EXTERNAL CAPACITOR ON VDD OF ANDY100
APN-EXTCAPANDY100-V01

INTRODUCTION

This application note describes the advantages of including an external capacitor on the VDD pin of the ANDY100 IC, and the best way to do it. Furthermore, the changes in the behavior of the tag introduced by the external capacitor are discussed.

Even if the ANDY100 with an external capacitor is fully compatible with commercial readers, some considerations have to be taken into account for a proper system operation. Therefor, some tips for the development of the software of the reader are provided.

SUPPLY CAPACITOR OF UHF RFID TAGS

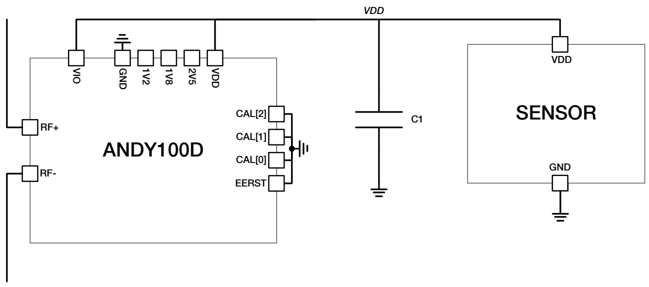
Passive UHF RFID tags retrieve the energy to power up the circuits from the RF field emitted by the reader. Given the ASK modulation of the RF beam and the dynamic power consumption of the tag, the received power may be lower than the consumed power during some time periods. Therefor, as almost any electronic circuit, the tag requires a bypass capacitor to keep a stable supply voltage.

Usually, UHF RFID tags can operate with a small bypass capacitor of a few nF. For simplicity, most tags integrate this capacitor inside the IC. Such is the case of the ANDY100 IC. If the tag is used just for identification, no external component is required.

However, when using the ANDY100 IC with external sensors, additional power has to be provided. Even if the sensors are defined as *low power consuming*, it is common to find out that the peak power consumption of the sensors is pretty high. The average power consumption may be low enough to be energized wirelessly, but during the initialization of the sensor and during the measurement instant high current rushes can appear. When dealing with such external components, if the bypass capacitor has not been increased including an external capacitor the system can oscillate:

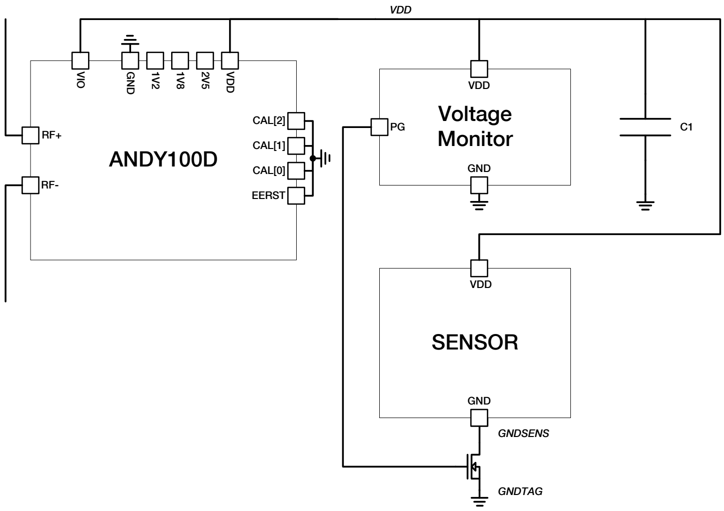
- The tag starts harvesting energy from the RF field and the supply voltage starts increasing.
- The external sensor reaches its power-on threshold and increases its power consumption to perform the initialization and/or measurements.
- The supply voltage of the tag falls below the power-off threshold voltage of the sensor.
- The sensor is turned off, decreasing its power consumption.
- The tag keeps on harvesting energy from the RF field, and the supply voltage starts increasing again.

In such situations, this oscillation will occur continuously and the supply voltage will never reach a stable value. In order avoid this behavior, an external component has to be included in the system to provide the energy required by the peak current rushes. The energy storage can be provided connecting a greater bypass capacitor in VDD, as shown in the next figure.



EXTERNAL SUPPLY CAPACITOR TO PREVENT STARTUP OSCILLATION

Nevertheless, the external capacitor is not a complete solution. If the trip-on and trip-off threshold voltages of the sensor are close, the system will oscillate anyway. It is necessary to charge the capacitor above the trip-off threshold of the sensor so that the supply voltage, even after the voltage drop caused by the initialization of the sensor keeps above the trip-off point. An effective solution is to include a dual threshold voltage monitor in the system, and to switch on the sensor only when the supply capacitor is charged with enough energy. The following circuit shows an example of this solution.



For example, the MAX6427MR IC of Maxim can be used to connect the sensor once the supply voltage is above 2.4V, and disconnect it when the supply voltage falls below 1.8V. In this example, the energy available for the initialization of the sensor is

$$E_{C_{ON}} = \frac{1}{2} \cdot C \cdot {V_{ON}}^2 \tag{1}$$

$$E_{C_{OFF}} = \frac{1}{2} \cdot C \cdot {V_{OFF}}^2 \tag{2}$$

$$E_{Available} = E_{C_{ON}} - E_{C_{OFF}} = \frac{1}{2} \cdot C \cdot ({V_{ON}}^2 - {V_{OFF}}^2) \quad (3)$$

In order to estimate the required value of C, the peak power consumption of the sensor and the duration of the initialization process have to be known. With this values, the energy required by the sensor during the initialization can be calculated.

$$E_{INIT} = P_{INIT} \cdot t_{INIT} \quad (4)$$

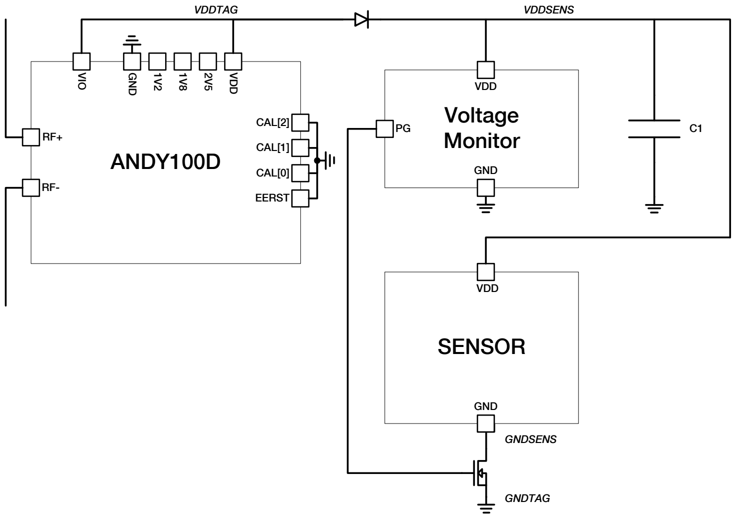
In order to ensure that the supply voltage after the initialization of the sensor is above the trip-off voltage, the minimum value of C can be obtained. The energy provided by the capacitor shall be greater than the the energy required by the sensor for the initialization process.

$$E_{Available} \geq E_{INIT} \quad (5)$$

From equations 3 and 4, the required minimum value of C can be obtained:

$$C \geq \frac{2 \cdot P_{INIT} \cdot t_{INIT}}{{V_{ON}}^2 - {V_{OFF}}^2} \quad (6)$$

With this implementation, the system will not oscillate anymore. Nevertheless, the supply voltage of the tag will now be a stable value maintaining the tag alive even in absence of RF field (for short period of times). This may cause unexpected behavior of the tag as the internal flags will not be reset after RF field off periods. To avoid system malfunctioning, a diode can be used to isolate the supply voltage of the tag and the supply voltage of the sensor. This way, the additional supply capacitor will only affect to the sensor circuitry.



SYSTEM CONSIDERATIONS

The solution presented here allows us to design systems with low power sensors connected to UHF RFID tags. However, the inclusion of a large external capacitor in VDD changes slightly the functionality of the system.

The most relevant difference is the wake-up time of the tags. Identification tags are designed to be awake in less than 1.5ms. Thus, when designing the software that controls the readers the response time expected from the tags is considered negligible.

However, when an external supply capacitor has to be charged, the wake-up time of tags is increased proportionally to the value of C. If the value of the supply capacitor is in the order of tens of μF (typical configuration in ANDY100 powered tags), the charge of the tag can take several seconds.

Moreover, the actual supply voltage of the tag is filtered with a high RC time constant. This means that the supply voltage takes the average value of the energy harvested during a time span of several seconds. In order to get a high enough supply voltage, it is important to maximize the RF field emission time in the reader. Notice that this has to be done always in accordance to local regulations.

READER SOFTWARE DEVELOPMENT TIPS

In order to maximize the read range of UHF RFID sensors and to speed up the wake-up of the sensor tags, one simple goal has to be kept in mind: maximize the radiated energy. This means to maximize the emitted power and maximize the duty cycle of the emission.

The first part is usually the easy one: maximize radiated power. The configurable maximum emission power depends on the reader included in the system. The control API usually includes a power configuration method to change this setting. If the communication range is important for the application, this parameter should be set to the maximum value. However, notice that depending on the antenna connected to the reader and the local regulations a lower value may be required.

Nevertheless, if the communication range of the system is not an issue (low range applications), it is preferable to configure a lower emission power to save power in the reader side. In this type of application, the communication link can also be improved reducing the output power.

When dealing with the second part of the maximize radiated energy goal, the software design takes a more important role. The configuration of the duty cycle of the RF field is not usually a configuration parameter of the reader. This means that the amount of time spent radiating power depends on the internal implementation of the RFID procedures included in the API of each reader.

For example, when triggering a *read_tags* procedure, a reader may emit power for 100ms querying for tags while another reader may do the same for 500ms. Some readers allows the designer to specify the amount of time the querying procedure shall take. If instead of searching visible tags, a specific memory location of a tag has to be read a *read_tag_memory* procedure may be used. In this case, the duty cycle of the emission during the execution of this procedure will be different from the previous case. Moreover, this time may also differ from one reader to another.

Even when dealing with the same reader, it is common to have different options and procedures to perform the same actions. For example, many readers allow to perform procedures in a synchronous or an asynchronous way. In each case the internal execution of the same procedure can be different.

In order to optimize the software, the reader shall be characterized. This characterization will allow the designer to select the best procedures available in the APIs to perform the desired actions with the maximum duty cycle of RF emission.