Keywords: 1-Wire, 1-Wire communication, 1-Wire network, wireless power, parasitic capacitance, power delivery, communications, IoT

APPLICATION NOTE 6755

WIRELESSLY POWERING AND ACCESSING A 1-WIRE NETWORK

Abstract: If the timing aligns with 1-Wire® protocol specifications, a regulated voltage source can power and maintain communication on a 1-Wire network. Simplify the analysis process by modeling the voltage source resistance, the 1-Wire pull-up resistance, and the 1-Wire network as a capacitive load. This way, you can calculate first-order equations related to initially charging up the 1-Wire network and pulling the 1-Wire parasitic capacitance to the supply rail and ground. Time constants ε, δ, tREC, and tf help specify a maximum total typical capacitance that can allow proper 1-Wire communication for a given pull-up resistance and pull-up voltage. A similar version of this application note originally appeared on Power Electronics on May 30, 2018.

Initial Charging of a 1-Wire Network

1-Wire® devices power-up parasitically by charging an internal reservoir from the 1-Wire communication line. V_{PUP}, the pull-up voltage on the 1-Wire network, is dependent upon V_{OUT} and R_{PUP}. The maximum current that can be supplied to the 1-Wire network also depends on these two parameters.

When powering a 1-Wire network from a high-impedance source like the MAX66242 voltage regulator at V_{OUT}, before sending 1-Wire function commands, take care to ensure that enough time passes before the devices attached to the 1-Wire network are charged and ready to communicate. This occurs when the initial capacitance C_{IO} at its I/O pin is charged.

Most 1-Wire devices specify typical and maximum C_{IO} values that exist on their 1-Wire I/O port. The maximum C_{IO} exists when V_{PUP} is first applied to the 1-Wire network. After the 1-Wire network is fully charged, only the typical C_{IO} affects 1-Wire communication. Therefore, the $C_{IO\text{-}MAX}$ should be charged to the minimum pull-up voltage $V_{MIN\text{-}PUP}$ required by the 1-Wire device. Equation (1) defines the minimum pull-up voltage $V_{MIN\text{-}PUP}$ across the total maximum capacitance $C_{TOTAL\text{-}MAX}$ of the 1-Wire network.

$$V_{MIN\text{-}PUP} = V_S(1 - e^{t_{CHARGE}/ -R_{S+PUP}C_{TOTAL\text{-}MAX}}) \qquad \text{[Eq. 1]}$$

where $C_{TOTAL\text{-}MAX} = \Sigma^{N}_{i=0} (C_{MAX\text{-}IO,\ i} + C_{LAYOUT})$, $R_{S+PUP} = R_S + R_{PUP}$, $V_{MIN\text{-}PUP}$ is the minimum pull-up voltage required on the 1-Wire network, and VS is the open-circuit voltage at V_{OUT}. The capacitance C_{LAYOUT} represents the capacitance introduced to the 1-Wire network because of junctions on the 1-Wire node (See **Figure 1** for a depiction.)

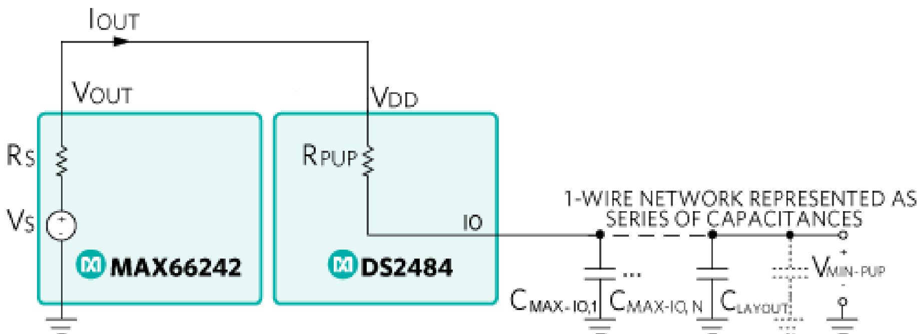

Figure 1. 1-Wire network modeled as a series of I/O capacitances C_{IO} and parasitic layout capacitance C_{LAYOUT} as a result of junctions on the 1-Wire node.

$V_{MIN-PUP}$ is the largest minimum-pull-up voltage in the 1-Wire network. So, if device number one has a minimum pull-up voltage of 2.8V and device number two has a minimum pull-up voltage of 3.0V, then $V_{MIN-PUP}$ should equal to 3.0V for the 1-Wire network.

Equation (2) determines the time t_{CHARGE} necessary to charge the total maximum capacitance $C_{TOTAL-MAX}$ to the minimum pull-up voltage $V_{MIN-PUP}$ of a 1-Wire network:

$$t_{CHARGE} = -R_{S+PUP}C_{TOTAL-MAX}\ln(1 - V_{MIN-PUP} / V_S) \qquad \text{[Eq. 2]}$$

Parasitic Capacitance During 1-Wire Communication

The total typical capacitance $C_{TOTAL-TYP}$ on the 1-Wire network after powering up is defined as the sum of all typical capacitances C_{TYP-IO} plus the parasitic capacitance of the layout C_{LAYOUT}. This is represented in schematic form in Figure 9 by replacing $C_{MAX-IO,N}$ with $C_{TYP-IO,N}$ where $C_{TOTAL-TYP} = \sum^{n}_{i=1} C_{TYP-IO,\ i} + C_{LAYOUT}$. The typical capacitance C_{TYP-IO} refers to the parasitic capacitance at the I/O that originates from each of the device's internal 1-Wire receivers/transmitters. In every 1-Wire communication sequence, the typical capacitance C_{TYP-IO}, the pull-up voltage V_{PUP}, and the pull-up resistance R_{PUP} are responsible for the following four fundamental timing parameters:

1. ε – the time taken to pull up from 0V to the 1-Wire network's threshold-high voltage V_{TH}.
2. δ – the time taken to pull up from 0V to the 1-Wire host input-high voltage $V_{IH-HOST}$.
3. t_{REC} – the time taken to pull up from V_{TH} to V_{PUP}. t_{REC} defines the maximum time available for the 1-Wire network to recharge during communication.
4. t_f – the time taken to pull down from V_{PUP} to the 1-Wire network's threshold-low voltage V_{TL}.

Time constants ε, δ, t_{REC}, and t_f help specify a maximum total typical capacitance $C_{TOTAL-TYP}$ that can allow proper 1-Wire communication for a given R_{PUP} and V_{PUP}. If $C_{TOTAL-TYP}$ is exceeded, then timing constraints are not met, rendering 1-Wire communication improbable. For the value of the four time constraints, see the datasheet for the respective 1-Wire device.

Pull-up Fundamental Timing Parameters ε, δ, and t_{REC}

Figure 2 illustrates time ε needed to charge up the 1-Wire total typical capacitance CTOTAL-TYP from 0V to VTH. **Figure 3** presents this concept in schematic form.

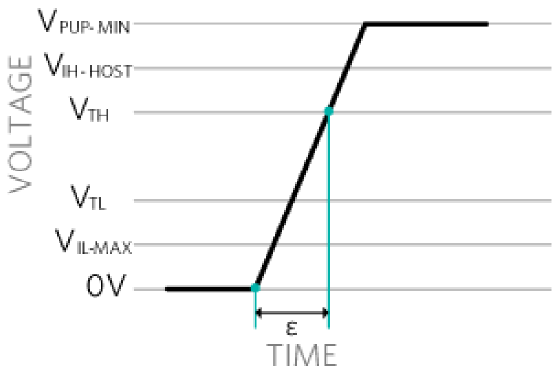

Figure 2. Time ε to charge the total typical capacitance $C_{TYP\text{-}TOTAL}$ from 0V to V_{TH}.

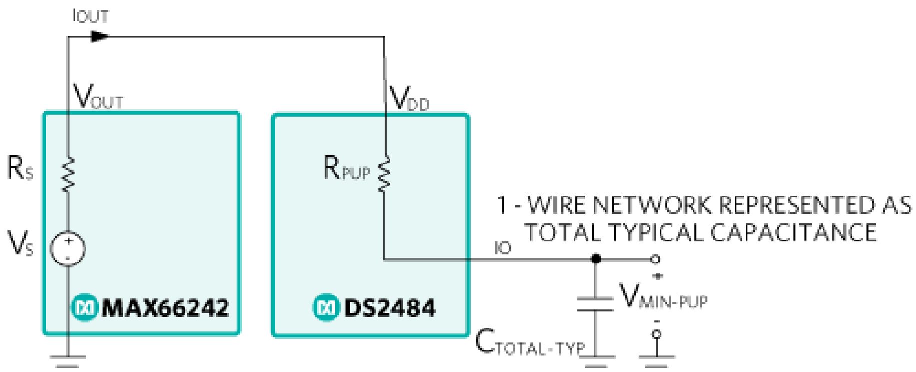

Figure 3. 1-Wire network modeled as an equivalent total typical capacitance $C_{TOTAL\text{-}TYP}$ that includes the parasitic layout capacitance C_{LAYOUT}.

Equation (3) defines ε – the time required to charge $C_{TOTAL\text{-}TYP}$ from 0V to V_{TH} via R_{S+PUP}.

$$\varepsilon = -R_{S+PUP}C_{TOTAL\text{-}TYP}\ln(1 - V_{TH} / V_S) \quad \text{[Eq. 3]}$$

Figure 4 illustrates time δ needed to charge up the 1-Wire total typical capacitance $C_{TOTAL\text{-}TYP}$ from 0V to $V_{IH\text{-}HOST}$.

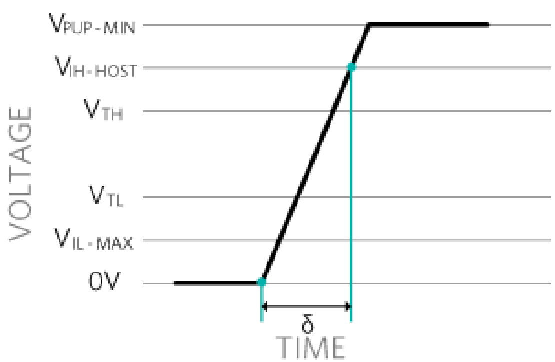

Figure 4. Time δ to charge total typical capacitance $C_{TYP\text{-}TOTAL}$ from 0V to $V_{IH\text{-}HOST}$.

Equation (4) defines ε – the time required to charge $C_{TOTAL\text{-}TYP}$ from 0V to V_{TH} via R_{S+PUP}.

$$\delta = -R_{S+PUP}C_{TOTAL\text{-}TYP}\ln(1 - V_{IH\text{-}HOST} / V_S) \quad \text{[Eq. 4]}$$

Figure 5 illustrates the shortest time t_{REC} needed to recharge the 1-Wire total typical capacitance $C_{TOTAL\text{-}TYP}$ from V_{TH} to $V_{PUP\text{-}MIN}$.

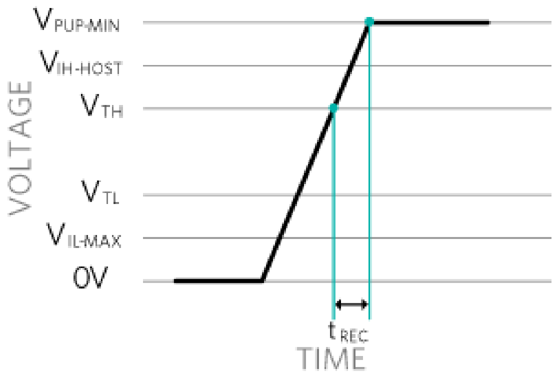

Figure 5. Shortest time t_{REC} possible to charge total typical capacitance $C_{TYP\text{-}TOTAL}$ from V_{TH} to $V_{PUP\text{-}MIN}$.

Follow this three-step procedure to calculate t_{REC}:

1. Calculate the time required to charge from 0V to V_{TH} – this is equivalent to ε in Equation (3).
2. Calculate the time required to charge from 0V to $V_{PUP\text{-}MIN}$.
   $t' = -R_{S+PUP}C_{TOTAL\text{-}TYP}\ln(1 - V_{PUP\text{-}MIN} / V_S)$
3. Use the quotient rule to find $t_{REC} = t' - \varepsilon$.
   $t_{REC} = R_{S+PUP}C_{TOTAL\text{-}TYP}\ln[(1 - V_{TH}/V_S) / (1 - V_{PUP\text{-}MIN}/V_S)]$ [Eq. 5]

Pull-Down Timing Parameter t_f

Unlike ε, δ, and t_{REC}, time t_f does not depend on R_S and R_{PUP} because time t_f defines the time required for the 1-Wire host or device to pull down the 1-Wire network. Therefore, the pull-down resistance R_{PDOWN} of the 1-Wire host or device defines the time tf necessary to discharge $C_{TOTAL\text{-}TYP}$ from V_{PUP} to V_{TL} as illustrated in **Figure 6**.

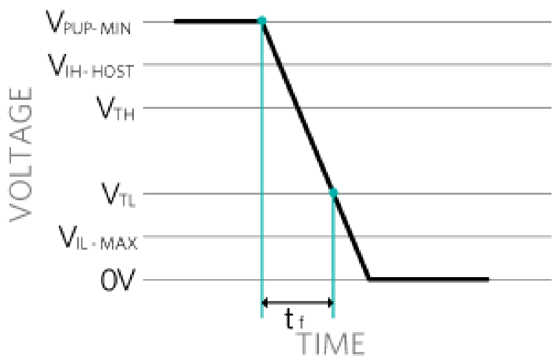

Figure 6. Time t_f to discharge total typical capacitance $C_{TYP\text{-}TOTAL}$ from $V_{PUP\text{-}MIN}$ to V_{TL}.

The pull-down resistance R_{PDOWN} for the 1-Wire host and device comes from the maximum output low-voltage V_{OL} and the corresponding output low-current I_{OL} provided in the electrical characteristics table of the respective datasheet. **Figure 7** illustrates the pull-down resistance R_{PDOWN} and the pull-down current I_{OL}.

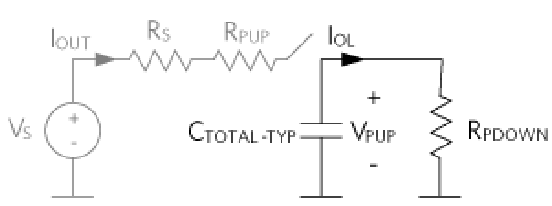

Figure 7. Simplified RC circuit that models the pull-down resistance R_{PDOWN} from either the 1-Wire host or device. I_{OL} is the pull-down current.

For example, the DS2484 I^2C-to-1-Wire bridge has a maximum V_{OL} of 0.4V at 4mA. This means that the maximum pull-down resistance is R is 100Ω.

PDOWN

Equation (6) defines the discharge time t_f.

$t_f = -R_{PDOWN}C_{TOTAL\text{-}TYP}\ln(V_{TL} / V_{PUP\text{-}MIN})$ [Eq. 6]

Note that time t_f should be met for the 1-Wire host and the device. The 1-Wire host pulls down the 1-Wire node at the beginning of each basic operation, i.e., reset, write 1 bit, write 0 bit, and read a bit. The 1-Wire device pulls down the 1-Wire node during a reset operation to generate a presence pulse.

1-Wire communication and power delivery are possible when the four fundamental parameters ε, δ, t_{REC}, and t_f are met for all devices on the network. You can determine the maximum number of devices and bus length achievable in the NFC-powered system by knowing the total allowable capacitance to meet all edge timings specified by the 1-Wire protocol.

For more information about ε, δ, and t_{REC}, and how they affect 1-Wire communication in standard or overdrive mode, refer to Application Note 126 – 1-Wire Communication Through Software. For more information about how typical capacitance affects 1-Wire communication, refer to Application Note 148 – Guidelines for Reliable Long Line 1-Wire Networks.

Compatible 1-Wire Devices

Table 1 lists 1-Wire devices with their respective input/output capacitance C_{IO}, pull-up voltage V_{PUP}, pull-up resistance R_{PUP}, voltage threshold-low V_{TL}, and voltage threshold-high V_{TH} specifications. V_{TL} is the voltage below which, during a falling-edge on the 1-Wire network, a logic low is detected. V_{TH} is the voltage above which, during a rising-edge on the 1-Wire network, a logic high is detected. Both V_{TL} and V_{TH} are a function of V_{PUP} and 1-Wire recovery times.

	C_{IO} (pF)		V_{PUP} (V)		R_{PUP} (kΩ)		V_{TL} (V)		V_{TH} (V)	
Device	**TYP**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
iButtons										
DS1925 High-Capacity Temp. Logger w/ 122kb Data-Log Mem.		120000	3.0	5.25		2.2	$0.5V_{PUP}$	$0.75V_{PUP}$		
DS1923 Hygrochron Temperature/Humidity Logger	100	800	3.0	5.25		2.2	0.4	3.2	0.7	3.4
DS1922 High Temp. Logger w/ 8kb Data-log Mem.										
DS1922L/T Temp. Logger w/ 8kb Data-log Mem.										
DS1921G Thermochron	100	800	2.8	5.25		2.2	0.71	2.70	0.66	2.70
DS1921H/Z High Resolution Thermochron										

DS1904 Real-Time Clock		50	2.8	6.0	5 (Note 1)		0.8		2.2	6.0
DS1972 EEPROM		1000	2.8	5.25	0.3	2.2	0.5	V_{PUP}-1.8	1	V_{PUP}-1.0
DS1992/3 Memory	100	800	2.8	6.0	5 (Note 1)		0.3		2.2	
DS1990R Serial Number	100	800	2.8	6.0	0.6	5	0.3		2.2	
DS1977 Password-Protected 32kb EEPROM		5000	2.8	5.25	0.6	2.2	0.5	3.2	0.7	3.4
DS1982/DS9105 Memory		800	2.8	6.0	5 (Note 1)		0.8		2.2	
DS1996	100	800	2.8	6.0	5 (Note 1)			2.2		
DS1920 Temperature Logger		800	2.8	6.0			0.8		2.2	
DS1990A	100	800	2.8	6.0	0.6	5	0.3		2.2	
DeepCover® Secure Authenticators with SHA-256										
DS28E15 512b User EEPROM		1500	2.97	3.63	0.3	1.5	0.65V_{PUP}		0.75V_{PUP}	
DS28E22 2kb User EEPROM										
DS28E25 4kb User EEPROM										
DeepCover® Secure Authenticators with ECDSA										
DS28E35 1kb User EEPROM		1500	2.97	3.63	0.3	1.5	0.65V_{PUP}		0.75V_{PUP}	
Memory										
DS24B33 4kb EEPROM		2500	2.8	5.25	0.3	2.2	0.5	V_{PUP} -1.8	1.0	V_{PUP} -1.0
DS2413 Addressable Switch	100	800	2.9	5.25	1.5	2.2	0.4	3.2	0.7	3.6
DS28E04-100 Switch, EEPROM, PIO	100	800	2.8	5.25	0.3	2.2	0.46	4.40	1.0	4.9
DS2408 Addressable Switch		1200	3.3	5.25		2.2	0.5	3.2	0.8	3.4
DS2431 1kb EEPROM		1000	2.8	5.25	0.3	2.2	0.5	V_{PUP}-1.8	1.0	V_{PUP}-1.0
DS2430A 256-bit EEPROM		1000	2.8	5.25	0.3	2.2	0.46	V_{PUP}-1.8	1.0	V_{PUP}-1.1

DS2401 Serial Number		800	2.8	6.0	1.5	5.0	0.3		2.2	
DS2406 Switch w/ 1kb Mem.		800	2.8	6.0			0.5		2.2	
DS28E80 Radiation Resistant		6500	2.97	3.63	300	750	0.65V_{PUP} (Note 1)		0.75V_{PUP} (Note 1)	
DS28E05 112-byte EEPROM		1500	1.71	3.63	0.3	750				
DS28E05 112-byte EEPROM		1000	3.0	5.25	0.3	2.2				
Thermometers										
DS28EA00 Sequence Detect and PIO		1000	3.0	5.5	0.3	2.2	0.46	V_{PUP}-1.9	1.0	V_{PUP} -1.1
DS1825 with 4-bit address		25	3.0	3.7	4.7 (Note 1)		0.7		3.0	
DS18S20-PAR		25	3.0	5.5	4.7 (Note 1)		0.8		3.0	
DS1822-PAR										
DS18B20-PAR										
Timekeeping with Interrupt										
DS2417		50	2.2		5.0		0.8		2.2	

Table 1. List of 1-Wire devices.

Conclusion

By modeling an NFC transponder connected to a 1-Wire network as an RC circuit, we can verify whether harvested power delivery and communication are feasible. A smartphone or any device equipped with an NFC transceiver under ISO15693 and FIPS180-4 can authenticate, identify, access memory from, conduct data acquisition on, and control a 1-Wire network. With an NFC system, we can wirelessly power a 1-Wire network and allow secure asset and information management for a node of closed mobile systems and internet of things (IoT) devices.

A similar version of this application note originally appeared on Power Electronics on May 30, 2018.

Related Parts		
DS1822	Econo 1-Wire Digital Thermometer	Free Samples
DS1825	Programmable Resolution 1-Wire Digital Thermometer With 4-Bit ID	Free Samples
DS18B20	Programmable Resolution 1-Wire Digital Thermometer	Free Samples
DS18S20	1-Wire Parasite-Power Digital Thermometer	Free Samples

DS1904	iButton RTC	
DS1920	Temperature iButton	
DS1923	iButton Hygrochron Temperature/Humidity Logger with 8KB Data-Log Memory	
DS1925	iButton High-Density Temperature Logger with 122KB Data-Log Memory	
DS1972	iButton 1024-Bit EEPROM	
DS1977	iButton 32KB EEPROM	
DS1982	iButton 1Kb Add-Only	Free Samples
DS1992	iButton 1Kb/4Kb Memory	Free Samples
DS1996	iButton 64Kb Memory	Free Samples
DS2401	Silicon Serial Number	Free Samples
DS2406	Dual Addressable Switch Plus 1Kb Memory	Free Samples
DS2408	1-Wire 8-Channel Addressable Switch	Free Samples
DS2413	1-Wire Dual Channel Addressable Switch	Free Samples
DS2417	1-Wire Time Chip With Interrupt	Free Samples
DS2431	1024-Bit 1-Wire EEPROM	Free Samples
DS2484	Single-Channel 1-Wire Master with Adjustable Timing and Sleep Mode	Free Samples
DS24B33	1-Wire 4Kb EEPROM	Free Samples
DS28E05	1-Wire EEPROM	Free Samples
DS28E07	1024-Bit, 1-Wire EEPROM	Free Samples
DS28E15	DeepCover Secure Authenticator with 1-Wire SHA-256 and 512-Bit User EEPROM	Free Samples
DS28E22	DeepCover Secure Authenticator with 1-Wire SHA-256 and 2Kb User EEPROM	Free Samples
DS28E25	DeepCover Secure Authenticator with 1-Wire SHA-256 and 4Kb User EEPROM	Free Samples
DS28E80	Gamma Radiation Resistant 1-Wire Memory	Free Samples
DS28EA00	1-Wire Digital Thermometer with Sequence Detect and PIO	Free Samples
MAX66242	DeepCover Secure Authenticator with ISO 15693, I²C, SHA-256, and 4Kb User EEPROM	Free Samples

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