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APPLICATION NOTE 4342

Transitioning from the DS2433 to the DS24B33 4Kb 1-Wire® EEPROM

By: Bernhard Linke, Principal Member Technical Staff
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Abstract: The DS24B33 1-Wire EEPROM is the replacement for its 12-year older predecessor, the DS2433. In general, the DS24B33 is logically a pin-compatible, drop-in replacement for the DS2433. The two devices do have some minor differences for the designer to consider when migrating from an old device to the new one in an existing design. This document discusses the differences in device performance, characteristics, operating conditions, and how those differences may affect the application design. Additionally, the document highlights a few enhancements found in the new device.

Introduction

The DS24B33 is the replacement for the DS2433 and uses newer semiconductor technology. In general, the DS24B33 is logically a pin-compatible, drop-in replacement for the DS2433; both devices have a 1-Wire interface and 4Kb of EEPROM organized as 16 pages of 32 bytes each. However, the new semiconductor technology causes some unavoidable changes to the performance and characteristics, as well as the permissible operating conditions of the new device. The performance and characteristic changes will not necessarily cause adverse effects to older existing designs using the DS24B33. This document discusses the impact of those changes in detail, so the designer can assess whether a change will cause problems for the existing design. As this document reviews each parameter change, it suggests an action to modify the existing design.

Performance and Characteristics Changes

1. **Read Low Time**
   Explanation: This parameter specifies the duration for which the master must pull the 1-Wire line low at the beginning of a read-data time slot. This duration must be long enough to bridge the gap until a 1-Wire slave pulls the line low when responding with a logic-0.

   From DS2433 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
t_{LOWR}	Standard speed	1		15	µs	8
	Overdrive speed	1		2		

   Note 8: The duration of the low pulse sent by the master should be a minimum of 1µs with a maximum value as short as possible to allow time for the pullup resistor to recover the line

to a high level before the 1-Wire device samples in the case of a write-one time, or before the master samples in the case of a read-one time.

From DS24B33 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
t_{RL}	Standard speed	**5**		15-δ	µs	2, 17
	Overdrive speed	1		2-δ		

Note 2: System requirement.

Note 17: δ represents the time required for the pullup circuitry to pull the voltage on IO up from V_{IL} to the input high threshold of the bus master. The actual maximum duration for the master to pull the line low is $t_{RLMAX} + t_F$.

Impact: The improved network behavior for standard speed adds lowpass filtering to the 1-Wire front-end, which increases the response time. The maximum specification limit is not affected. For mathematical correctness, the "δ" is introduced to indicate that the upper limit also depends on the rise time in the application. Note that the improvement in network behavior also affects the minimum value of the write-one low time (t_{LOW1} and t_{W1L}, respectively), which is 5µs minimum for the DS24B33 vs. 1µs with the DS2433. Typically, the master generates a read data time slot in the same way as a write-one time slot. Therefore, a firmware update to meet the DS24B33's t_{RL} requirements is likely to update the timing of a write-one time slot in the right way.

Action: Verify that the 1-Wire master matches the DS24B33 requirements. If the lower limit is not met, a glitch can appear on the 1-Wire line when the master stops pulling low before the slave takes over pulling low. In a multislave network the glitch can cause other slaves to lose synchronization with the master. In a single-drop network this potential glitch will likely not affect communication.

2. **Recovery Time**
Explanation: This parameter specifies the minimum idle time (high time) between time slots for 1-Wire slaves to recharge their parasitic power supply and to get ready for the next action (time slot or reset/presence detect sequence). The duration must be long enough both to replenish energy consumed in the previous activity and to accumulate energy for the next activity. Since a reset/presence detect sequence is longer than a time slot, the parasitic power supply must be well charged for the device to generate a presence pulse that meets the timing specification. The recovery time affects the effective 1-Wire data rate, which is $1/t_{SLOT}$. Note that the time slot definition in the DS2433 data sheet **does not include** the recovery time.

From DS2433 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
t_{REC}	Standard speed	1			µs	
	Overdrive speed	1				

From DS24B33 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
t_{REC}	Standard speed	**5**			µs	2, 13
	Overdrive speed	**2**				
	V_{PUP} ≥ 4.5V	1				
	Directly prior to reset pulse ≤ 640µs	**5**				

	Directly prior to reset pulse > 640µs	**10**			

Note 2: System requirement.

Note 13: Applies to a single DS24B33 attached to a 1-Wire line.

Impact: The DS2433 data sheet does not specify the condition at which the parameter is tested. If the recovery time in an application is too short, a long sequence of write-0 time slots can cause a 1-Wire slave to run "out-of-power" and lose synchronization with the master. With insufficient power, timing specifications that relate to slave performance (i.e., anything that is not a system requirement) may not be met, causing the application to operate unreliably.

Action: Verify that the 1-Wire master matches the DS24B33 requirements. Note that the specifications in the data sheet apply for a pullup resistor of maximum 2.2kΩ and a single-slave network. For multislave networks the recovery time is longer. If the pullup resistor in the application is higher than 2.2kΩ, replace the resistor. See the section **Pullup Resistor** in this document for recommended resistor values. For additional guidance refer to application note 3829, "Determining the Recovery Time for Multiple-Slave 1-Wire® Networks."

3. **Programming Current**

Explanation: This parameter specifies the current that a 1-Wire EEPROM needs to copy data from its scratchpad to the EEPROM. To ensure reliable programming during this write cycle, the voltage on the 1-Wire line, V(IO), must not fall below a specified limit (V_{PUPMIN} = 2.8V). The voltage drop across a pullup resistor is calculated as $\Delta V = R_{PUP} \times I_{PROG}$. Therefore, the voltage on the 1-Wire line is $V(IO) = (V_{PUP} - \Delta V)$ and must not drop below 2.8V at any time during programming. In an application that only reads from a 1-Wire EEPROM, the programming current specification is not relevant.

From DS2433 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
I_{LPROG}			500		µA	5

Note 5: The Copy Scratchpad takes 5ms maximum during which the voltage on the 1-Wire bus must not fall below 2.8V.

From DS24B33 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
I_{PROG}				**2**	mA	18

Note 18: Current drawn from IO during the EEPROM programming interval. The pullup circuit on IO should be such that during the programming interval the voltage at IO is greater than or equal to V_{PUPMIN}. If V_{PUP} in the system is close to V_{PUPMIN}, then a low-impedance bypass of R_{PUP}, which can be activated during programming, may need to be added.

Impact: The DS2433 data sheet only specifies a typical value. For the DS24B33, the maximum programming current is specified. To ensure that the 2.8V minimum requirement is met, one needs to know the maximum programming current. Meeting the minimum voltage requirement is particularly important if the pullup voltage is near its lower specification limit. Example: to meet the 2.8V minimum requirement in a 5V environment, the pullup resistor must be $R_{PUP} \le (5.0V - 2.8V)/2mA = 1100\Omega$.

Action: If the application writes to the DS24B33, verify that the 2.8V minimum condition (V_{PUPMIN})

is met for the maximum programming current. In particular for V_{PUP} values near 3.3V, a switched low-impedance bypass to the pullup resistor is required. For additional guidance refer to application note 4255, "How to Power the Extended Features of 1-Wire® Devices," or application note 4206, "Choosing the Right 1-Wire® Master for Embedded Applications."

4. **Input Load Current**
Explanation: This parameter specifies the current that a 1-Wire slave draws from the 1-Wire line when no communication is taking place. At this time, the parasitic power supply is fully charged. The input load current can vary significantly from device to device. The voltage drop across the pullup resistor caused by the input load current is calculated as $\Delta V = R_{PUP} \times I_L$.

From DS2433 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
I_L			5		µA	4

Note 4: Input load is to ground.

From DS24B33 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
I_L	IO at V_{PUPMAX}	0.05		5	µA	

Note 4: Input load is to ground.

Impact: The DS2433 data sheet only specifies a typical value. The DS24B33 data sheet specifies a minimum and a maximum value.

Action: With the maximum value identical to the DS2433's typical value, this parameter change is fully compatible to existing DS2433 applications. No action is required.

5. **Input Capacitance**
Explanation: This parameter specifies the value of the capacitor in the parasitic power supply of a 1-Wire device. Traditionally, this value is in the 600pF to 800pF range. If the parasitic supply is fully discharged, some idle time for recharge is necessary to get a 1-Wire device ready for communication. There is usually more than enough idle time when equipment powers up. During normal operation only a partial recharge of the parasitic capacitor occurs.

From DS2433 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
$C_{IN/OUT}$	T_A = +25°C		100	800	pF	6

Note 6: Capacitance on the data pin could be 800pF when power is first applied. If a 5kΩ resistor is used to pull up the data line to V_{PUP}, 5µs after power has been applied the parasitic capacitance will not affect normal communications.

From DS24B33 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
C_{IO}	T_A = -40°C to +85°C		**2000**		pF	5, 6

Note 5: Capacitance on the data pin could be 2500pF when V_{PUP} is first applied. If a 2.2kΩ resistor is used to pull up the data line, then 15µs after V_{PUP} has been applied the parasitic capacitance will not affect normal communications.

Note 6: Guaranteed by design, characterization, and/or simulation only. Not production tested.

Impact: Since the DS24B33 requires a higher programming current than the DS2433, it needs a parasitic supply capacitor that is significantly larger than that in the DS2433. This reduces the number of slaves that a given 1-Wire master can drive. An application that was marginally functional with a DS2433 (low V_{PUP}, high R_{PUP}, short t_{REC}) will most likely not work with a DS24B33.

Action: To accommodate the higher input capacitance of the DS24B33, it may be necessary to choose a lower 1-Wire pullup resistor or use a dedicated 1-Wire master such as the DS2480B. For applications running at a low pullup voltage, a resistive pullup interface may have to be replaced by an active pullup driver such as the DS2482.

Operating Condition Changes

1. **Pullup Voltage**
Explanation: This parameter specifies the 1-Wire operating voltage. The upper limit is the voltage that a 1-Wire device can sustain on its IO pin without stress over unlimited time.

From DS2433 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
V_{PUP}	T_A = -40°C to +85°C	2.8		6	V	1

Note 1: V_{PUP} = external pullup voltage.

From DS24B33 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
V_{PUP}	T_A = -40°C to +85°C	2.8		**5.25**	V	2, 3

Note 2: System requirement.

Note 3: When operating near the minimum operating voltage (2.8V), a falling-edge slew rate of 15V/µs or faster is recommended.

Impact: Due to a newer semiconductor process, the maximum value that the DS24B33 can sustain is lower than the DS2433. Since most applications operate at 5V ±5% or lower, this change should not be an issue.

Action: If an application runs at 6V ±5%, reduce the pullup voltage, e.g., by putting one or two general-purpose silicon diode(s) in series with the pullup resistor. The ~0.7V drop across a diode in forward direction reduces the 1-Wire voltage for safe operation.

2. **Pullup Resistor**
Explanation: This parameter specifies the permissible range for the 1-Wire pullup resistor. If the resistor is too high, there is not enough time to recharge the parasitic power supply of a 1-Wire slave. If the resistor value is too low, the maximum V_{IL} specification may not be met.

From DS2433 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
R_{PUP}					kΩ	

The DS2433 data sheet does not explicitly state the value of R_{PUP} in the Electrical Characteristics table, but gives some guidelines in the text. The text in Figure 8 of the DS2433 data sheet specifies for a single-drop environment: "5kΩ for reading, 2.2kΩ with V_{PUP} ≥ 4V for writing. Depending on the 1-Wire communication speed and the bus load characteristics, the optimal pullup resistor value will be in the 1.5kΩ to 5kΩ range."

From DS24B33 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
R_{PUP}		**0.3**		**2.2**	kΩ	2, 4

Note 2: System requirement.

Note 4: Maximum allowable pullup resistance is a function of the number of 1-Wire devices in the system, 1-Wire recovery times, and current requirements during EEPROM programming. The specified value here applies to systems with only one device and with the minimum 1-Wire recovery times. For more heavily loaded systems, an active pullup such as that found in the DS2482-x00 or DS2480B may be required.

Impact: Compared to the DS2433 data sheet, the DS24B33 data sheet is specific about the range for the pullup resistor. The DS24B33's upper limit matches the test conditions for t_{REC}. The lower limit does not stress the DS24B33 in a 5V ±5% environment. However, under worst-case conditions (i.e., impedance of DS24B33 output transistor = V_{OLMAX}/4mA = 100Ω), it yields a V_{OL} value of 100Ω/(100Ω + 300Ω) × V_{PUP} when the DS24B33 pulls the 1-Wire line low. To meet the maximum V_{IL} requirements of other 1-Wire slaves and the master, the lowest and safest R_{PUP} value at 2.8V is 600Ω.

Action: Check the pullup resistor in the application. If it is higher than 2.2kΩ, replace it with a lower resistor or use a different 1-Wire master. See section on **Input Capacitance** for additional recommendations.

Technical Improvements

1. **EEPROM Endurance**
Explanation: This parameter specifies the number of write cycles that an EEPROM cell can survive without errors at a given temperature. Typically, the endurance is much higher than the specified minimum value.

From DS2433 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
N_{CYCLE}	T_A = +25°C V_{PUP} = 5.0V	50k				7

Note 7: During the execution of the Copy Scratchpad command, the DS2433 automatically erases the memory locations to be written to. No extra steps need to be taken by the bus master.

From DS24B33 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
N_{CY}	At +25°C	**200k**				20, 21
	At +85°C	**50k**				

Note 20: Write-cycle endurance is degraded as T_A increases.

Note 21: Not 100% production-tested; guaranteed by reliability monitor sampling.

Impact: At +25°C, the DS24B33 is at least four times as good as the DS2433. The endurance of the DS2433 at +85°C is not specified.

2. **EEPROM Data Retention**
Explanation: This parameter specifies how long data remains intact in memory without being rewritten (refreshed). Typically, the data retention is much longer than the specified minimum value.

From DS2433 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
t_{DR}					Years	

Not specified.

From DS24B33 Data Sheet

SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
t_{DR}	At +85°C	**40**			Years	22, 23, 24

Note 22: Data retention is degraded as T_A increases.

Note 23: Guaranteed by 100% production test at elevated temperature for a shorter time; equivalence of this production test to data-sheet limit at operating temperature range is established by reliability testing.

Note 24: EEPROM writes may become nonfunctional after the data retention time is exceeded. Long-time storage at elevated temperatures is not recommended; the device can lose its write capability after 10 years at +125°C or 40 years at +85°C.

Impact: The DS24B33 matches current industry standards.

3. **ROM Function "Resume"**
Explanation: Like many newer 1-Wire slaves, the DS24B33 supports the network function command Resume. Once the DS24B33 is successfully selected using Match ROM, Search ROM, or Overdrive Match ROM, the Resume command allows access to the same device again without having to specify the 64-bit registration number.

Impact: In a multislave network, Resume reduces communication overhead otherwise needed to access the same device multiple times in sequence, e.g., to randomly read the memory or when updating memory data. The presence of this command in the DS24B33 and its absence in the DS2433 allows the application to distinguish between the two parts electronically.

4. **1-Wire Front-End**
Explanation: The front-end is the part of the chip that implements the communication protocol to access the device's resources, such as memory. The front-end determines the timing tolerances of communication waveforms and the performance of 1-Wire slaves in a noisy environment.

Impact: Like many newer 1-Wire slaves, the DS24B33 front-end implements switch-point hysteresis (see data sheet, parameters V_{TH} and V_{HY}), which improves performance in multidrop networks. An individually trimmed oscillator controls the communication timebase of the DS24B33. This leads to a more precise, and less voltage- and temperature-dependent communication timing than with traditional 1-Wire slaves.

5. **E/S Register**
Explanation: This register, which is part of the scratchpad logic, tracks the ending offset when

writing to the scratchpad and provides status information such as partial byte, power failure (PF-flag), and whether a copy scratchpad command was accepted (AA-flag). The AA-flag is very important for NV SRAM-based iButtons®, but not critical for entirely parasitically-powered 1-Wire devices such as EEPROMs.

Impact: With the original DS2433, the state of the AA-flag was undefined on power-up. With the DS24B33, this flag is cleared to 0 during a power-on-reset. Despite its improved functionality with the DS24B33, the AA-flag should not be used as a primary indicator for programming success.

Good Practice for Programming the DS2433 and DS24B33

In hard-wired applications, both device types behave exactly the same and are fully interchangeable. In case of an unreliable 1-Wire connection (e.g., a so-called touch environment) or in applications where a drop below V_{PUPMIN} could occur, e.g., caused by a low battery, the following approach ensures reliable programming.

1. Read the entire page that is to be updated. This ensures that, in case the Copy Scratchpad fails, the old data is still known and can be used to restore the page data.
2. Always write the entire page, even if only a few contiguous bytes need to be changed.
3. At the end of the Copy Scratchpad flow, always check the success byte (alternating 0–1 pattern, equivalent to AAh).
4. After Copy Scratchpad, always read back the EEPROM page that was to be updated.

If the success byte reads AAh and the EEPROM page data shows the intended new data, the write access was successful. No further action is required.

In all other cases (nonmatching EEPROM page data, success byte different from AAh), repeat the Write Scratchpad, Copy Scratchpad sequence until successful. This algorithm works reliably with both the DS2433 and the DS24B33. Existing software that already works this way is fully compatible with the DS24B33.

Conclusion

The DS24B33 represents a new generation of the original DS2433 1-Wire EEPROM. Maintaining software backward compatibility, the DS24B33 supports the time-saving Resume network function, has tighter 1-Wire timing tolerances, and has a front-end with switch-point hysteresis. The new EEPROM cell structure allows an endurance (number of write/erase cycles) of minimum 200k cycles vs. the 50k cycles of the DS2433. The DS24B33 requires a higher programming current than its predecessor. Depending on the operating voltage, this may require a modified 1-Wire master circuit to write to the DS24B33.

Related Parts		
DS2433	4Kb 1-Wire EEPROM	
DS24B33	1-Wire 4Kb EEPROM	Free Samples

More Information