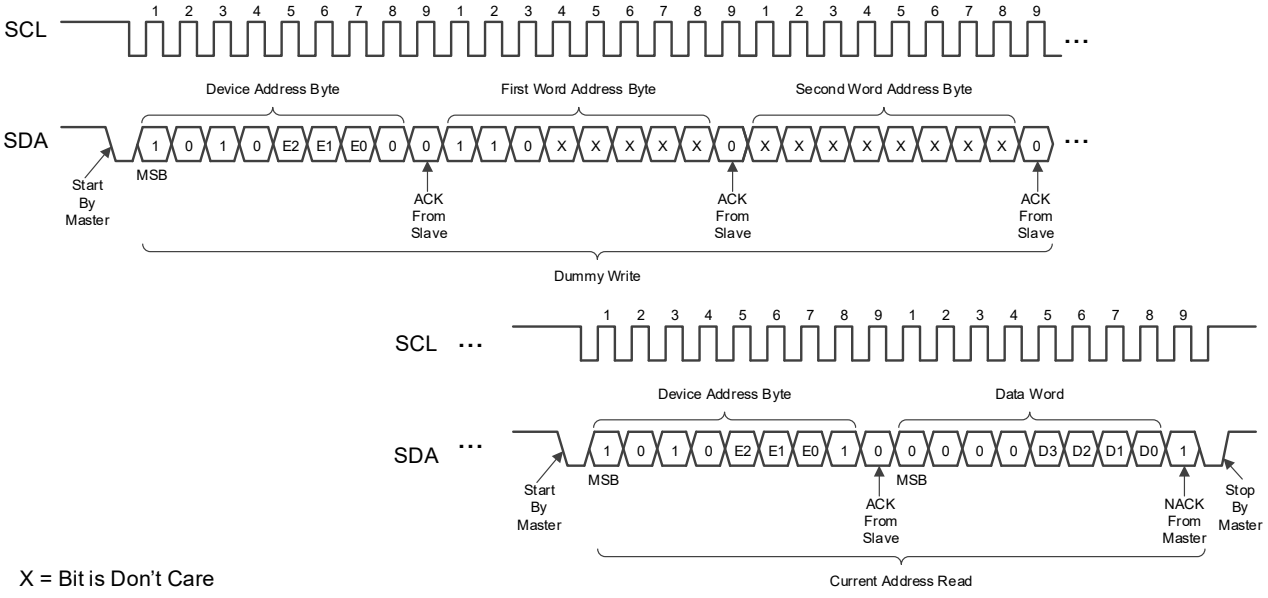


Figure 21. Read DAC Register

INITIAL DELIVERY STATE

The TD24C128-C serial EEPROM is delivered as follows:

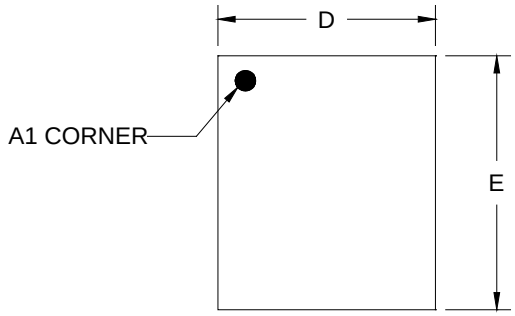
- All bits in the memory array are set to ‘1’ (each byte contains FFh).
- All bits in the Identification Page are set to ‘1’ (each byte contains FFh).
- All bits in the SWP register and DAC register are set to ‘0’.

REVISION HISTORY

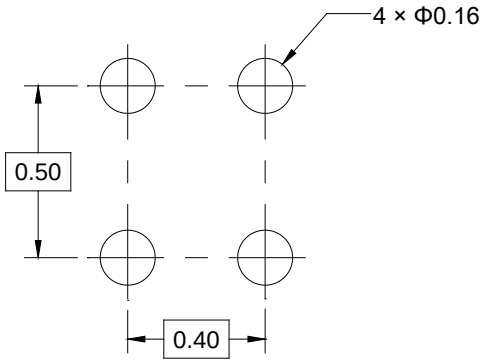
REVISION	DATE	COMMENTS
REV.A	Jul. 2019	Initial version release
REV.A.1	Sep. 2019	Updated: — I_{CC} and I_{SB} value in *DC Characteristics* table
REV.A.2	Aug. 2020	Updated: —*ABSOLUTE MAXIMUM RATINGS* section
REV.A.3	Mar. 2024	Removed: — *4-Ball 400 x 400μm WLCSP Package Information* Updated: — *FEATURES* — V_{BOR} and t_{INIT} value in Table 1
REV.A.4	Oct. 2026	Updated: — Operating Temperature Range — Package Outline Dimensions Added: — N_W at T_A = +125℃, Page mode — Tape and Reel Information

PACKAGE OUTLINE DIMENSIONS

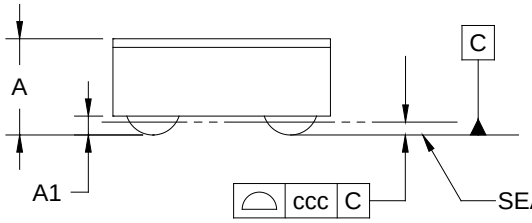
WLCSP-0.63×0.74-4B



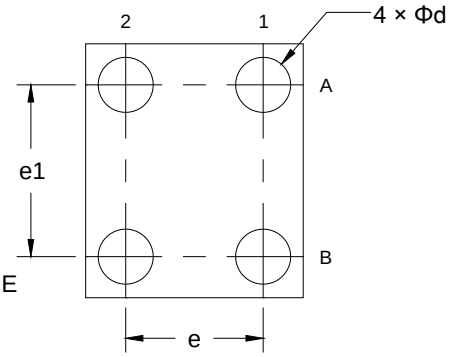
TOP VIEW



RECOMMENDED LAND PATTERN (Unit: mm)



SIDE VIEW



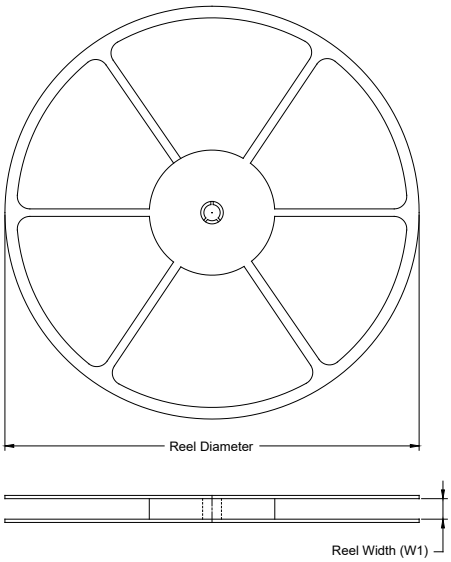
BOTTOM VIEW

Symbol	Dimensions In Millimeters		
	MIN	NOM	MAX
A	-	-	0.301
A1	0.045	-	0.065
D	0.603	-	0.663
E	0.709	-	0.769
d	0.130	-	0.190
e	0.400 BSC		
e1	0.500 BSC		
ccc	0.050		

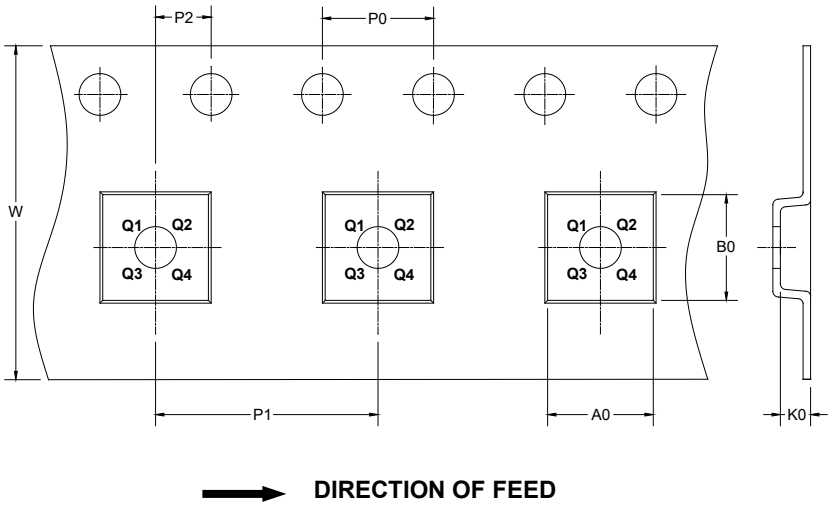
NOTE: This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



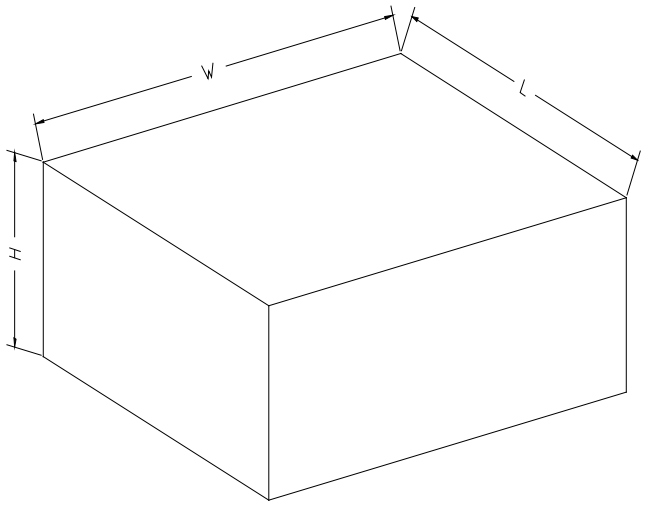
NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
WLCSP-0.63×0.74-4B	7"	8.6	0.73	0.84	0.39	4.0	4.0	2.0	8.0	Q1

DD0001

CARTON BOX DIMENSIONS



NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
7″ (Option)	368	227	224	8
7″	442	410	224	18

DD0002