Keywords: 1-Wire, NFC, wireless, NFC system, NFC transponder, NFC transceiver, wireless power transfer, wireless communication

APPLICATION NOTE 6725

USING AN NFC SYSTEM TO WIRELESSLY POWER AND ACCESS A 1-WIRE NETWORK

Abstract: For inductive power transfer, access, control, and information exchange to a 1-Wire® network, you can take advantage of a near-field communications (NFC) system. With harvested power from the NFC link, temperature sensing, authentication, and memory storage can be accomplished via a single node for 1-Wire communication. You can also analyze available harvested voltage, current, and 1-Wire timing constraints by modeling the transponder's radio frequency (RF) power converter and 1-Wire network as an equivalent RC circuit.

Introduction

By using a single conductor and ground, 1-Wire devices provide functionality to mechanical assemblies and electronic systems and reduces the number of nodes needed in a system to just one. Through symmetric and asymmetric authentication, identification, memory, data acquisition, and control, 1-Wire technology also provides secure asset and information management, all in a low-power design. A variety of applications can benefit such as automotive, cloud networks, consumable pharmaceuticals and healthcare equipment, mobile sales channels, and the smart grid. An NFC transceiver, with a built-in 256-bit secure hash algorithm (SHA-256) coprocessor for symmetric authentication, paired with an NFC transponder that includes an I^2C master/slave port and an energy-harvesting output provides security for wireless access to a node of closed portable devices. An NFC system that is compatible with ISO-15693 and FIPS 180-4 supports wireless power and secure access to 1-Wire devices. Wireless access to a 1-Wire network, in turn, offers new use cases and additional flexibility for electronics in applications where NFC is the preferred method of wireless power transfer and communication.

Translating Communication Protocols

To provide wireless access to a 1-Wire network, there must be some translation between the wireless communication protocol such as NFC and the 1-Wire communication protocol. Most major smartphone brands already incorporate NFC to allow users to connect to electronics and unpowered objects such as key fobs, labels, and cards. As such, an NFC-equipped smartphone or device can access a 1-Wire network wirelessly.

In an NFC system, the transceiver is the initiator and produces an RF field to deliver power, send function commands, and enable information exchange. The transponder powers itself from the RF field generated by the transceiver. It also receives function commands to execute and relays data from memory or from attached devices to the NFC reader.

Electromagnetic induction between nearby antennas allows NFC to transmit and receive power, obtain control, and transfer data. A transceiver starts communicating with a transponder by using properly routed PCB traces or wounded wire in a calculated manner.

In **Figure 1**, an NFC hardware setup using a transceiver such as the MAX66300 and a transponder like the MAX66242 is shown. Learn how to implement an antenna design for the MAX66300 in Application Note 5921 – Designing an Antenna for MAX66300. Get more details about NFC and the secure dual-interface of the MAX66242 in Application Note 5995 - Need NFC/RFID? Tomorrow is Today in This Constant State of Innovation.

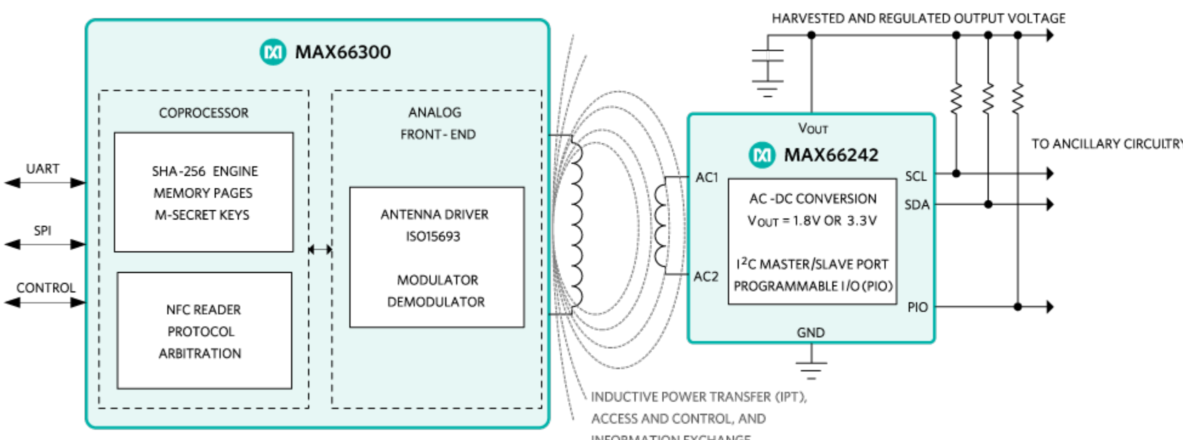

Figure 1. An NFC system consisting of the MAX66300 transceiver and the MAX66242 transponder. Ancillary circuitry is connected to the MAX66242 V_{OUT}, I^2C interface, and the PIO.

The MAX66242 transponder offers two functional features to provide wireless access to attached ancillary circuitry:

1. An internal AC-DC converter converts power from the harvested RF field to a regulated output voltage at V_{OUT}. This allows the MAX66242 to power attached ancillary circuitry, the I^2C interface, and the programmable input-output (PIO).

2. An integrated I^2C master and slave interface allows bidirectional access and control

In the I^2C master mode, the MAX66242 relays information from connected circuitry such as sensors, a microcontroller, and other ancillary circuitry to an NFC transceiver such as the MAX66300 or a smartphone. In the I^2C slave mode, the MAX66242 is an intermediary between the connected host circuitry and an NFC transceiver.

The PIO provides additional functional features. For example, it enables ancillary circuitry when the NFC link is ready for communication and also provides general-purpose control and monitoring information. Read the MAX66242 unabridged datasheet for more details on the PIO.

To access and control a 1-Wire network, the MAX66242 requires bidirectional I^2C and 1-Wire protocol translation. An I^2C-to-1-Wire bridge such as the DS2484 facilitates this task. **Figure 2** shows how I^2C and 1-Wire protocol translation is handled by the MAX66242 and DS2484.

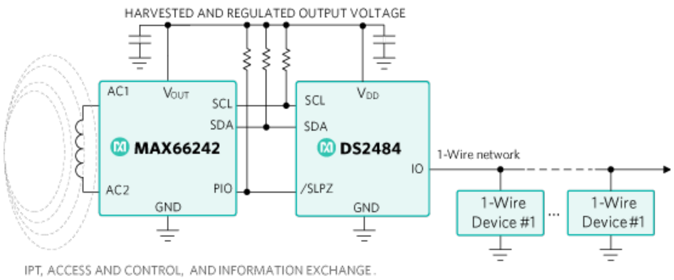

Figure 2. Wireless to 1-Wire Bridge. The MAX66242 powers the DS2484 and 1-Wire devices through V_{OUT}.

The DS2484 complements the MAX66242 by converting between I^2C and 1-Wire protocol with adjustable timing and a sleep mode. By allowing the MAX66242 to place the DS2484 in sleep mode through SLPZ, the DS2484 powers up when required by the NFC transceiver. Once the power down (PDN) bit is toggled to zero in the DS2484 configuration register, the 1-Wire network starts powering up for communication.

If your application requires symmetric key-based authentication of the 1-Wire network, the MAX66242 provides a built-in SHA-256 engine for computing a message authentication code (MAC) under FIPS 180-4. If the application instead needs an asymmetric public-key based authentication, the DS2475, an elliptic curve digital signature algorithm (ECDSA) coprocessor with I^2C to 1-Wire master capability, can be used instead of the DS2484. The DS2475 generates certificates and signatures under the P-256 curve. Learn more about FIPS 180-4 and the P-256 curve from the National Institute of Standards and Technology (NIST). The DS2475 unabridged datasheet provides more detail on the part.

How Harvested Voltage V_{OUT} and Current I_{OUT} Can Power a 1-Wire Network

The MAX66300 and the MAX66242 complete an NFC system that meets the ISO 15693 and the FIPS 180-4 standards. When both are connected to individual PCB antennas tuned to 13.56MHz, the MAX66242 harvested output voltage V_{OUT} and output current I_{OUT} can be characterized. The measured results in this section were obtained using the MAX66300-X24EVKIT, which includes the MAX66300 and MAX66242.

Figure 3 shows the available voltage at V_{OUT} harvested by the MAX66242 concerning the distance from the MAX66300 antenna. The voltage values for V_{OUT} are obtained when both the transmit and receive antennas are parallel and centered to each other. The MAX66300 output driver antenna configuration in Figure 3 uses on-off keying (OOK) and drives the antenna differentially using the ANT1 and ANT2 pins. The voltage at V_{OUT} varies with different antenna configurations, orientations, and environments, examples include being in the presence of nearby metals or other transponders in the read zone. At 3.2cm or less, V_{OUT} can output 3.3V or 1.8V depending on the user configuration. At distances greater than 10.2cm, no harvested voltage regulation is present at V_{OUT}.

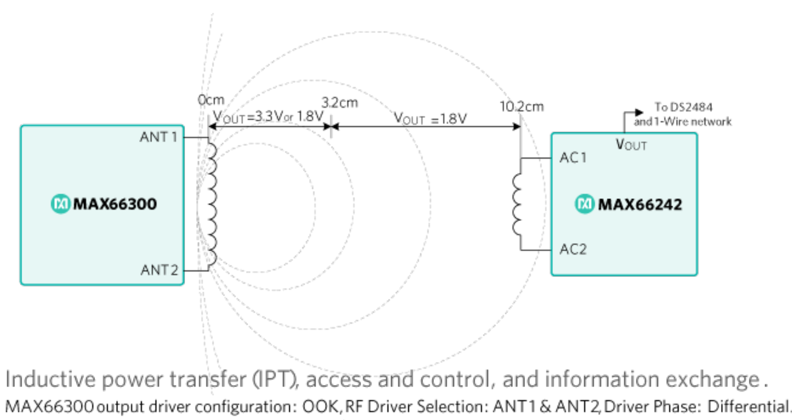

Figure 3. The MAX66242 V_{OUT} versus distance from the MAX66300 loop antenna.

To power, access, and control a 1-Wire network wirelessly, the energy harvested from the NFC link must power the MAX66242, the DS2484, and the 1-Wire devices as shown in Figure 2. To properly design an NFC-powered 1-Wire network, it is critical to understand the amount of current available I_{OUT} from the harvested output voltage V_{OUT}. **Figure 4** models I_{OUT} and V_{OUT} as an ideal rectified voltage V_S and source resistance R_S.

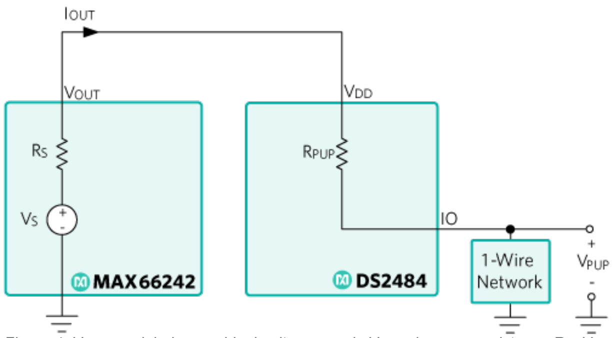

Figure 4. V_{OUT} modeled as an ideal voltage supply V_S and source resistance R_S. V_{DD} is the voltage supply for the DS2484. The 1-Wire network pullup voltage is V_{PUP}. R_{PUP} is the pullup resistance of 1-Wire network.

The ideal rectified voltage V_S equals the open-circuit voltage at V_{OUT}. The source resistance R_S effectively increases the pullup resistance of the 1-Wire network to R_S + R_{PUP}, where R_{PUP} is internal to the DS2484. Get more details about the resistance value of R_{PUP}, including the active pullup (APU) and the strong pullup (SPU), from the DS2484 data sheet. V_{DD} is the voltage supply for the DS2484. Note that V_{OUT} shares the same node as V_{DD} and, therefore, are equal. The 1-Wire network pullup voltage is V_{PUP}. Figure 5 shows the load regulation of V_{OUT} with the same configuration described in Figure 3 at a distance of 0cm from the antenna of the NFC transceiver.

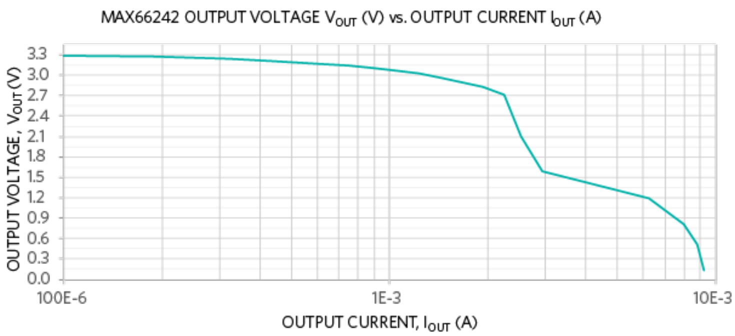

Figure 5. Output voltage (V_{OUT}) versus output current (I_{OUT}) for 3.3V V_{OUT} mode.

The output voltage (V_{OUT}) is defined as the ideal rectified voltage (V_S) minus the voltage drop across the source resistance (R_S) due to I_{OUT}. The source resistance (R_S) is defined in Equation (1) as follows:

$R_S = (V_S – V_{OUT}) / I_{OUT}$ (1)

Figure 6 shows how the source resistance (R_S) varies concerning the measured output current (I_{OUT}) when the output voltage (V_{OUT}) is set to the 3.3V mode. Source resistance (R_S) exhibits nonlinear characteristics because of the challenge in maintaining a constant harvested V_{OUT} with an increasing I_{OUT} demand.

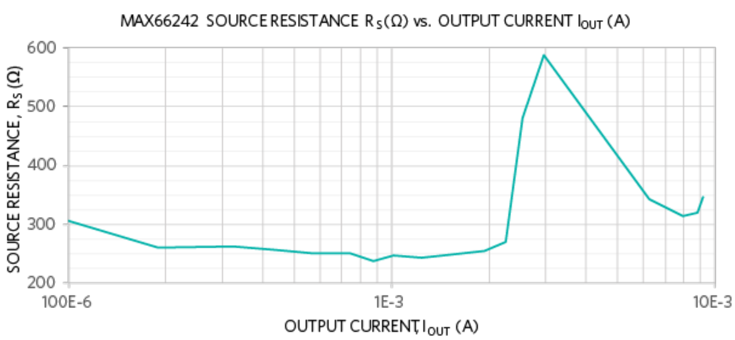

Figure 6. Source resistance (R_S) for 3.3V V_{OUT} mode.

Not only does R_S depend on I_{OUT} and V_{OUT}, but it is also initially influenced by the internal pullup resistance (R_{PUP}) of the DS2484. As such, if the 1-Wire network in Figure 4 is represented by an equivalent discharged capacitance (CTOTAL) as shown in **Figure 7**, R_S could have a value dependent on V_{OUT} and on an I_{OUT} that is initially set by R_{PUP}.

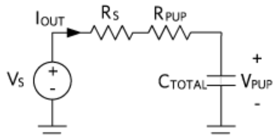

Figure 7. Simplified RC circuit that models the branch connection of the MAX66242 and DS2484 in Figure 4.

As C_{TOTAL} accumulates charge, R_S changes over time because I_{OUT} and V_{OUT} also adjust over time. Using Figure 5, V_{OUT} can be determined by knowing the instantaneous value of I_{OUT}. R_S reaches a final value once the charge on C_{TOTAL} reaches a steady-state value.

Given the nonlinearity between I_{OUT} and V_{OUT}, an iterative approach is needed to calculate the first R_S value. A convergent result for R_S can be determined by solving for I_{OUT} and by looking up the value of V_{OUT} on Figure 5.

Figure 8 illustrates the iterative procedure to calculate the initial value for R_S for an output current (I_{OUT}). A result for R_S is considered convergent if I^{N+1}_{OUT} differs by 10% or less compared to I^{N}_{OUT}. N represents the number of iterations in the flow diagram.

Note: Instead of calculating iterative versions of R_S, Figure 6 can be used in conjunction with Figure 5 to find a final value. However, a better method is to calculate R_S using the flow diagram and to use Figure 5 to look up V_{OUT} as shown in Figure 8. With this approach, only one plot instead of two is used for extrapolation from the measured results to reduce error.

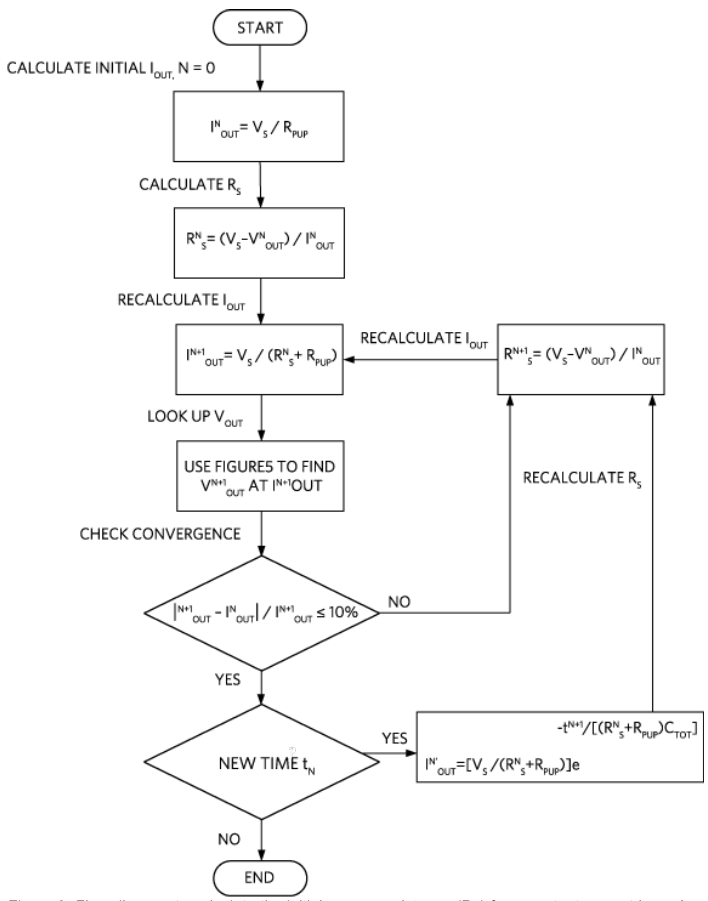

Figure 8. Flow diagram to calculate the initial source resistance (R_S) for an output current I_{OUT}. A result for R_S is considered close to convergence when two sequentially calculated output currents (I_{OUT}) differ by 10% or less. The flow diagram also allows to calculate the R_S for a future time (t_{N+k}) other than the initial time (t_0).

Figure 8 can also be used to recalculate the source resistance (R_S) while the equivalent capacitance (C_{TOTAL}) continues to accumulate charge at time t_N. Set the boolean for "New time t_N?" to 'YES' to use the exponential decay function to calculate I_{OUT} at a later time (t_{N+1}).

For applications that require more output current (I_{OUT}), an NFC transceiver with a high-voltage output driver and high-gain receiver can increase the range and power delivery.

Conclusion

With the MAX66242 as an RC circuit, and by modeling the regulated voltage harvested from the NFC RF field, we can calculate the source resistance added to the 1-

Wire pullup resistance that exists on the 1-Wire network. Calculating the source resistance (R_S) recursively allows us to find the output current (I_{OUT}) supplied by the harvested regulated voltage (V_{OUT}) of the MAX66242.

1-Wire is a registered trademark of Maxim Integrated Products, Inc.

Related Parts		
DS2475	DeepCover ECDSA Coprocessor with 1-Wire Master	Samples
DS2484	Single-Channel 1-Wire Master with Adjustable Timing and Sleep Mode	Samples
MAX66242	DeepCover Secure Authenticator with ISO 15693, I²C, SHA-256, and 4Kb User EEPROM	Samples
MAX66300	DeepCover Secure Authenticator with SHA-256 and RFID Reader	Samples

Application Note 6725: https://www.maximintegrated.com/en/an6725
APPLICATION NOTE 6725, AN6725, AN 6725, APP6725, Appnote6725, Appnote 6725