Advanced Configuration Application Note

NCS32100 Low Power Battery Backup Implementation

AND90207/D

Introduction

The NCS32100 supports a battery backup mode where VBAT can be tied to a 3.3 V nominal external battery backup. This is intended to be used in applications where the turns count needs to be maintained correctly even during times where the VCC power is out. Some systems rely on the turns count of a shaft to know the current position of an armature due to a ratioed range of motion. If the power is out either due to maintenance or accident, the master controller must be updated on the number of turns that occurred while the power was unavailable.

The current draw from the battery (connected to VBAT) during normal operation is < 1 μA. The NCS32100 reference design firmware is programmed to go into a low power battery mode anytime the VCC voltage falls below the VBAT voltage. During this time, all external communication between the NCS32100 and the outside master is not possible because the internal level shifters and drivers are powered down. When the VCC voltage drops below the VBAT voltage the NCS32100 will switch over to draw current from the VBAT pin, and in turn the connected backup battery. During this time, the firmware running on the internal MCU puts the sensor front end to sleep to conserve power. The firmware periodically wakes up the sensor front end to take a position reading and to update the multi−turn count. The amount of current that is drawn from the battery depends on the wakeup period. The NCS32100 will be able to track turns count at higher speeds with shorter wakeup periods, but it will also consume more amortized current from the battery in battery mode. The NCS32100 Reference Design firmware allows the user to select the wakeup period to control the current draw and the turns count proficiency to meet the needs of their specific application.

Interaction between Internal Front End and Internal MCU

The low power battery backup mode relies on both hardware in the NCS32100, and firmware programmed on the internal NCS32100 MCU. The diagram below shows the internal connections between the NCS32100 internal MCU and the internal sensor front end (SFE).

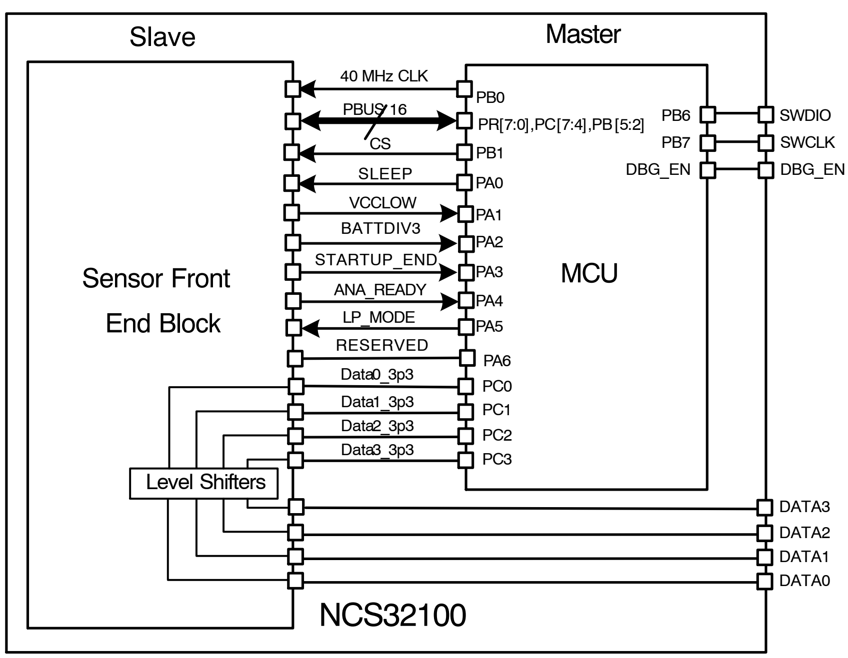

Figure 1. NCS32100 Internal Interface between the Sensor Front End and Integrated MCU

The signals that are used during a backup battery low power mode sequence are the following:

Table 1. SIGNALS USED FOR LOW POWER BATTERY MODE ROUTINE

Signal	Direction (as seen by the MCU)	Description
LP_MODE	Output	Used to reset the sensor front end filters
VCCLOW	Input	Indicator that the VCC supply is down and the VBAT voltage is being used to power the device
SLEEP	Output	Used by the MCU to put the sensor front end analog blocks to sleep
CLK_40MHz	Output	40 MHz master clock provided by the internal MCU

With these 3 signals, the internal NCS32100 MCU has the information and control that it needs to orchestrate a low power battery backup mode. The sensor front end informs the MCU that the VCC supply has fallen below the VBAT voltage by asserting the VCCLOW signal high. At this point the sensor front end switches from VCC to VBAT for the devices source of supply power. There is an internal pull down on the VCC pin to prevent it from floating to the VBAT voltage when the switch over occurs. If power is re−instated on VCC, the supply current will overpower the pull−down resistor and the sensor front end will put the VCCLOW signal low signifying that power is being used from the VCC pin. The MCU can drive the SLEEP signal and the LP_MODE signal on the sensor front end to power down various parts of the device. The LP_MODE signal (when asserted high) will power down the interface level shifters and most of the DSP block in the sensor front end. The SLEEP signal will power down the analog blocks in the sensor front end when asserted high. The MCU also provides the 40 MHz clock to the system. It can turn that clock off to save power as needed as well. Be aware that for any change in the LP_MODE or SLEEP signals to take effect, the clock must be active to latch in the changed values. If the MCU wants to make a change to either of these signals, it needs to be done at least 2.5 clock cycles before it turns the clock off. In order for the multi−turn count to be accurately tracked, the sensor front end needs it’s analog blocks powered on so that it can take measurements from the sensor coils. The sensor front end also needs an active excitation frequency, which requires the analog blocks and the 40 MHz master clock to be active. If the LP_MODE signal is driven high and the SLEEP mode signal is driven low, all the necessary blocks will be powered. If the MCU provides the 40 MHz clock then the DSP and excitation coil drivers will have what is needed to operate. With the SLEEP pin driven low and the LP_MODE pin driven high, the NCS32100 will be in low power mode, but will not be asleep. In this mode the device will still draw around 20 mA + because the analog front end is active and the chip is actively driving the excitation coil. If the device is in sleep mode and low power mode with the 40 MHz clock turned off, then the total current draw on VBAT is < 25 μA (if the MCU is in hibernation mode). The current draw from the battery can be lowered substantially while still keeping track of the turns count by going in and out of sleep mode while in low power mode. As long as the analog front end is awakened at least 3 times per rotation of the rotor the turns count will be maintained correctly. The MCU firmware controls the wakeup timing, and therefore controls the overall current draw from the battery and how fast the rotor can spin without a lapse in turns count accuracy.

There are two registers that are used to control the timing associated with the SLEEP signal and the LP_MODE signal in the sensor front end. They are as follows:

Table 2. NCS32100 REGISTERS USED FOR WAKEUP DELAYS DURING LOW POWER BATTERY MODE ROUTINE

Register Name	Register Address	Description
NORMAL WAKEUP DELAY	0x4C	Number of clock cycles that the DSP waits before processing samples from the analog front end when transitioning from low power mode to normal mode.
DSP WAKEUP DELAY	0x4F	Number of clock cycles that the DSP waits before processing samples from the analog front end when transitioning from sleep mode to low power mode.

The NORMAL WAKEUP DELAY register and the DSP WAKEUP DELAY register are important because they prevent the DSP from using incoming samples from the analog front end to calculate position and turns count during times when the samples might be corrupt due to the settling time required by the analog circuitry and the excitation coil ramp up. The image below shows what the excitation coil frequency voltage looks like when the device is toggling in and out of sleep mode.

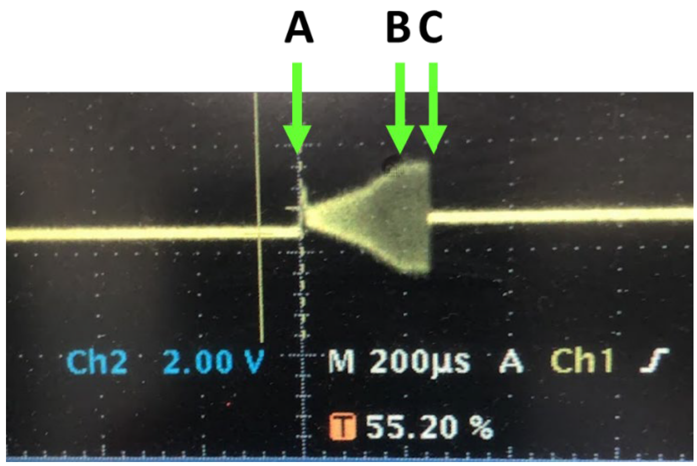

Figure 2. Excitation Frequency during Low Power Mode Wakeup

At point A, the MCU puts the SLEEP pin low, and at point C, the MCU is asserting the SLEEP pin high again. This represents one of the periodic wakeups that are used to update the turns count before going back to sleep. If samples from the analog front end are used by the DSP to calculate position and turns count during the ramp up time between points A and B, then the turns count might be corrupted because the analog circuitry has not yet settled, and the excitation frequency is not yet stable. Point B is the moment at which the excitation is stable, and the samples are ready for correct position and turns count calculation. The amount of time this ramp up takes is unique to each sensor design. Larger excitation coils will require more time to stabilize. Because of this variability in timing, the DSP delays are programmable. The best way to ensure that the turns count will be tracked correctly is to measure the ramp−up time as shown in the image above, and then set the NORMAL WAKEUP DELAY and DSP WAKEUP DELAY registers appropriately. For the image above, the registers should be set to allow for at least 200 µs of ramp up time before samples are used by the DSP. The diagram below shows where each of the timing registers take effect. The transition from low power to the normal state is different than the transition from low power in and out of sleep because in normal mode, the supply voltage will be different than what is supplied by the backup battery. With a different supply voltage, the excitation ramp up timing will be different, thus requiring its own timing setting. The diagram below shows a full backup battery low power mode routine. The blue areas represent when the excitation coil frequency is active. The areas where the DSP WAKEUP DELAY and the NORMAL WAKEUP DELAY register apply are noted.

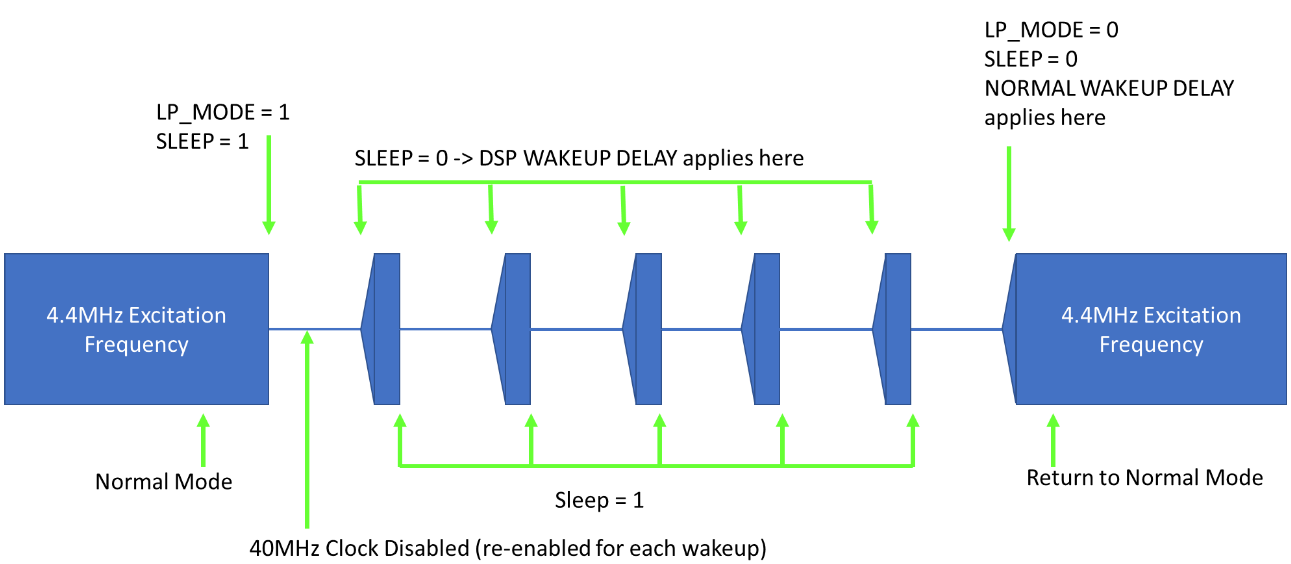

Figure 3. Backup Battery Mode with Periodic Wakeup Routine

Reference Firmware Solution

The reference design firmware, which is programmed on the NCS32100 by default, uses the signal defined above to create a low power backup battery mode solution with programmable wakeup timing. The state machine diagram below shows the general behavior of the NCS32100 reference design firmware. States E and F define the low power battery backup routine. State E is entered from the main state when VCC power is lost. The period at which the wakeup timer expires is programmable by using register 0x90 as defined in the NCS32100 Reference Design Manual. The actual current consumption from the battery in battery mode is dependent on 3 things.

- The DSP WAKEUP DELAY setting: The longer the device is awake during the low power mode the higher the overall current consumption will be.
- The wakeup period: The slower the wakeup period, the lower the overall power consumption will be, but the device will be limited on what rotor speeds it can handle and still give an accurate turns count in battery mode.
- The VBAT voltage. The higher the voltage the higher the overall power consumption. Because the voltage depends on the age of the battery and the type of battery, we focus instead on current consumption from the battery.

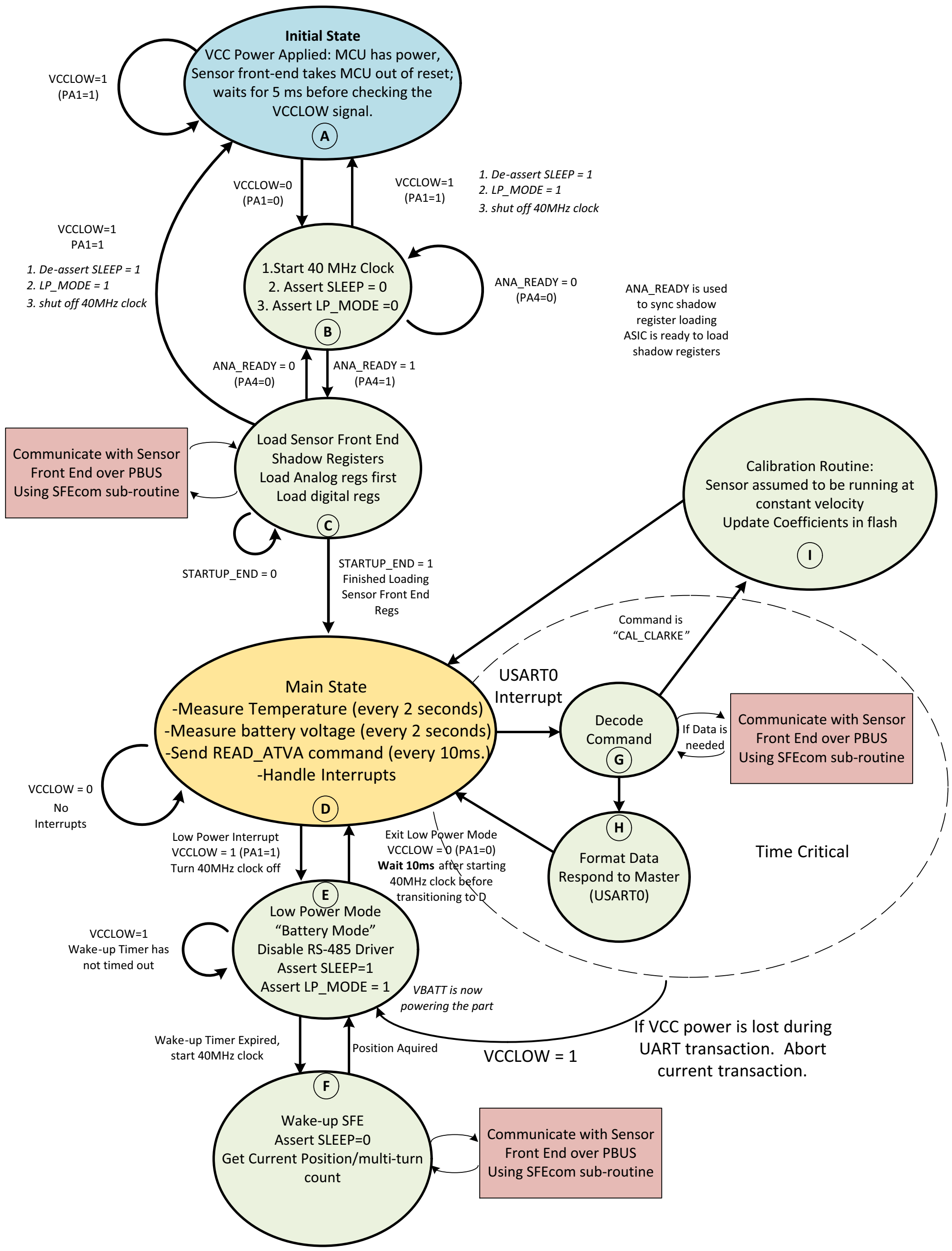

Figure 4. Internal NCS32100 Firmware State Machine Routine

Programmability

To guarantee correct turns count tracking, the low power battery backup mode needs to wakeup at least 3 times per rotation. Therefore, the wakeup period determines the fastest the rotor can move and still maintain accurate turn count tracking.

The wakeup period needed to maintain correct turns count tracking can be calculated using the following equation:

$$\mathrm{WakeupPeriod(s)} = \frac{60}{3 \times \mathrm{Speed}_{RPM}}$$

The default MCU firmware is programmed to wake up every 3 ms any time the rotor is detected as moving, and then revert to the wakeup period defined in register 0x90 anytime the rotor is not detected as moving. This algorithm allows the user to save as much current draw on the battery as possible while still accurately tracking turns counts up to around 6000 rpm. The wake−up period can be configured by the user by writing to register 0x90. This register is 21 by default, and it can be changed to one of 9 values found in the table in the register 0x90 definition. The battery mode algorithm works by moving between a 3 ms wakeup to the wakeup defined by the user in register 0x90. It changes the wakeup period based on the movement of the rotor. If the rotor is not moving, then the algorithm will change the wakeup period to the user defined value in 0x90. If the rotor is detected to move, then the wakeup period will be changed to the 3 ms wakeup until it is detected that the rotor is not moving anymore. This is done to conserve battery power. It is assumed that the rotor will not be moving most of the time battery mode is engaged. The user is allowed to change to slower wakeup time so that they can guarantee turns counts will not be lost during the worst−case acceleration from stand still. The max acceleration from stand still is application dependent.

With the NCS32100 reference design firmware, register 0x90 allows the user to select the standby wakeup period. The following wakeup periods are available.

Table 3. POSSIBLE REGISTER SETTINGS FOR WAKEUP PERIOD TIMING

Register Contents	Period Timing (ms)	Average Current Draw on VBAT (mA)	Max Speed at which Turns Count will be Tracked (rpm)
3	3	10	6600
4	5	5	4000
21	16	1.45	1250
31	24	1	830
42	31	0.8	650
55	41	0.6	487
72	53	0.5	370
100	73	0.4	270
200	140	0.3	140

Battery Considerations

The overall battery life can be calculated as the milli amp hour rating of the battery divided by the amortized backup battery mode current draw. For example, if a 2500 mAh battery is used, and the amortized power is expected to be around 1 mA, then the lifetime of the battery is expected to be 2500 hours, or about 100 days if the encoder were in battery mode continuously. Considerations with the battery should be made, such as:

- The backup battery should not be connected in circuit until the encoder is in application to avoid draining the battery while the encoder is sitting on the shelf
- Batteries should be rechargeable or replaceable if encoder servicing is appropriate in application

Conclusion

The NCS32100 allows for a programmable low power backup battery mode for tracking turns count anytime the VCC is unexpectedly lost. The NCS32100 allows for many flexible solutions for this featured via firmware programming. The default reference design firmware allows for turns count tracking up to 6000 rpm while still allowing for low power consumption from a battery. The standby wakeup period is programmable and should be adjusted based on the applications max expected acceleration from a stand still position.

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