iC-PV AN2

APPLICATION NOTE: Batteries

preliminary

BATTERY REQUIREMENTS

Note: The information given in this document also applies to iC-PVL.

The multiturn encoder device iC-PV operates with a back-up battery supply. This document will give hints for the selection of the battery. During operation, the battery voltage must always stay above 3.0 V. Device operation is pulsed, i.e. the battery current is drawn mainly in short pulses. Between the pulses there is a relatively long idle time. Typically, the pulse width T_{on} is 5 µs with a height of I_{pulse} of 4 mA. The pulse current drain will always stay below I_{max} = 10 mA. The idle current consumption I_{idle} is approximately 1 µA at room temperature. The pulse repetition rate lies between 10 Hz up to 8000 Hz, depending on operating mode and rotating speed of the encoder magnet. Automotive or industrial applications mostly demand an operating life of 10-15 years. A system with iC-PV can reach this time with a battery capacity of 0.5 Ah or more. Depending on the battery usage profile during system lifetime, a smaller battery may also be sufficient.

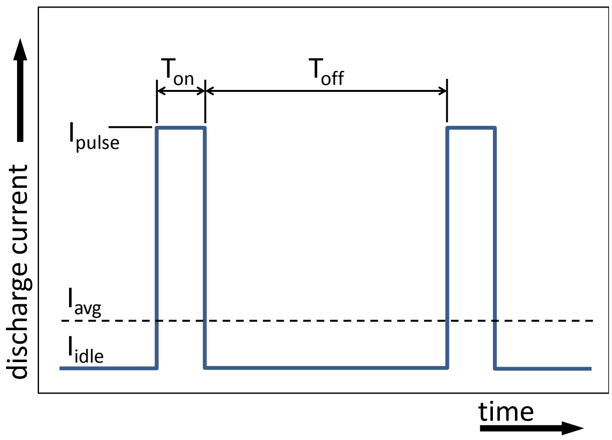

Figure 1: Principle of pulsed current drain

Because of the pulsed current drain of iC-PV, battery lifetime may benefit from an additional blocking capacitor at pin VBAT. Depending on the used battery, the lifetime will be increased if the current pulses are filtered out to certain degree. Application support may be provided directly by the respective battery manufacturer.

The current drain of iC-PV in battery mode follows the principle shown Figure 1. Typical values can be taken from Table 1.

Characteristics of pulsed current drain		
Parameter	**Description**	**Typ. Value**
I_{pulse}	Pulse current	4 mA
T_{on}	Pulse width	5 µs
I_{idle}	Idle current	1 µA
T_{off}	Idle time	0.125 - 100 ms
DC	Duty cycle	1:25 - 1:20 000
I_{avg}	Average current	1.5 - 800 µA

Table 1: Characteristics of pulsed current drain

PROTECTION AGAINST (REVERSE) CHARGING CURRENT

Lithium primary battery cells require an effective protection against charging currents. High charging current will most likely damage the battery. The underwriters laboratories Inc. (UL) engineer standards define two ways of protection, where a redundant setup prevents charging current even for a single cause of failure:

1. Two reverse current protecting diodes in series connection. In case of malfunction of one protective diode, the other one prevents a current flow into the battery. Instead of diodes, also equivalent devices may be used.

2. A reverse current protective diode or equivalent device, protecting the battery from charging current. In case of a malfunction of the diode, a resistor is placed in series to limit the charging current to a safe value, i.e. a limit specified by the manufacturer. No severe damage will occur as long as the current stays below this limit. A typical value is 10 mA of charging current, but depends on the battery manufacturer.

The supply switching circuitry in iC-PV is protected against (reverse) current flow into the battery (charging current). Current flow into the battery is very unlikely, even if specific device failures occur. Nevertheless, it can not be completely excluded. Therefore, if a redundant protection is required, an additional protective diode may be placed in series to the VBAT pin at iC-PV. Alternatively, a current limiting resistor may be sufficient.

Example calculation for current limiting resistor: Highest possible voltage at VDD = 5.5 V. Worst case failure mode is VDD shorted to VBAT. Lowest permissible battery voltage: 3.0 V. The voltage difference would be 5.5 V - 3.0 V = 2.5 V in that case. To limit the current to 10mA in that failure mode a resistor of 2.5 V / 10mA = 250 Ohms would be necessary. With some safety margin a value of 300 Ohms is practical.

CIRCUIT EXAMPLE

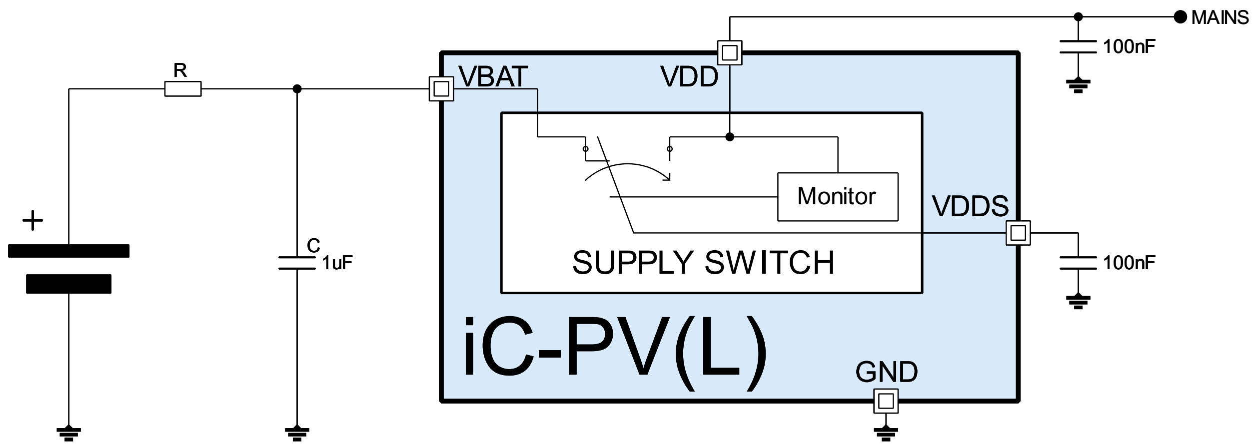

Figure 2: Circuit example for iC-PV battery supply

The example in Figure 2 connects the iC-PV to a battery supply via a RC circuit. As a first consequence, this RC filter structure will smooth the pulsed current drain. The battery will see a more continuous current drain closer to the average current. Secondly, the resistor limits the charge current in case of an iC-PV supply switch malfunction. The resistor value must be suitable to limit the charge current to the desired limit in all possible error cases. Additionally, the voltage drop during normal operation should be minimal.This is possible, since the capacitor C delivers the energy for one pulse and is recharged slowly through resistor R.

BATTERY TYPES

iC-Haus recommends the usage of primary cells with a nominal voltage of 3.6 V or more. These are available for moderate as well as for extended temperature range (e.g. 125 °C). Suitable cells are mainly based on lithium thionyl chloride (LiSOCL2). They feature high energy density, high output voltage stability and operating life up to 25 year. The self-discharge per year is typically in the range of 1 %.

Form Factor 1/2 AA
A cylindrical cell with 25.2 mm length and 14.5 mm diameter. Nominal capacities up to 1.2 Ah are available.

Form Factor 1/6 D
A flat wafer cell, comparable to a coin cell. Diameter 32.9 mm, height 10.2 mm. Nominal capacities up to 1.7 Ah are available.

Form Factor 1/10 D
A flat wafer cell, comparable to a coin cell. Diameter 32.9 mm, height 6.5 mm. Nominal capacities up to 1.0 Ah are available.

Form Factor 2450
A flat wafer cell, comparable to a coin cell. Diameter 24.5 mm, height 5.8 mm. Nominal capacities up to 0.55 Ah are available.

Form Factor ER22G75, BEL Wafer
A flat wafer cell. Diameter 22.8 mm, height 7.5 mm. Nominal capacities up to 0.42 Ah are available.

CALCULATION OF BATTERY LIFETIME

The basic principles for calculating battery lifetime can best be illustrated using an example. The intention is to show the procedure in principle only. It is up to the user to adopt this to individual application requirements and battery properties.

Assumptions

- Selected Device: iC-PVL
- Rated Voltage: 3.6V
- Code Disc: 32 magnetic pole pairs per 360° mechanical

The expected average current consumption in battery mode can be calculated with the help of chapter "CURRENT CONSUMPTION IN BATTERY MODE" in the iC-PVL datasheet. Two application specific information are important here:

- Maximum expected acceleration (from shaft halt) in battery mode
- Maximum expected RPM in battery mode

Lets assume that the code disc can accelerate up to 6.000 RPM (100 rounds per second) within 1s. With this information the maximum acceleration of the code disc can be calculated:

$$\alpha_{disk} = \frac{2 * \pi * 100 \frac{1}{s}}{1s} = 628.3 \frac{rad}{s^2} \quad (1)$$

The code disk has 32 magnetic pole pairs per 360° so the acceleration with regards to the magnetic signals can be calculated as:

$$\alpha_{mag} = \alpha_{disk} * 32 = 20.1 * 10^3 \frac{rad}{s^2} \quad (2)$$

Looking at the A_MAX parameter description in the iC-PVL datasheet an A_MAX setting of "011" is suitable for this application. The maximal average battery current is 10 µA in that case.

A_MAX	Addr. 0x03; bit 5:3				
Code	α_{max} $[\frac{°}{s^2}]$	α_{max} $[\frac{rad}{s^2}]$	typ $f_{min}[Hz]$	typ $I_{avg}[\mu A]$	max $I_{avg}[\mu A]$
000	$160 \cdot 10^6$	$3000 \cdot 10^3$	2000	52	72
001	$40 \cdot 10^6$	$760 \cdot 10^3$	1000	26	36
010	$10 \cdot 10^6$	$190 \cdot 10^3$	500	14	18
011	$2.5 \cdot 10^6$	$48 \cdot 10^3$	250	7	10
100	$625 \cdot 10^3$	$12 \cdot 10^3$	125	4	6
101	$160 \cdot 10^3$	$3 \cdot 10^3$	63	2.5	4
110	$40 \cdot 10^3$	$0.75 \cdot 10^3$	32	2	3
111	$10 \cdot 10^3$	$0.2 \cdot 10^3$	16	1.5	2.5

Figure 3: Selection of iC-PVL parameter A_MAX

Note: When calculating the maximum acceleration that can occur in the application it needs to be considered, that external mechanical influences like shock or vibration can also induce large acceleration spikes into the mechanical system. These potential influences must be taken into account. If the maximum acceleration set by parameter A_MAX is exceeded in battery mode, a position error (POS_ERR) will be raised by iC-PVL. This is an indication that the current position value might be wrong and the system needs to be re-initialized.

If there is only sporadic movement during battery supply, the 10 µA average battery current can be used for battery lifetime calculation.

If there can be enduring movement during battery supply the values given in table "I(VBAT) for angular velocity [RPM]" in the iC-PVL specification have to be taken into account.

Example:
The system is at standstill 99% of the time in battery mode. 1% of the time the system is spinning at 6000 RPM in battery mode. From table "I(VBAT) for angular velocity [RPM]" iC-PVL will draw 800 µA at f_{mag} = 100 Hz * 32 = 3200 Hz. According to the previous calculations the maximum average battery current in standstill is 10 µA. The total average battery current can now be calculated:

$$I_{\text{total avg}} = 0.99 * 10\,\mu A + 0.01 * 800\,\mu A = 17.9\,\mu A \tag{3}$$

With this current the battery lifetime can be calculated. The achievable lifetime depends on the capacity and type of the battery. Please consider:

- VBAT needs to stay above 3 V at all times, thus only the battery capacity to 3 V battery voltage is usable.
- The expected operating temperature range must be considered, because battery capacity depends on the temperature.
- Battery self discharge has to be taken into account.

The relevant information can be found in the specific battery data sheet. Application support may be provided directly by the respective battery manufacturer.

REVISION HISTORY

Rel.	Rel. Date*	Chapter	Modification	Page
A1	2018-11-30		Initial Release	

* Release Date format: *YYYY-MM-DD*