USING THE CS114 IN LOW POWER BATTERY APPLICATIONS

This application note discusses the following:

- Choosing a battery
- Using the CS114 in low power mode
- Calculating the average power

1 CHOOSING A BATTERY

One of the most important aspects of designing a battery powered application is to choose the appropriate battery. A battery's characteristics will vary depending on internal chemistry, current drain and temperature. Batteries are classified into two broad categories: Primary batteries, which are non rechargeable and secondary batteries, which are rechargeable. Primary batteries are generally lower cost and have higher energy densities than rechargeable batteries. While secondary batteries are not indefinitely rechargeable due to dissipation of the active materials, loss of electrolyte and internal corrosion. They must also be charged before use.

The proper battery can be the difference between a successful product and a costly failure. Some of the features to consider are:

- **Voltage –** It is important to know the nominal, minimum and maximum voltage of the battery. e.g. A 1.5V alkaline battery will discharge from 1.5V to 0.9V.
- **Discharge Current –** The average discharge current determines how large the battery must be to operate the device for a given amount of time. It is important to also know the maximum discharge current (intermittent loads) to ensure that the battery can deliver these loads.
- **Battery Life –** The battery life will be dependent on the discharge current. Usually the battery life is specified at the discharge current that gives maximum battery life and this reduces for larger discharge currents.
- **Size and Weight –** The chemistry of the battery and the power consumption of the application will greatly impact the size and weight of the battery selection. Be aware that typically a smaller, lighter battery with the same energy usually costs more than a larger, heavier one.
- **Shelf Life –** Consider how old the battery is before the customer gets it (inventory, supply chain, shop inventory. Some batteries have a much longer shelf life than others. Sometimes the shelf life is specified as a self discharge current which should always be subtracted from the battery life.
- **Temperature –** Battery chemistry will determine the range of temperatures that a battery can be used at however even if the battery is specified for operation at an extreme temperature be aware that battery performance and life could still be affected. Low temperatures compromise performance, while high temperatures dramatically reduce the life of cells.
- **Primary or Secondary –** Rechargeable or secondary cells can be used many times, but are generally more expensive and require a charger.
- **Charging –** Improper charging is the leading cause of early failure in rechargeable batteries. A better charger will often pay for itself in increased performance and reduced replacement costs.
- **Cycle Life –** Rechargeable batteries can only be recharged a certain number of times.

- **Cost –** A technically ideal battery could be cost prohibitive. For example a lithium primary battery might be more than 30 times the cost of an alkaline battery. Also remember to factor in the cost of battery connectors, manufacture and additional circuitry for circuit protection and / or charger circuitry.

In the electronics industry the choice of battery is frequently chosen from one of the following:

Battery Style	**Alkaline** **(e.g. 2 x AA battery)**	**Coin Cell** **(e.g. CR2032)**	**Primary Lithium Battery** **(e.g. ½AA 3.6V Lithium Thionyl Chloride)**	**Secondary Battery** **(e.g. Panasonic CGA103450)**
Voltage	1.5V Nominal Discharges from 1.5V to 0.9V for 95% discharge	3.0V Nominal Discharges from 3.3V to 2.5V for 95% discharge	3.6V Nominal Discharges from 3.7V to 3.5V for 95% discharge	3.6V Nominal Discharges from 4.2V to 3.2V for 95% discharge
Max Discharge Current	1000mA typical	3mA typical	50mA typical	200mA typical
Battery Life	3000mAh typical	230mAh typical	1200mAh typical	1800mAh
Ease of measurement of battery voltage	Easy. Output voltage varies significantly with battery life	Difficult. Flat response until nearly fully discharged. Output voltage varies significantly with temperature.	Very difficult. Very flat response until nearly fully discharged. Output voltage varies significantly with temperature. A software gas gauge may be implemented.	A battery “gas gauge” is usually incorporated into the charger circuitry. Current into and out of the battery is constantly monitored and battery life calculated.
Size and Weight	Bulky and heavy Solution	Smallest Solution	Small Solution	Bulky solution
Shelf Life	Approx 5 years	Approx 10 years	Approx 10 years	Approx 1 year
Temperature	-20°C to 55°C typical	-20°C to 55°C typical	-55°C to 85°C	-20°C to 60°C typical
Primary or Secondary	Primary	Primary	Primary	Secondary
Charging	-	-	-	Li-ion circuits require charging circuits with over-voltage, under-voltage and over discharge protection.
Cycle Life	-	-	-	500 cycles typical
Cost	Lowest cost solution	Low cost solution	Expensive Solution	Very expensive solution

Table 1 – Battery comparison guide

2 USING THE CS114 IN LOW POWER MODE

2.1 Configuration 1 – Dynamically powering the CS114 by pulling the $\overline{CS}$ pin low

The easiest way to operate the CS114 in low power mode is by dynamically controlling the $\overline{CS}$ signal. Once the $\overline{CS}$ pin is pulled low the CS114 powers up. It must be held low for at least 7.8 ms before the I^2C interface is fully enabled. After this time reading from and writing to registers over the I^2C interface will fully configure and control the CS114. Pulling the $\overline{CS}$ pin high will power down the CS114. It will remain in power down until the $\overline{CS}$ pin is pulled low again.

The only disadvantage of this configuration is that the device continues to consume a nominal sleep current. While this is low enough for most applications some applications will demand lower sleep currents which are possible using the alternative configurations below.

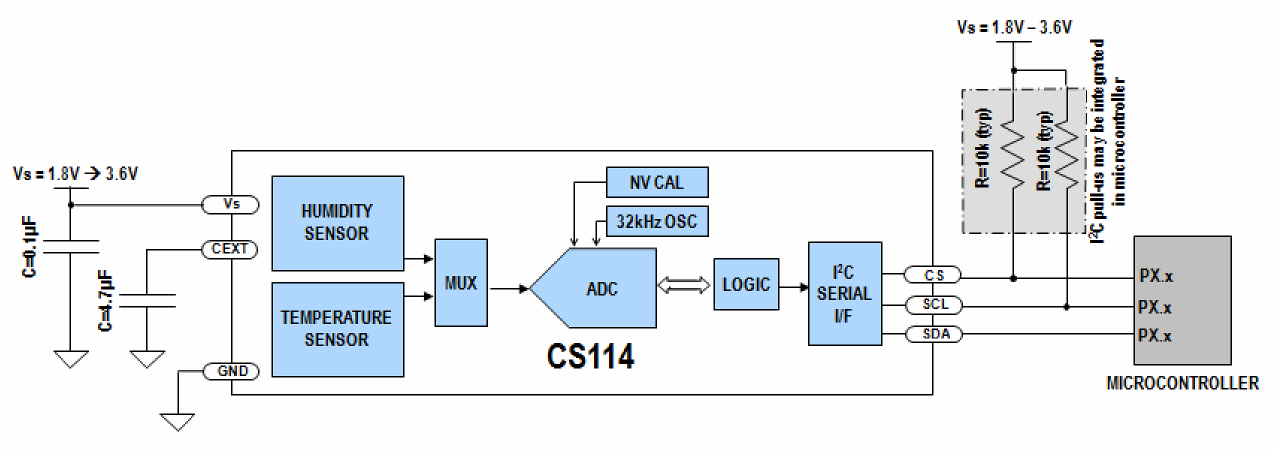

Figure 1 – In configuration 1 the microcontroller dynamically controls the power states (powered up or sleep mode) or the CS114 by using the $\overline{CS}$ pin ($\overline{CS}$ is low to power up).

2.2 Configuration 2 – Powering the CS114 by dynamically pulling the V_S pin high

For applications that require a lower sleep current, the CS114 can be dynamically powered by a port pin from the microcontroller each time a conversion (or conversions) is required. Since the CS114 only draws 400µA, most microcontroller port pins should have no problem sourcing this current. In this mode of operation the sleep current of the CS114 can be neglected. Because the CS114 will be powered OFF between conversions the $\overline{\text{CS}}$ pin becomes redundant and can be permanently pulled low.

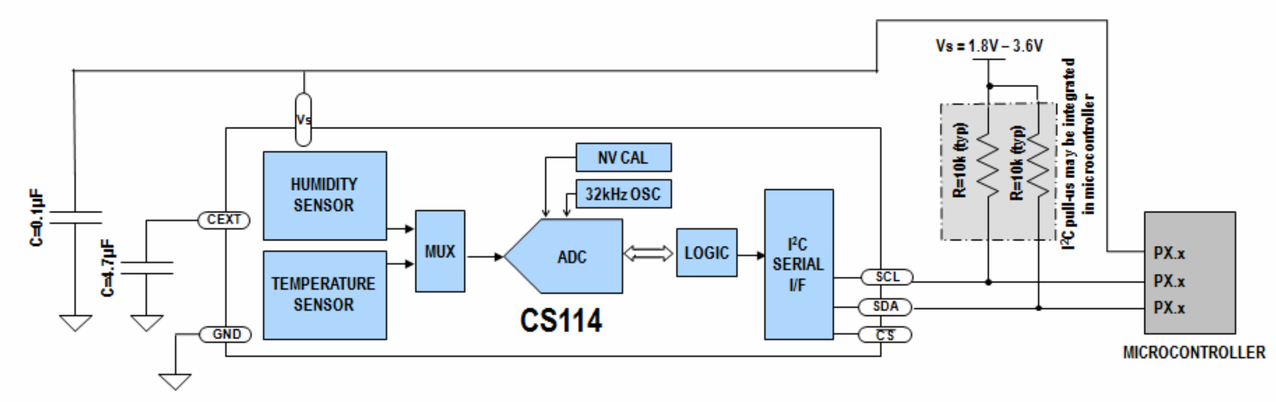

Figure 2 – In configuration 2 the $\overline{\text{CS}}$ pin is permanently tied low and the microcontroller dynamically powers up the CS114 via a port pin.

This mode of operation will not be possible if the microcontroller logic high output is greater than the maximum supply voltage of the CS114 (3.6V). If this is the case the CS114 can be powered from a port pin via a 3.6V zener diode (or similar) or using a transistor switch to the appropriate power supply.

2.3 Configuration 3 – Powering the CS114 by dynamically pulling the GND pin low

Some microcontrollers are designed to sink current and may be able to source only a few micro-amps of current. In such instances, the CS114 can be powered by dynamically controlling the GND pin. The V_S pin is always connected to the 1.8V to 3.6V power supply and a port pin from a microcontroller outputs a logic low to power connect the GND pin to ground (powering up the CS114) and a logic high to connect the GND pin to the power supply (powering down the CS114). The $\overline{CS}$ pin and capacitor grounds are also connected to the GND pin. As with configuration 2 in this configuration the sleep current of the CS114 can be neglected.

An additional advantage of this design is that the ground plane of the CS114 can be separated from the ground plane of the rest of the PCB. This will help reduce thermal heating of the CS114.

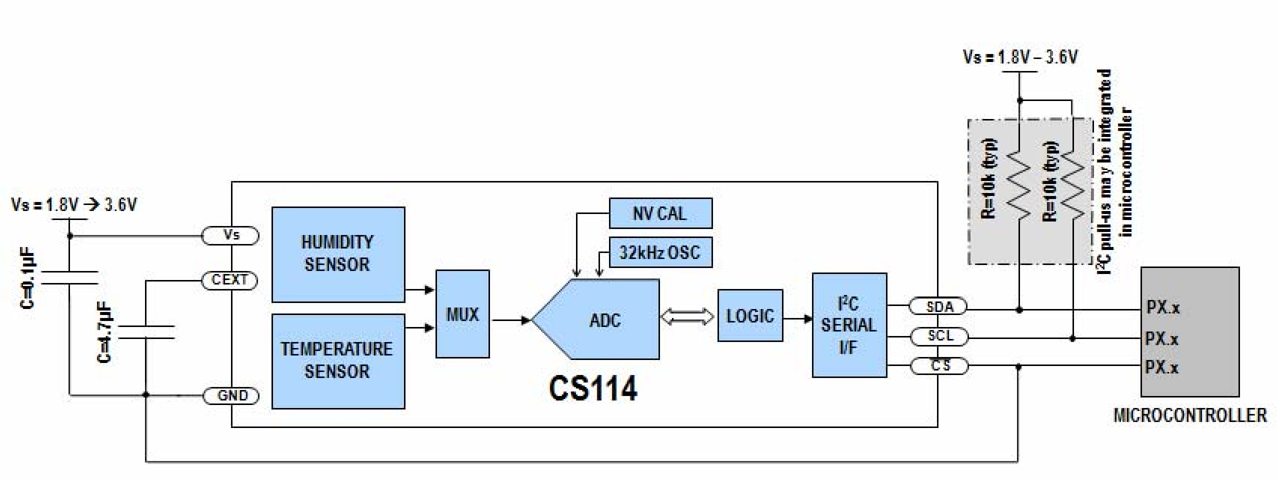

Figure 3 – In configuration 3 a port pin on the microcontroller dynamically powers up the CS114 by pulling the GND, $\overline{CS}$, and capacitors to ground.

3 CALCULATING THE AVERAGE POWER

Let's consider an application taking a humidity and temperature measurement every minute using the CS114 in configuration 2. The power specifications are as follows:

- The CS114 conversion current is 400µA.
- In configuration 2 the sleep current is negligible (<<1µA depending on microcontroller)
- The conversion time and noise performance of the sensor measurement can be traded off for the particular application. The default conversion time of the CS114 is 300ms however this can be reduced to 47ms at the expense of noise. However at 47ms the noise performance of the sensor measurements is still negligible.
- Two conversions will be performed – one humidity and one temperature.
- The conversion time (including wakeup overhead) is 47ms per conversion.
- Every time the CS114 is powered up a 4.7µF capacitor (on C_{REF}) must be fully charged. The charging process is better than 50% efficient.

The power consumption can be calculated as follows:

Total Charge = Conversion Charge + Sleep Charge + Capacitor Charge + Re-initialisation Charge

- Conversion Charge = Conversion Current × Conversion Time × No of Conversions

  = 400µA × 47ms x 2 conversions

  = 37.6µAs per set of conversions (1 minute)
- Sleep Charge = Sleep Current × Sleep Time (lets assume 0.1µA sleep current in configuration 2)

  = 0.1µA × (60s – (47ms x 2 conversions))

  = 6µAs per minute (assuming one set of conversions per minute)
- Capacitor Charge Current = Capacitance × Charge Voltage ÷ Efficiency

  = 4.7µF × 1.8V ÷ 50%

  = 17µAs per set of conversions (1 minute)
- CS114 re-initialisation charge = Conversion current × Re-initialisation time

  = 400µA × 500µs

  = 0.2µAs per set of conversions (1 minute)

- **Total Charge = 37.6µAs + 6µAs + 17µAs + 0.2µAs = 60µAs per minute**

  = 1µA average current

What is the average current at other conversion rates?

- For a double conversion (temperature + humidity) every 1s the average current is 55µA.
- For a double conversion (temperature + humidity) every 10s the average current is 5.6µA.
- For a double conversion (temperature + humidity) every 1 minute the average current is 1µA.
- For a double conversion (temperature + humidity) every 5 minutes the average current is 0.3µA.