CAT24C164
16-Kb CMOS Serial EEPROM, Cascadable

HALOGEN FREE
LEAD FREE™
RoHS Compliance

FEATURES

- **Supports Standard and Fast I^{2}C Protocol**
- **1.8 V to 5.5 V Supply Voltage Range**
- **16-Byte Page Write Buffer**
- **Hardware Write Protection for entire memory**
- **Schmitt Triggers and Noise Suppression Filters on I^{2}C Bus Inputs (SCL and SDA).**
- **Low power CMOS technology**
- **1,000,000 program/erase cycles**
- **100 year data retention**
- **Industrial temperature range**
- **RoHS-compliant 8-lead PDIP, SOIC, TSSOP and 8-pad TDFN packages.**

For Ordering Information details, see page 15.

DEVICE DESCRIPTION

The CAT24C164 is a 16-Kb CMOS cascadable Serial EEPROM device organized internally as 128 pages of 16 bytes each, for a total of 2048x8 bits. The device supports both the Standard (100 kHz) as well as Fast (400 kHz) I^{2}C protocol.

Data is written by providing a starting address, then loading 1 to 16 contiguous bytes into a Page Write Buffer, and then writing all data to non-volatile memory in one internal write cycle. Data is read by providing a starting address and then shifting out data serially while automatically incrementing the internal address count.

External address pins make it possible to address up to eight CAT24C164 devices on the same bus.
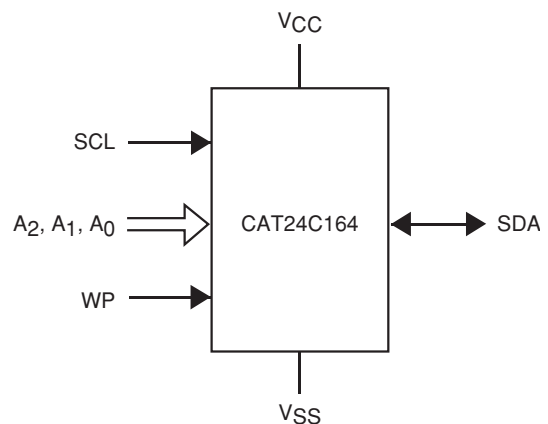
PIN CONFIGURATION

PDIP (L)
SOIC (W)
TSSOP (Y)
TDFN (VP2)

A_0	1	8	V_{CC}
A_1	2	7	WP
A_2	3	6	SCL
V_{SS}	4	5	SDA

For the location of Pin 1, please consult the corresponding package drawing.

PIN FUNCTIONS

A_0, A_1, A_2	Device Address Inputs
SDA	Serial Data Input/Output
SCL	Serial Clock Input
WP	Write Protect Input
V_{CC}	Power Supply
V_{SS}	Ground

FUNCTIONAL SYMBOL

V_{CC}

SCL

A_2, A_1, A_0

CAT24C164

SDA

WP

V_{SS}

* Catalyst carries the I^{2}C protocol under a license from the Philips Corporation.

ABSOLUTE MAXIMUM RATINGS[1]

Storage Temperature	-65°C to +150°C
Voltage on Any Pin with Respect to Ground[2]	-0.5 V to +6.5 V

RELIABILITY CHARACTERISTICS[3]

Symbol	Parameter	Min	Units
N_{END}[4]	Endurance	1,000,000	Program/ Erase Cycles
T_{DR}	Data Retention	100	Years

D.C. OPERATING CHARACTERISTICS

V_{CC} = 1.8 V to 5.5 V, T_A = -40°C to 85°C, unless otherwise specified.

Symbol	Parameter	Test Conditions	Min	Max	Units
I_{CCR}	Read Current	Read, f_{SCL} = 400 kHz		1	mA
I_{CCW}	Write Current	Write, f_{SCL} = 400 kHz		1	mA
I_{SB}	Standby Current	All I/O Pins at GND or V_{CC}		1	µA
I_L	I/O Pin Leakage	Pin at GND or V_{CC}		1	µA
V_{IL}	Input Low Voltage		-0.5	V_{CC} x 0.3	V
V_{IH}	Input High Voltage		V_{CC} x 0.7	V_{CC} + 0.5	V
V_{OL1}	Output Low Voltage	V_{CC} ≥ 2.5 V, I_{OL} = 3.0 mA		0.4	V
V_{OL2}	Output Low Voltage	V_{CC} < 2.5 V, I_{OL} = 1.0 mA		0.2	V

PIN IMPEDANCE CHARACTERISTICS

V_{CC} = 1.8 V to 5.5 V, T_A = -40°C to 85°C, unless otherwise specified.

Symbol	Parameter	Conditions	Max	Units
C_{IN}[3]	SDA I/O Pin Capacitance	V_{IN} = 0 V	8	pF
C_{IN}[3]	Input Capacitance (other pins)	V_{IN} = 0 V	6	pF
I_{WP}[5]	WP Input Current	V_{IN} < V_{IH}, V_{CC} = 5.5 V	200	µA
		V_{IN} < V_{IH}, V_{CC} = 3.3 V	150	
		V_{IN} < V_{IH}, V_{CC} = 1.8 V	100	
		V_{IN} > V_{IH}	1	

Note:

(1) Stresses above 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 outside of those listed in the operational sections of this specification is not implied. Exposure to any absolute maximum rating for extended periods may affect device performance and reliability.

(2) The DC input voltage on any pin should not be lower than -0.5 V or higher than V_{CC} + 0.5 V. During transitions, the voltage on any pin may undershoot to no less than -1.5 V or overshoot to no more than V_{CC} + 1.5 V, for periods of less than 20 ns.

(3) These parameters are tested initially and after a design or process change that affects the parameter according to appropriate AEC-Q100 and JEDEC test methods.

(4) Page Mode, V_{CC} = 5 V, 25°C

(5) When not driven, the WP pin is pulled down to GND internally. For improved noise immunity, the internal pull-down is relatively strong; therefore the external driver must be able to supply the pull-down current when attempting to drive the input HIGH. To conserve power, as the input level exceeds the trip point of the CMOS input buffer (~ 0.5 x V_{CC}), the strong pull-down reverts to a weak current source.

A.C. CHARACTERISTICS[1]

V_{CC} = 1.8 V to 5.5 V, T_{AI} = -40°C to 85°C.

Symbol	Parameter	Standard		Fast		Units
		Min	Max	Min	Max	
F_{SCL}	Clock Frequency		100		400	kHz
$t_{HD:STA}$	START Condition Hold Time	4		0.6		μs
t_{LOW}	Low Period of SCL Clock	4.7		1.3		μs
t_{HIGH}	High Period of SCL Clock	4		0.6		μs
$t_{SU:STA}$	START Condition Setup Time	4.7		0.6		μs
$t_{HD:DAT}$	Data In Hold Time	0		0		μs
$t_{SU:DAT}$	Data In Setup Time	250		100		ns
t_R	SDA and SCL Rise Time		1000		300	ns
t_F[2]	SDA and SCL Fall Time		300		300	ns
$t_{SU:STO}$	STOP Condition Setup Time	4		0.6		μs
t_{BUF}	Bus Free Time Between STOP and START	4.7		1.3		μs
t_{AA}	SCL Low to Data Out Valid		3.5		0.9	μs
t_{DH}	Data Out Hold Time	100		100		ns
T_i[2]	Noise Pulse Filtered at SCL and SDA Inputs		100		100	ns
$t_{SU:WP}$	WP Setup Time	0		0		μs
$t_{HD:WP}$	WP Hold Time	2.5		2.5		μs
t_{WR}	Write Cycle Time		5		5	ms
t_{PU}[2, 3]	Power-up to Ready Mode		1		1	ms

Note:

(1) Test conditions according to "A.C. Test Conditions" table.

(2) Tested initially and after a design or process change that affects this parameter.

(3) t_{PU} is the delay between the time V_{CC} is stable and the device is ready to accept commands.

A.C. TEST CONDITIONS

Input Levels	0.2 x V_{CC} to 0.8 x V_{CC}
Input Rise and Fall Times	≤ 50 ns
Input Reference Levels	0.3 x V_{CC}, 0.7 x V_{CC}
Output Reference Levels	0.5 x V_{CC}
Output Load	Current Source: I_{OL} = 3 mA ($V_{CC} \geq$ 2.5 V); I_{OL} = 1 mA ($V_{CC} <$ 2.5 V); C_L = 100 pF

POWER-ON RESET (POR)

CAT24C164 incorporates Power-On Reset (POR) circuitry which protects the internal logic against powering up in the wrong state.

A CAT24C164 device will power up into Standby mode after V_{CC} exceeds the POR trigger level and will power down into Reset mode when V_{CC} drops below the POR trigger level. This bi-directional POR feature protects the device against 'brown-out' failure following a temporary loss of power.

PIN DESCRIPTION

SCL: The Serial Clock input pin accepts the Serial Clock generated by the Master.

SDA: The Serial Data I/O pin receives input data and transmits data stored in EEPROM. In transmit mode, this pin is open drain. Data is acquired on the positive edge, and is delivered on the negative edge of SCL.

A0, A1 and A2: The Address inputs set the device address when cascading multiple devices. When not driven, these pins are pulled LOW internally.

The CAT24C164 can be made compatible with the CAT24C16 by tying A2, A1 and A0 to V_{SS} or by leaving A2, A1 and A0 float.

WP: The Write Protect input pin inhibits all write operations, when pulled HIGH. When not driven, this pin is pulled LOW internally.

FUNCTIONAL DESCRIPTION

The CAT24C164 supports the Inter-Integrated Circuit (I2C) Bus data transmission protocol, which defines a device that sends data to the bus as a transmitter and a device receiving data as a receiver. Data flow is controlled by a Master device, which generates the serial clock and all START and STOP conditions. The CAT24C164 acts as a Slave device. Master and Slave alternate as either transmitter or receiver.

I²C BUS PROTOCOL

The I2C bus consists of two 'wires', SCL and SDA. The two wires are connected to the V_{CC} supply via pull-up resistors. Master and Slave devices connect to the 2-wire bus via their respective SCL and SDA pins. The transmitting device pulls down the SDA line to 'transmit' a '0' and releases it to 'transmit a '1'.

Data transfer may be initiated only when the bus is not busy (see A.C. Characteristics).

During data transfer, the SDA line must remain stable while the SCL line is HIGH. An SDA transition while SCL is HIGH will be interpreted as a START or STOP condition (Figure 1). The START condition precedes all commands. It consists of a HIGH to LOW transition on SDA while SCL is HIGH. The START acts as a 'wake-up' call to all receivers. Absent a START, a Slave will not respond to commands. The STOP condition completes all commands. It consists of a LOW to HIGH transition on SDA while SCL is HIGH.

Device Addressing

The bus Master begins a transmission by sending a START condition. The Master then sends the address of the particular Slave device it is requesting. The most significant bit of the 8-bit slave address is fixed as 1. (see Figure 2). The next three significant bits (A2, A1, A0) are the device address bits and define which device or which part of the device the Master is accessing (The A1 bit must be the compliment of the A1 input pin signal). Up to eight CAT24C164 devices may be individually addressed by the system. The next three bits are used as the three most significant bits of the data word address. The last bit of the slave address specifies whether a Read or Write operation is to be performed. When this bit is set to 1, a Read operation is selected, and when set to 0, a Write operation is selected.

Acknowledge

After processing the Slave address, the Slave responds with an acknowledge (ACK) by pulling down the SDA line during the 9th clock cycle (Figure 3). The Slave will also acknowledge the address byte and every data byte presented in Write mode. In Read mode the Slave shifts out a data byte, and then releases the SDA line during the 9th clock cycle. As long as the Master acknowledges the data, the Slave will continue transmitting. The Master terminates the session by not acknowledging the last data byte (NoACK) and by issuing a STOP condition. Bus timing is illustrated in Figure 4.

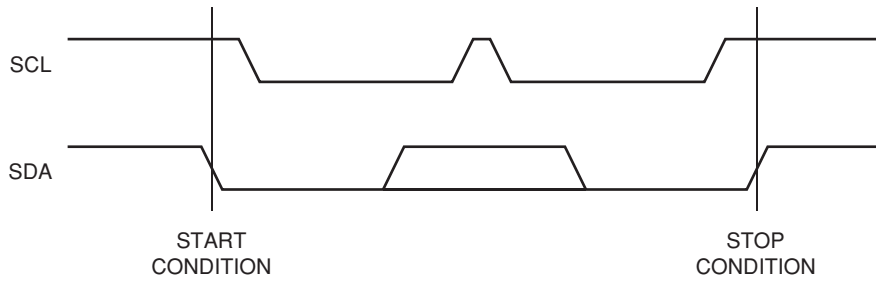## Figure 1. START/STOP Conditions

SCL

SDA

START
CONDITION
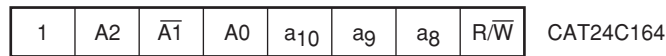
STOP
CONDITION

Figure 2. Slave Address Bits

1	A2	$\overline{A1}$	A0	a_{10}	a_9	a_8	$R/\overline{W}$

CAT24C164

Figure 3. Acknowledge Timing

BUS RELEASE DELAY (TRANSMITTER)

BUS RELEASE DELAY (RECEIVER)

SCL FROM
MASTER

1   8   9

DATA OUTPUT
FROM TRANSMITTER

DATA OUTPUT
FROM RECEIVER

START

ACK DELAY ($\leq t_{AA}$)

ACK SETUP ($\geq t_{SU:DAT}$)

Figure 4. Bus Timing

t_F t_{HIGH} t_R

t_{LOW} t_{LOW}

SCL

$t_{SU:STA}$

$t_{HD:DAT}$

$t_{SU:DAT}$

$t_{SU:STO}$

$t_{HD:STA}$

SDA IN

t_{AA} t_{DH} t_{BUF}

SDA OUT

Doc No. 1118, Rev. A
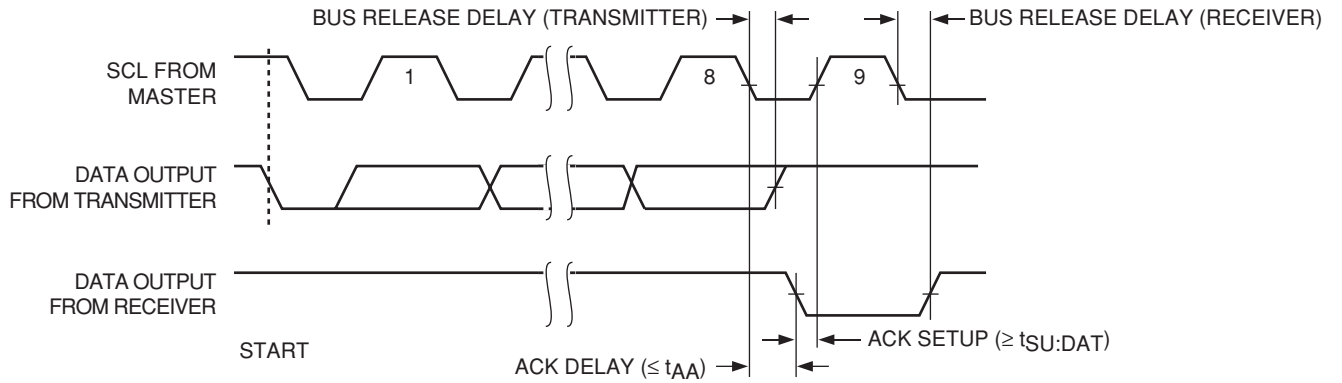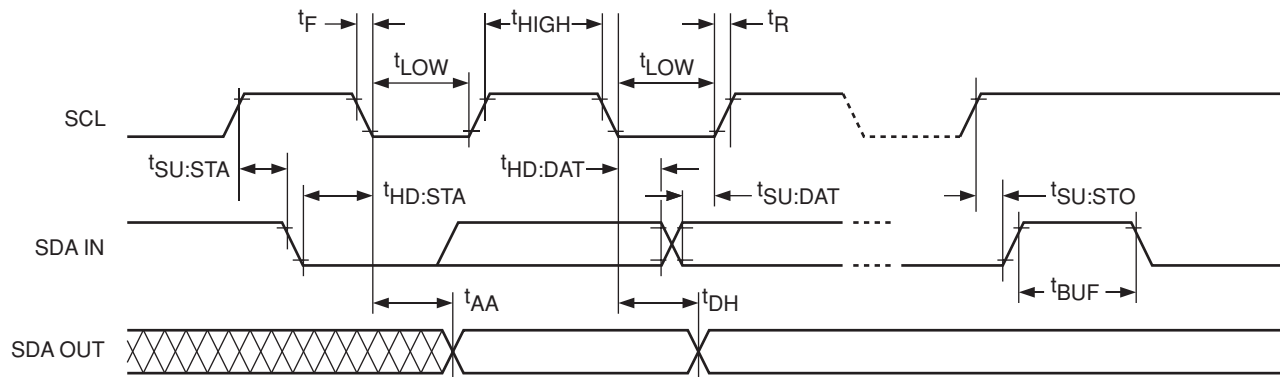
WRITE OPERATIONS

Byte Write

In Byte Write mode, the Master sends the START condition and the Slave address with the R/$\overline{W}$ bit set to zero to the Slave. After the Slave generates an acknowledge, the Master sends the byte address that is to be written into the address pointer of the CAT24C164. After receiving another acknowledge from the Slave, the Master transmits the data byte to be written into the addressed memory location. The CAT24C164 device will acknowledge the data byte and the Master generates the STOP condition, at which time the device begins its internal Write cycle to nonvolatile memory (Figure 5). While this internal cycle is in progress (t_{WR}), the SDA output will be tri-stated and the CAT24C164 will not respond to any request from the Master device (Figure 6).

Page Write

The CAT24C164 writes up to 16 bytes of data in a single write cycle, using the Page Write operation (Figure 7). The Page Write operation is initiated in the same manner as the Byte Write operation, however instead of terminating after the data byte is transmitted, the Master is allowed to send up to fifteen additional bytes. After each byte has been transmitted the CAT24C164 will respond with an acknowledge and internally increments the four low order address bits. The high order bits that define the page address remain unchanged. If the Master transmits more than sixteen bytes prior to sending the STOP condition, the address counter 'wraps around' to the beginning of page and previously transmitted data will be overwritten. Once all sixteen bytes are received and the STOP condition has been sent by the Master, the internal Write cycle begins. At this point all received data is written to the CAT24C164 in a single write cycle.

Acknowledge Polling

The acknowledge (ACK) polling routine can be used to take advantage of the typical write cycle time. Once the stop condition is issued to indicate the end of the host's write operation, the CAT24C164 initiates the internal write cycle. The ACK polling can be initiated immediately. This involves issuing the start condition followed by the slave address for a write operation. If the CAT24C164 is still busy with the write operation, NoACK will be returned. If the CAT24C164 has completed the internal write operation, an ACK will be returned and the host can then proceed with the next read or write operation.

Hardware Write Protection

With the WP pin held HIGH, the entire memory is protected against Write operations. If the WP pin is left floating or is grounded, it has no impact on the operation of the CAT24C164. The state of the WP pin is strobed on the last falling edge of SCL immediately preceding the first data byte (Figure 8). If the WP pin is HIGH during the strobe interval, the CAT24C164 will not acknowledge the data byte and the Write request will be rejected.

Delivery State

The CAT24C164 is shipped erased, i.e., all bytes are FFh.
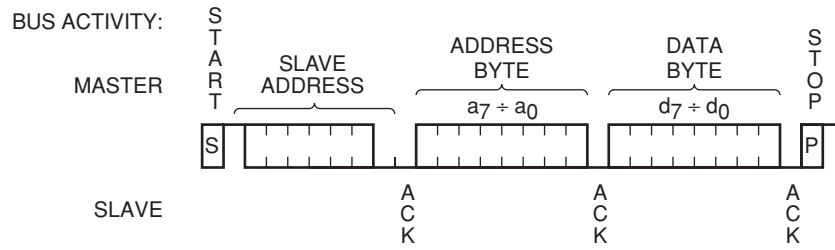
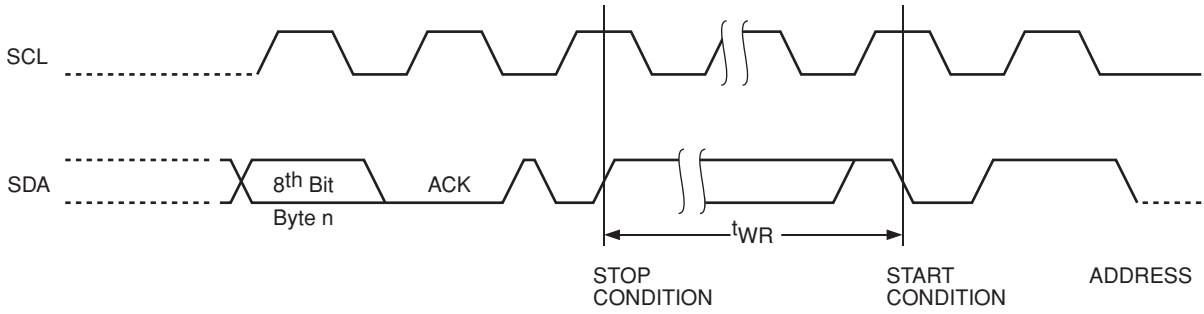## Figure 5. Byte Write Sequence

Figure 6. Write Cycle Timing
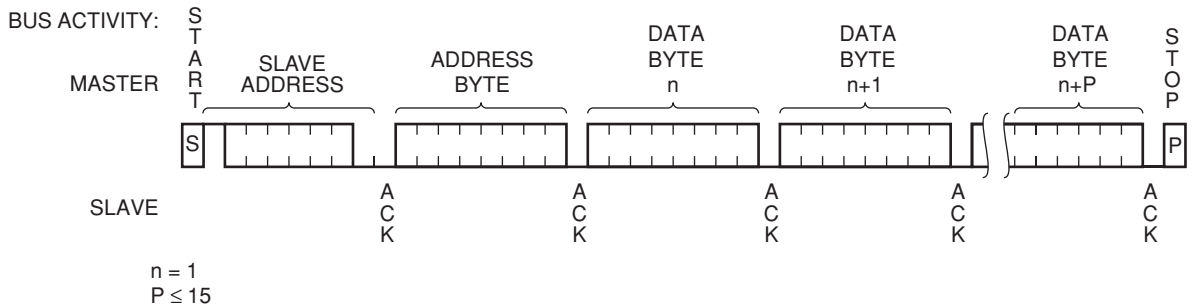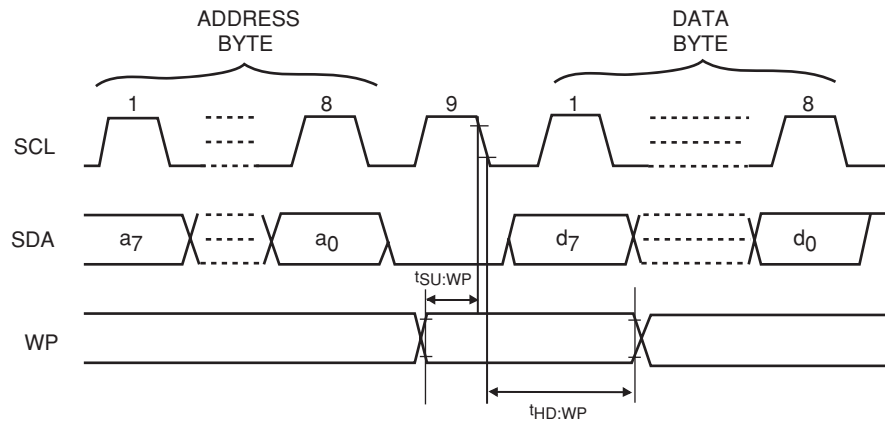

Figure 7. Page Write Sequence

$n = 1$
$P \leq 15$

Figure 8. WP Timing

READ OPERATIONS

Immediate Read

Upon receiving a Slave address with the R/$\overline{W}$ bit set to '1', the CAT24C164 will interpret this as a request for data residing at the current byte address in memory. The CAT24C164 will acknowledge the Slave address, will immediately shift out the data residing at the current address, and will then wait for the Master to respond. If the Master does not acknowledge the data (NoACK) and then follows up with a STOP condition (Figure 9), the CAT24C164 returns to Standby mode.

Selective Read

Selective Read operations allow the Master device to select at random any memory location for a read operation. The Master device first performs a 'dummy' write operation by sending the START condition, slave address and byte address of the location it wishes to read. After the CAT24C164 acknowledges the byte address, the Master device resends the START condition and the slave address, this time with the R/$\overline{W}$ bit set to one. The CAT24C164 then responds with its acknowledge and sends the requested data byte. The Master device does not acknowledge the data (NoACK) but will generate a STOP condition (Figure 10).

Sequential Read

If during a Read session, the Master acknowledges the 1st data byte, then the CAT24C164 will continue transmitting data residing at subsequent locations until the Master responds with a NoACK, followed by a STOP (Figure 11). In contrast to Page Write, during Sequential Read the address count will automatically increment to and then wrap-around at end of memory (rather than end of page).

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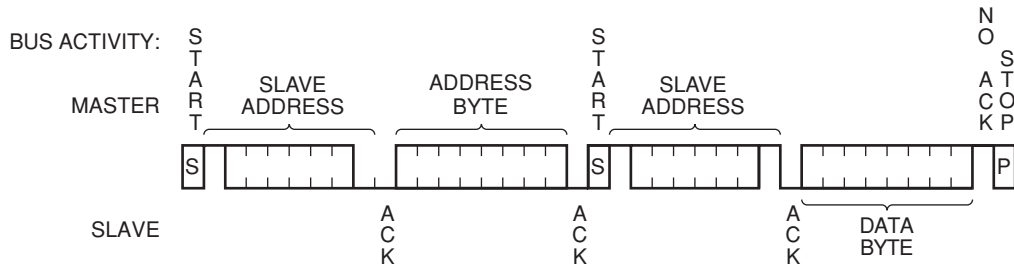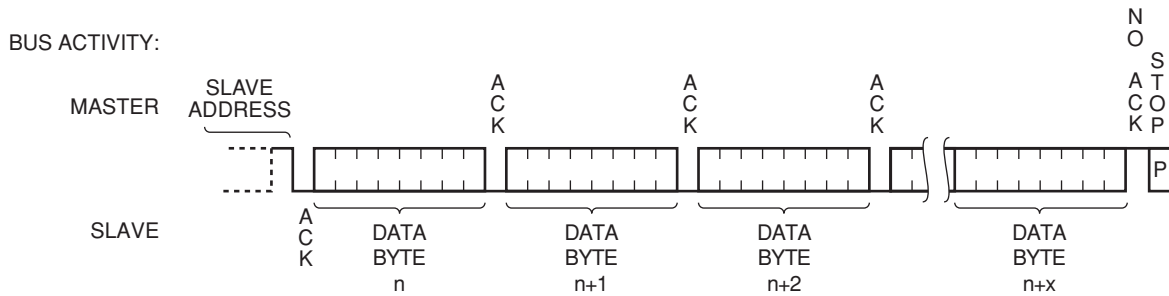**Figure 9. Immediate Read Sequence and Timing**
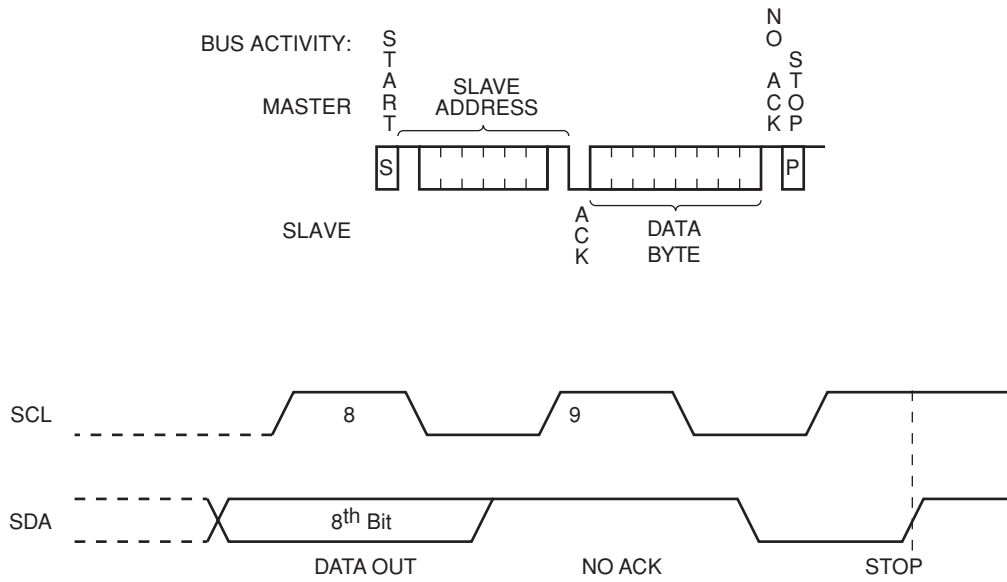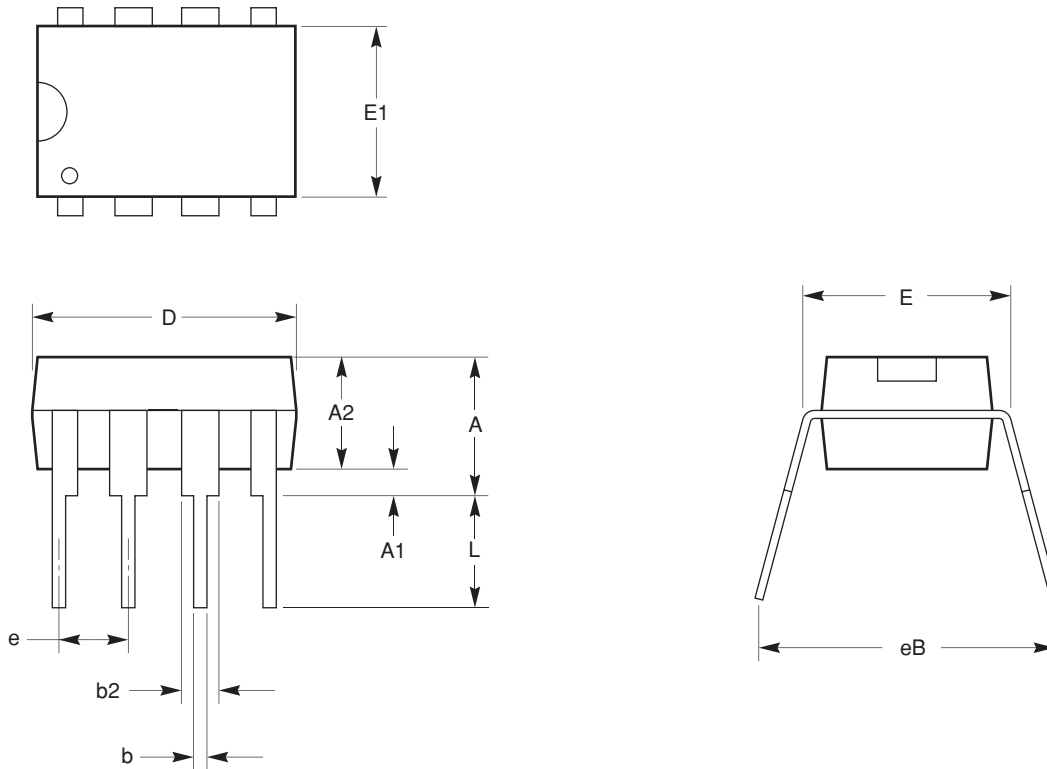

Figure 10. Selective Read Sequence

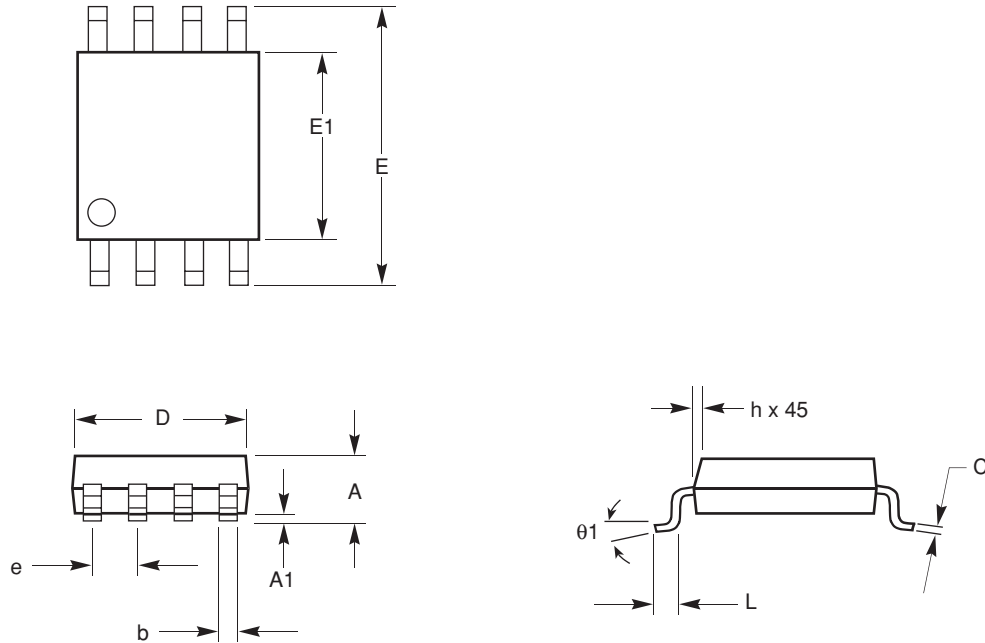**Figure 11. Sequential Read Sequence**

8-LEAD 300 MIL WIDE PLASTIC DIP (L)

SYMBOL	MIN	NOM	MAX
A			4.57
A1	0.38		
A2	3.05		3.81
b	0.36	0.46	0.56
b2	1.14		1.77
D	9.02		10.16
E	7.62	7.87	8.25
E1	6.09	6.35	7.11
e		2.54 BSC	
eB	7.87		9.65
L	0.115	0.130	0.150

Notes:
1. All dimensions are in millimeters.
2. Complies with JEDEC Standard MS001.
3. Dimensioning and tolerancing per ANSI Y14.5M-1982

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8-LEAD 150 MIL WIDE SOIC (W)

SYMBOL	MIN	NOM	MAX
A1	0.10		0.25
A	1.35		1.75
b	0.33		0.51
C	0.19		0.25
D	4.80		5.00
E	5.80		6.20
E1	3.80		4.00
e		1.27 BSC	
h	0.25		0.50
L	0.40		1.27
θ1	0°		8°

For current Tape and Reel information, download the PDF file from: http://www.catsemi.com/documents/tapeandreel.pdf.

Notes:
1. All dimensions are in millimeters.
2. Complies with JEDEC specification MS-012 dimensions.

8-LEAD TSSOP (Y)
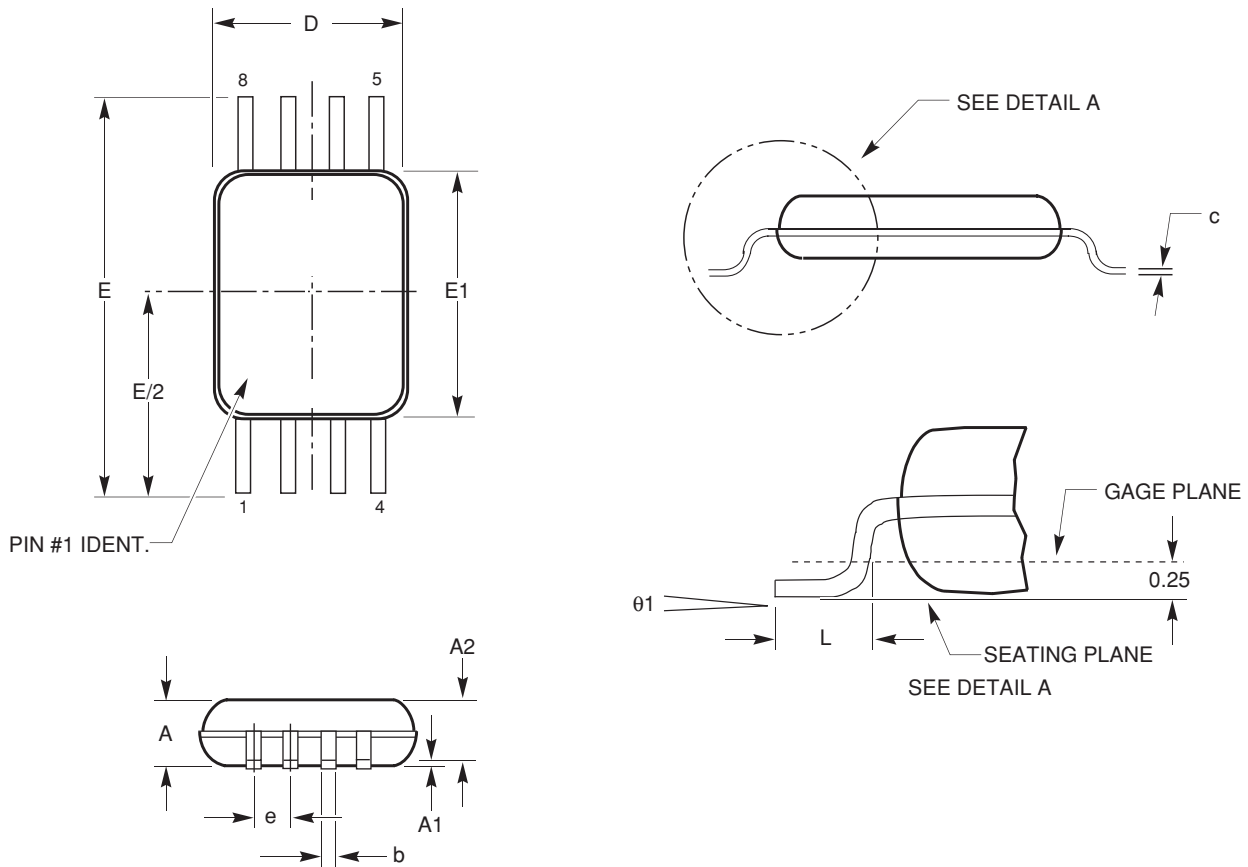
SYMBOL	MIN	NOM	MAX
A			1.20
A1	0.05		0.15
A2	0.80	0.90	1.05
b	0.19		0.30
c	0.09		0.20
D	2.90	3.00	3.10
E	6.30	6.4	6.50
E1	4.30	4.40	4.50
e	0.65 BSC		
L	0.50	0.60	0.75
θ1	0.00		8.00

For current Tape and Reel information, download the PDF file from: http://www.catsemi.com/documents/tapeandreel.pdf.

Notes:
1. All dimensions are in millimeters.
2. Complies with JEDEC specification MO-153.

8-PAD TDFN 2X3 PACKAGE (VP2)
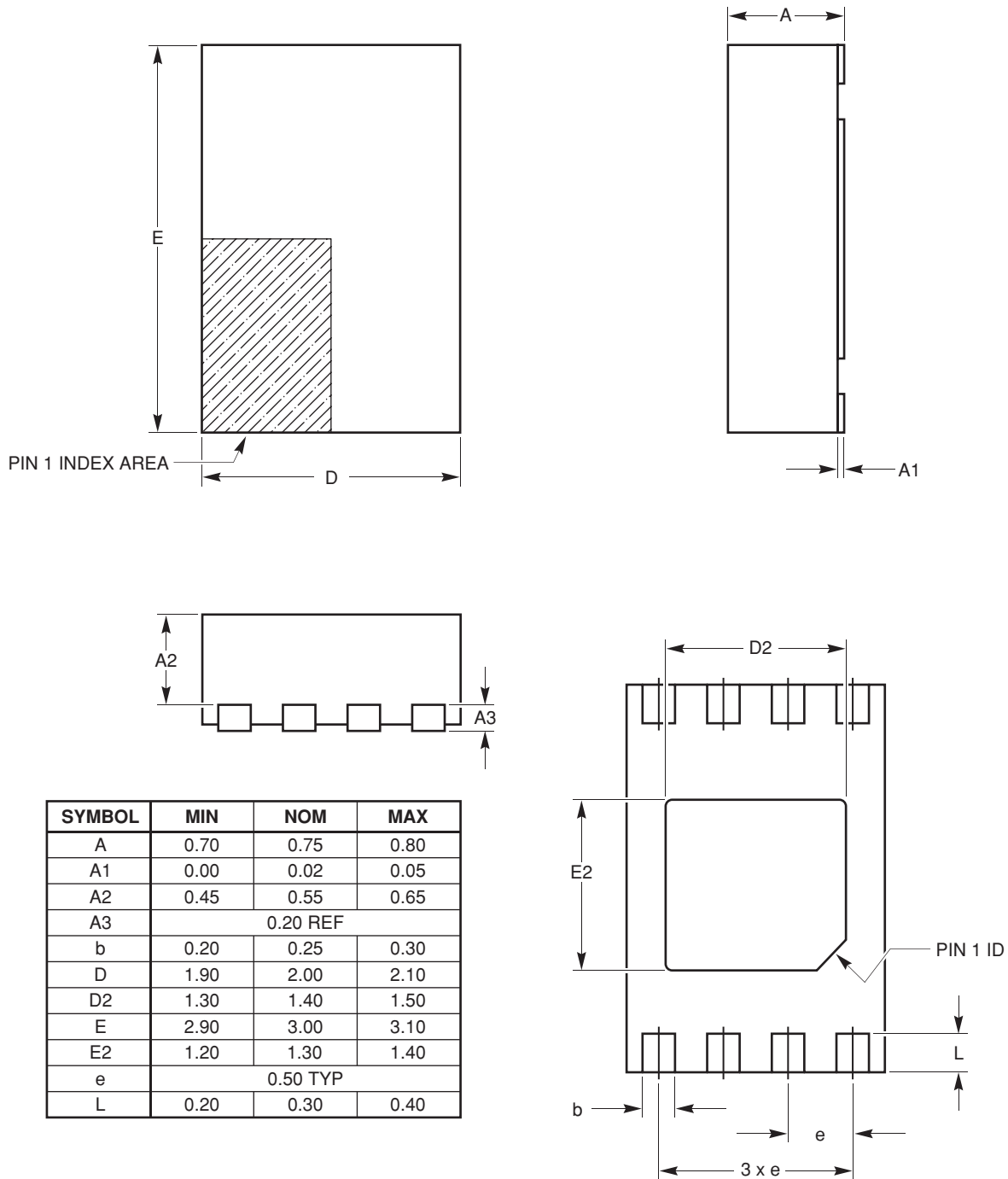
PIN 1 INDEX AREA

A

A1

A2

A3

D2

E2

PIN 1 ID

L

b

e

3 x e

SYMBOL	MIN	NOM	MAX
A	0.70	0.75	0.80
A1	0.00	0.02	0.05
A2	0.45	0.55	0.65
A3		0.20 REF	
b	0.20	0.25	0.30
D	1.90	2.00	2.10
D2	1.30	1.40	1.50
E	2.90	3.00	3.10
E2	1.20	1.30	1.40
e		0.50 TYP	
L	0.20	0.30	0.40

For current Tape and Reel information, download the PDF file from: http://www.catsemi.com/documents/tapeandreel.pdf.

Notes:
1. All dimensions are in millimeters.
2. Complies with JEDEC specification MO-229.

PACKAGE MARKING

8-Lead PDIP
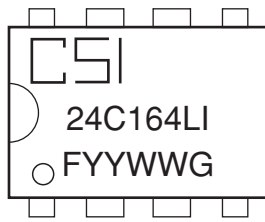
CSI
24C164LI
FYYWWG

CSI = Catalyst Semiconductor, Inc.
I = Temperature Range
YY = Production Year
WW = Production Week
G = Product Revision
F = Lead Finish
4 = NiPdAu

8-Lead SOIC
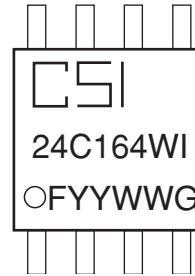
CSI
24C164WI
FYYWWG

CSI = Catalyst Semiconductor, Inc.
I = Temperature Range
YY = Production Year
WW = Production Week
G = Product Revision
F = Lead Finish
4 = NiPdAu

8-Lead TSSOP

YMGF
24164I

Y = Production Year
M = Production Month
G = Die Revision
I = Temperature Range
F = Lead Finish
4 = NiPdAu

8-Pad TDFN

X X N
N N N
Y M
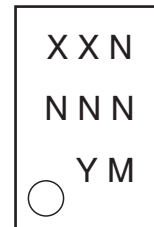
XX = Device Code
FR = NiPdAu
N = Traceable Code
Y = Production Year
M = Production Month

Notes:

(1) The circle on the package marking indicates the location of Pin 1.

(2) For TDFN package, the Product Revision marking is included in the Device Code (XX).

EXAMPLE OF ORDERING INFORMATION

Prefix	Device #	Suffix			

CAT   24C164   Y   I   –   G   T3

Company ID

Product Number
24C164

Temperature Range
I = Industrial (-40°C to +85°C)

T: Tape & Reel
3: 3000/Reel

Package
L: PDIP
W: SOIC, JEDEC
Y: TSSOP
VP2: TDFN

Lead Finish
G: NiPdAu
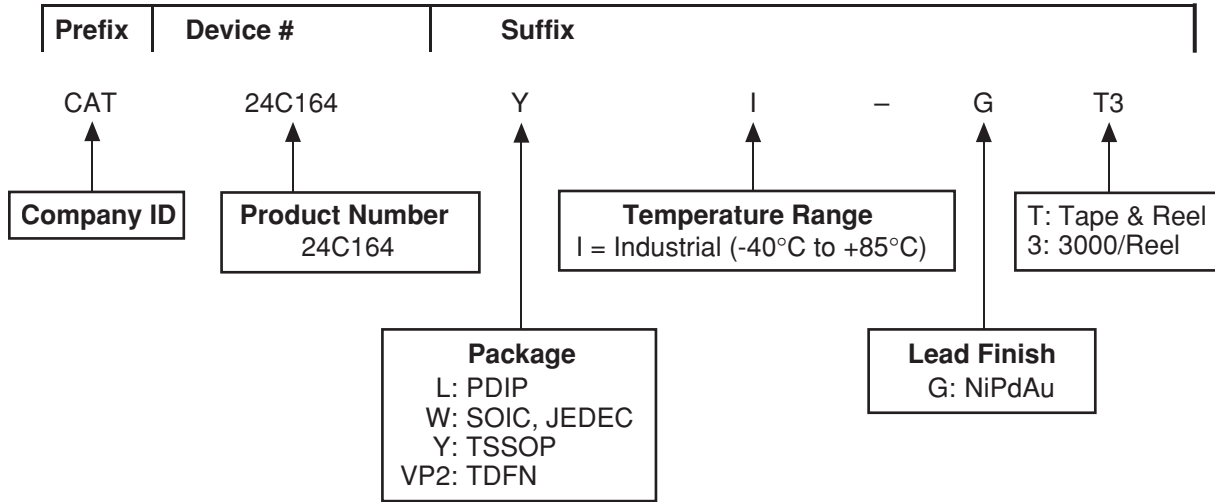
Notes:

(1) All packages are RoHS-compliant (Lead-free, Halogen-free).

(2) The standard lead finish is NiPdAu.

(3) The device used in the above example is a CAT24C164YI-GT3 (TSSOP, Industrial Temperature, NiPdAu, Tape & Reel).

(4) For additional package and temperature options, please contact your nearest Catalyst Semiconductor Sales office.

REVISION HISTORY

Date	Revision	Comments
08/11/06	A	Inital Release