
How to design a V_{BAT} system based on STM32L0/L1 series (with external components)

Introduction

This document describes how to design applications powered by interruptible power supply, which have to retain the content of the backup registers and to keep running RTC, when V_{DD} is turned off or unplugged. The device needs to be connected to an external backup voltage supplied by a battery or by another power source: this mode is called V_{BAT} .

The battery powered application with single power supply, which is powering the device during the whole application life time, can take a benefit from the low-power modes of the devices, such as STOP or STANDBY. This allows to retain the content of the backup registers and RTC information, while suspending the non-active part of the device without any additional component needed.

In applications requiring RTC, while V_{DD} is turned off or unplugged, products, belonging to STM32L0 and STM32L1 series, need external components configurations, while the V_{BAT} mode is self-managed by products belonging to STM32L4 series.

Use cases provided:

- Simple diagram to allow backup domain with minimum external component: diagram allowing longer battery lifetime
- Diagram for applications implementing USB
- Diagram for IoT or mobile application using only coin cells
- Low power diagram for IoT

Different possibilities are proposed, showing the trade-off between lifetime and cost.

Content

1	Case 1: supply MCU from main supply and battery or supercapacitor backup	4
2	Case 1b: supply from main supply and battery or supercapacitor backup wake up pin	5
3	Case 2: coin cell as main supply and supercapacitor backup. No USB	6
4	Case 2b: coin cell as main supply and supercapacitor as backup. No USB	8
5	Case 3: coin cell, supercapacitor backup and USB	10
6	Case 4: two coin-cells and internal PVD	11
7	Case 4b: two coin-cells and internal PVD	12
8	Case 5: two coin-cells and external PVD	13
9	Conclusion	14
10	Acronyms used	15
11	Revision history	16

List of figures

Figure 1.	Supply from main + supercapacitor or battery backup	4
Figure 2.	Supply from main + battery backup	5
Figure 3.	Coin cell and supercapacitor backup	6
Figure 4.	Coin cell and supercapacitor backup	8
Figure 5.	Coin cell and supercapacitor charger through USB bus	10
Figure 6.	Two coin cells and internal PVD	11
Figure 7.	Two coin cells and internal PVD (smaller BOM).	12
Figure 8.	Two coin cells with external PVD	13

1 Case 1: supply MCU from main supply and battery or supercapacitor backup

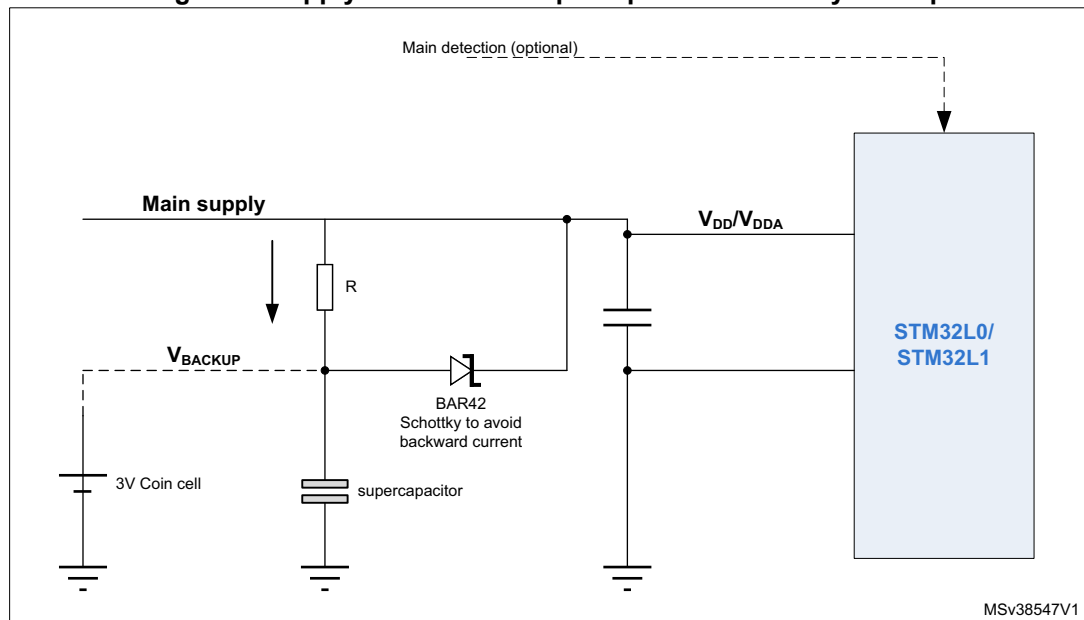
On application like metering for example, if main supply disappears, STM32L0/STM32L1 products should be able to keep RTC informations till next supply availability.

When main supply disappears, current will flow from supercapacitor through diode to V_{DD}/V_{DDA} of STM32L0/STM32L1 MCU supply pins, to keep minimum RTC domain voltage. Detection of main removal can be done either using STM32L0/STM32L1 MCU internal PVD or through GPIO threshold detection. When main supply is turned ON, current will then flow directly to V_{DD}/V_{DDA} supply pins and will charge supercapacitor through resistor.

The requirements for this application are:

- $V_{MAIN} > V_{BACKUP} - 0.3\text{ V}$
- V_{MAIN} needs to be at high impedance in OFF state

Figure 1. Supply from main + supercapacitor or battery backup



The detection of the main supply low voltage is done by STM32L0/STM32L1 MCU, integrated Programmable Voltage Detector (PVD) only during RUN mode (not needed in STOP, where the device consumption is extremely low).

As an example, for a 3.3 V supply, PVD threshold can be set to 3.05 V or 2.85 V.

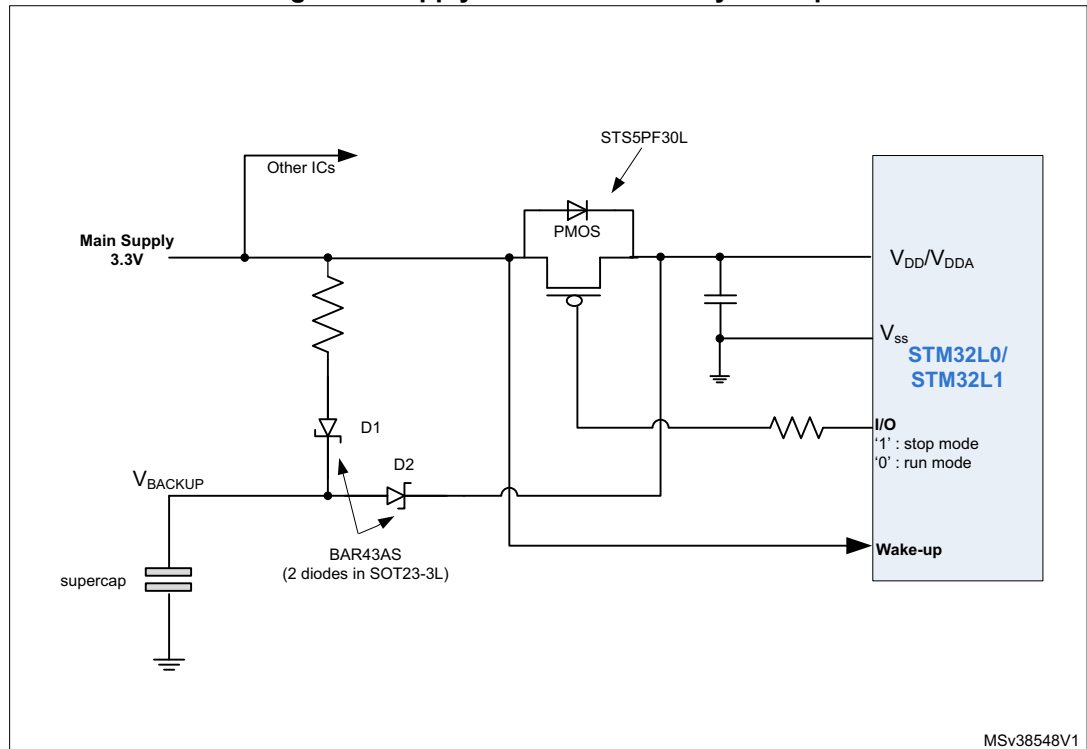
The main recovery detection is checked by activating PVD during periodic wake-up; if V_{DD} is below PVD threshold, STM32L0/STM32L1 MCU goes back to STOP mode.

Warning: The more often the main supply detection is checked, the faster the supercapacitor voltage will drop.

2 Case 1b: supply from main supply and battery or supercapacitor backup wake up pin

In this use case, the main supply detection is done through the wakeup pin: PVD polling is then no more necessary: this will improve the supercapacitor lifetime, comparing to what is described inside the [Section 1](#).

Figure 2. Supply from main + battery backup



The schottky diodes implemented in this schematic (see [Figure 2](#)), allow to charge the supercapacitor and to avoid reverse current to main supply source.

When main supply disappears, thanks to the detection with GPIO threshold programmable on wake-up (EXTI lines), STM32L0/STM32L1 MCU will drive PMOS gate to '1', so that current will flow from the supercapacitor through the diode D2 to V_{DD}/V_{DDA} of the STM32L0/STM32L1 MCU supply pins, to keep minimum RTC domain voltage.

When main supply is turned on, wake-up GPIO threshold is reached, so that I/O drives then low level and current will flow to V_{DD}/V_{DDA} supply pins through PMOS.

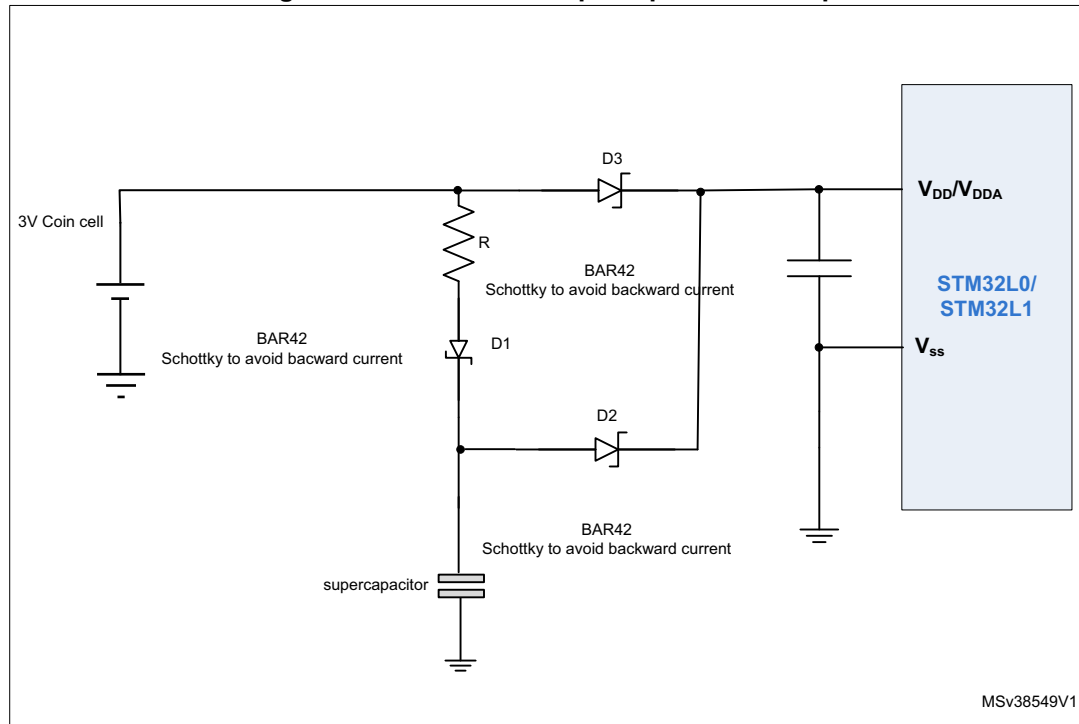
V_{DD}/V_{DDA} can also be switched to V_{BACKUP} when STM32L0/STM32L1 MCU goes into STOP mode, to allow user to remove main supply in very safe way.

Supercapacitor is charged as soon as main supply is high enough versus resistor and diode D1 drops.

3 Case 2: coin cell as main supply and supercapacitor backup. No USB

This use case shows how, with few components, the user can exchange the coin cell, keeping some informations like RTC in STM32L0/STM32L1 MCU.

Figure 3. Coin cell and supercapacitor backup



The [Figure 3](#) shows:

- Coin cell removal detection is done with PVD during RUN mode (no need in STOP mode, where consumption is extremely low).
- Additional consumption is 3 μ A during RUN mode only.
- Battery re-insertion detection is done during periodic wake-up: V_{DD} must be above PVD threshold. If not, MCU goes back to STOP mode.

Warning: The more often the battery re-insertion is checked, the faster the supercapacitor voltage will drop.

Coin cell removal is detected by STM32L0/STM32L1 PVD in RUN mode. As soon as voltage drops, STM32L0/STM32L1 MCU is put in STOP mode.

When coin cell is removed or dead, current will flow from supercapacitor through diode D2 to V_{DD}/V_{DDA} of the STM32L0/STM32L1 MCU supply pins, to keep minimum RTC domain voltage.

When coin cell is plugged back, current will flow to V_{DD}/V_{DDA} supply pins through diode D3. Coin cell re-insertion is detected through periodic wake up from the MCU.

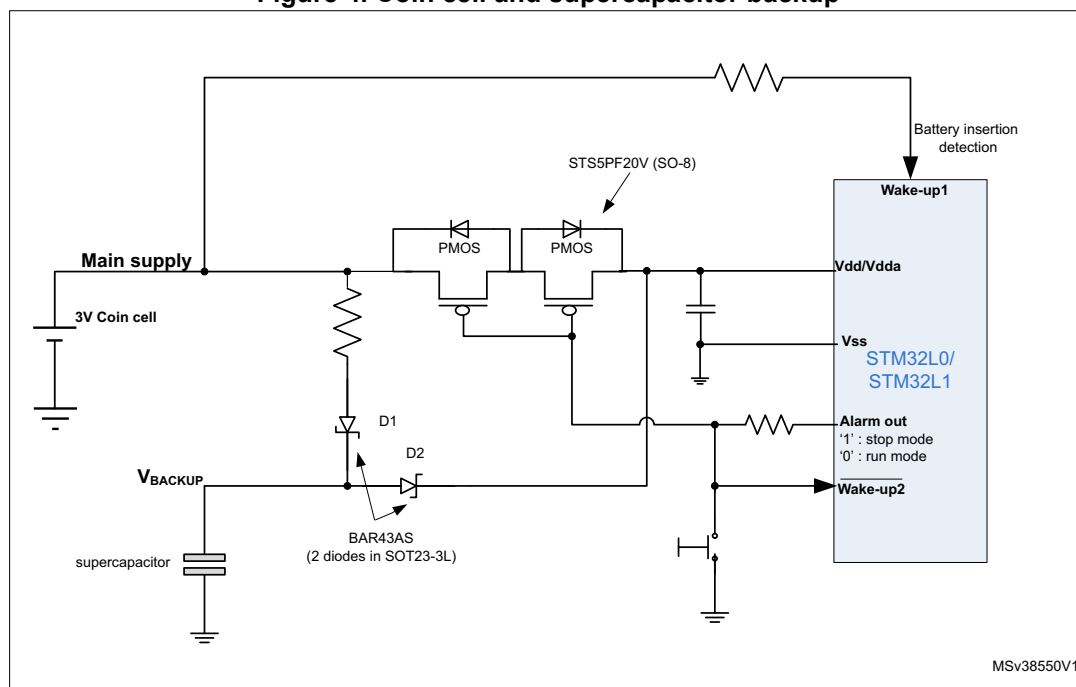
Supercapacitor is charged as soon as coin cell voltage is high enough versus resistor and diode D1 drops.

All diodes are mandatory to avoid any unwanted supercapacitor discharge.

4 Case 2b: coin cell as main supply and supercapacitor as backup. No USB

The purpose of the [Figure 4: Coin cell and supercapacitor backup](#) is to show that using a push button to switch back the application on main supply, the lifetime of the application is significantly improved.

Figure 4. Coin cell and supercapacitor backup



When the battery insertion is detected and when the MCU enters in STOP/STANDBY mode, the main supply is disconnected and V_{DD} uses the backup supply (capacitor or supercapacitor charged through a resistor).

In this use case there is no need to monitor V_{DD} in STOP/STANDBY mode: if coin cell is removed, the MCU is already in low power mode under V_{backup} .

The [Figure 4](#) shows:

- Schottky diode to avoid reverse current (diode on V_{DD} path could eventually be replaced by a MOS)
- PVD (for instance at 2V) is ON only in RUN mode, to detect battery disconnection and enter low power mode
- RTC ALARM OUT output can be used to turn-on automatically the MOSFET when exiting from low-power mode

Alarm out is a standard GPIO by default and needs to be configured as falling edge trigger.

First power up is guaranteed when coin cell is present and user has pressed the button: current will flow from coin cell to V_{DD}/V_{DDA} through PMOS. STM32L0/STM32L1 MCU will start and the GPIO used for alarm out, will be configured as push pull drive low.

When coin cell is removed or dead, thanks to the detection with GPIO threshold programmable on Wake-up1 (EXTI lines), STM32L0/STM32L1 MCU will drive PMOS gates

to '1' with alarm_out (GPIO pin set as falling edge trigger event) so that current will flow from supercapacitor through diode D2 to V_{DD}/V_{DDA} of the STM32L0/STM32L1 MCU supply pins to keep minimum RTC domain voltage.

When coin cell is replaced, Wake-Up1 GPIO threshold is reached so that alarm out drives then '0' level and current will flow to V_{DD}/V_{DDA} supply pins through PMOS.

This schematic showed in [Figure 4](#) allows user to change coin cell in very safe way before restarting.

Supercapacitor is charged as soon as main supply is high enough versus resistor and diode D1 drops.

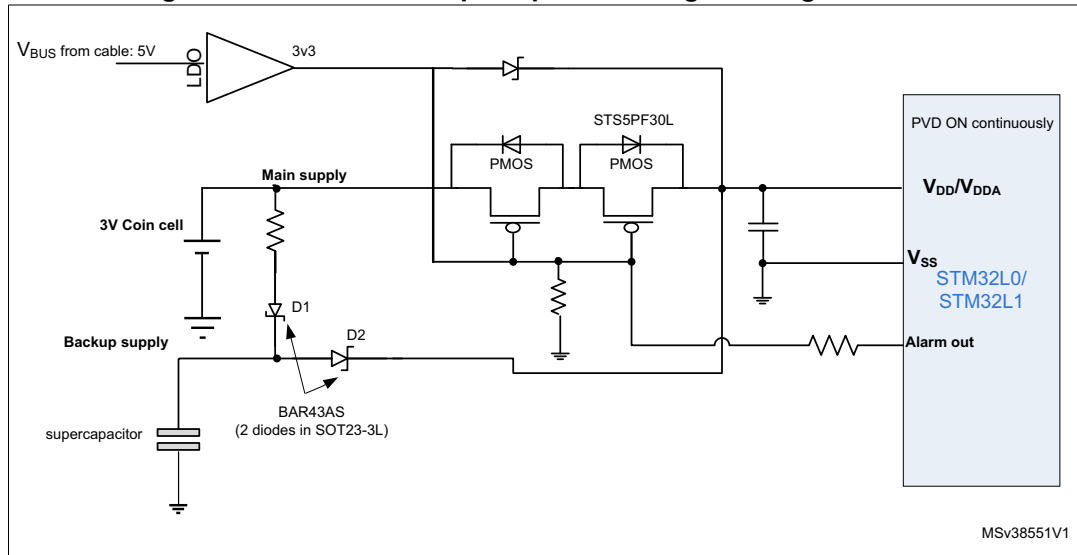
Other wake-up events can also turn-on the MOS like the user button.

If V_{DD} decoupling capacitor is big enough, this can be avoided: in this case, wake-up energy is coming from this capacitor and the supercapacitor, till the software enables again the MOS via an I/O.

5 Case 3: coin cell, supercapacitor backup and USB

When the embedded USB FS controller is used, the LDO implemented on the board can also be used to supply the application, when the USB cable is plugged (See [Figure 5](#)).

Figure 5. Coin cell and supercapacitor charger through USB bus



To improve lifetime in USB application, STM32L0/STM32L1 MCU current is sunk from V_{BUS} when it is available.

When LDO 3.3V used for USB purpose, will be turned ON, it will turn off PMOS gates, so that V_{DD}/V_{DDA} current comes from LDO.

Coin cell removal is detected by STM32L0/STM32L1 PVD in RUN mode. As soon as voltage drops, STM32L0/STM32L1 MCU is put in STOP mode and it drives alarm out GPIO to high level. Current will flow from supercapacitor through diode D2 to V_{DD}/V_{DDA} of the STM32L0/STM32L1 MCU supply pins to keep minimum RTC domain voltage.

When coin cell is plugged back, current will flow to V_{DD}/V_{DDA} supply pins through PMOS.

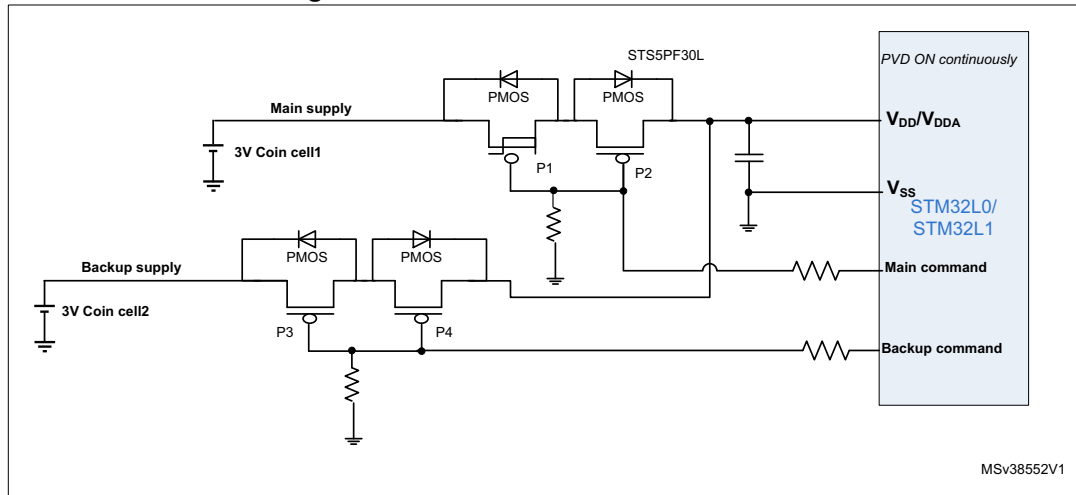
Supercapacitor is charged by coin cell as soon as coin cell voltage is high enough versus resistor and diode D1 drops.

All diodes are mandatory to avoid any unwanted supercapacitor discharge.

6 Case 4: two coin-cells and internal PVD

The [Figure 6](#) shows that in an application using two coin cells, this application should be able to switch from one to the other.

Figure 6. Two coin cells and internal PVD



If a voltage drop is detected by the STM32L0/STM32L1 MCU internal PVD, the MCU switches from main to backup supply.

This application works in both cases: $V_1 < V_2$ or $V_1 > V_2$.

Warning: Internal PVD needs to be ON continuously.

Coin cell1 removal is detected by STM32L0/STM32L1 PVD. When removal is detected, main command (GPIO) drives P1 and P2 gates to high level.

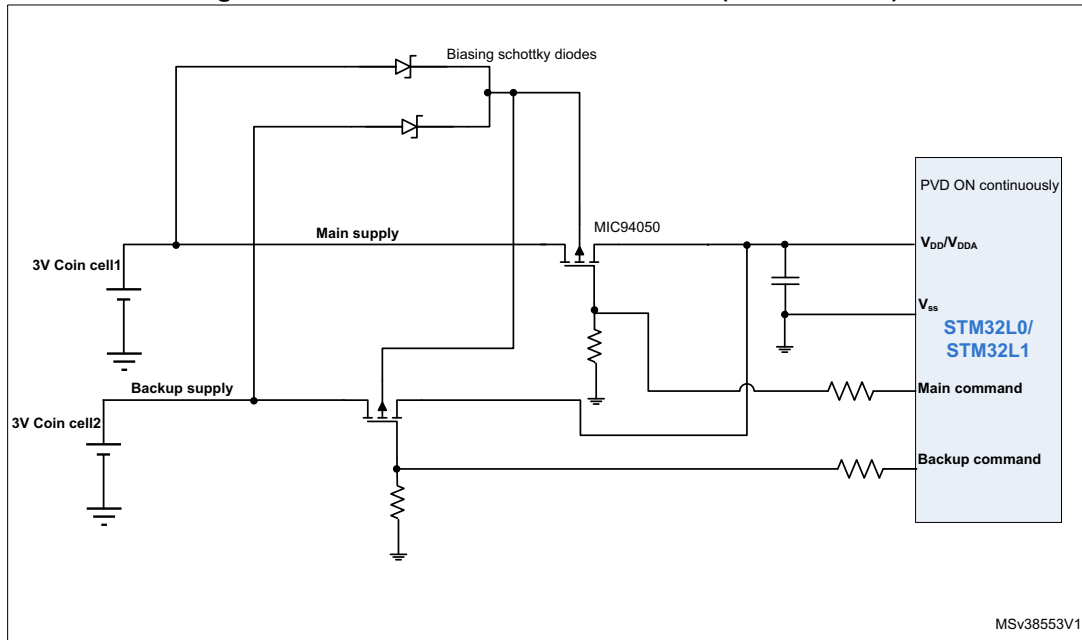
When coin cell1 is removed or dead, current will flow from coin cell2 through PMOS P3 and P4 to V_{DD}/V_{DDA} of the STM32L0/STM32L1 MCU supply pins.

P3 and P4 gates are driven low by backup command GPIO pin.

7 Case 4b: two coin-cells and internal PVD

Figure 7 shows a schematic with a reduced number of components, when application needs to switch from one coin cell to another one, keeping voltage on V_{DD} ball for its retention.

Figure 7. Two coin cells and internal PVD (smaller BOM)



The internal PVD of the STM32L0/STM32L1 MCU needs to be ON continuously, as in the previous use case 4 (see [Section 6: Case 4: two coin-cells and internal PVD](#)).

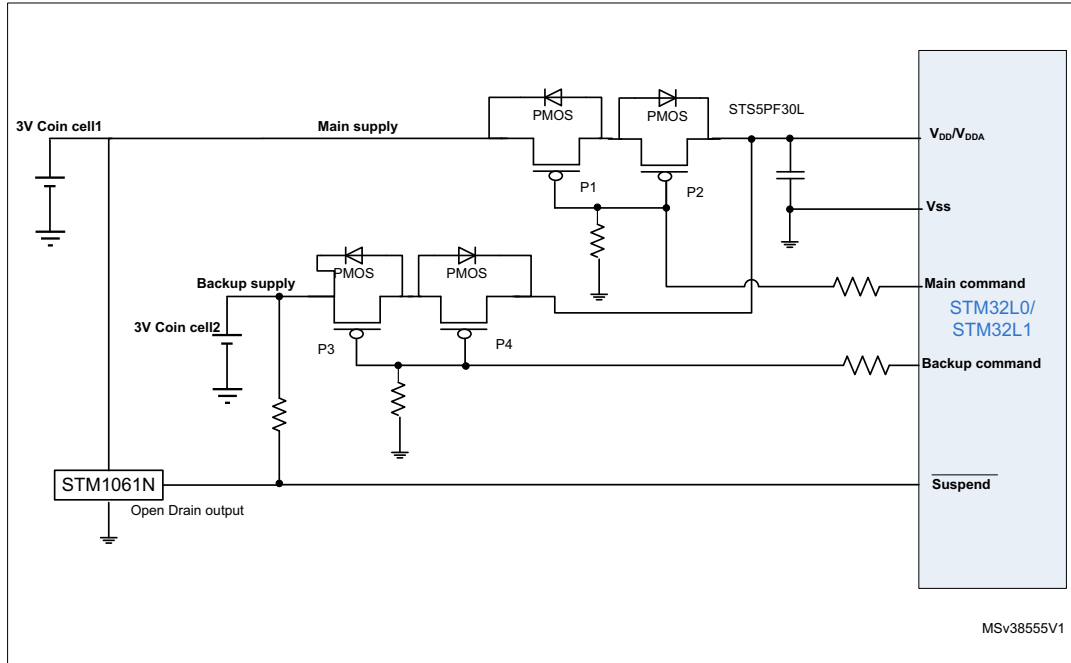
The above schematic allows lower number of MOSFET but requires four terminals MOS.

Basically, the behavior of the schematic is similar to [Figure 6: Two coin cells and internal PVD](#). Only the BOM is changed.

8 Case 5: two coin-cells and external PVD

In some application, user may decide to use an external voltage detector. An external component can be then used to detect low voltage and switch from one coin cell to the second one (see [Figure 8](#)).

Figure 8. Two coin cells with external PVD



The above schematics shows the use of an external low voltage detector like STM1061N. Consumption is about 1 uA. Around 2 uA are saved compare to use an internal PVD.

When coin cell1 is present, current is flowing from coin cell1 to V_{DD}/V_{DDA} through PMOS P1 and P2. After power up, main command drives low level, whereas backup command drives high level.

Coin cell1 removal is detected by STM1061N.

When removal is detected, STM1061N drives low level suspend (GPIO pin), so that STM32L0/STM32L1 MCU drives with main command gates P1/P2 to high level and with backup command P3/P4 to low level.

Current is then flowing from coin cell2 through P3/P4 to V_{DD}/V_{DDA} .

9 Conclusion

In this application note the schematics of the main applications using STM32L0/STM32L1 MCUs, and requiring RTC sustained (i.e. V_{BAT} mode) are proposed.

Selection between different proposals will be mainly done depending on the Bill of Material cost and system lifetime.

10 Acronyms used

USB	Universal Serial Bus
MCU	Microcontroller Unit
PVD	Power Voltage Detection
BOM	Bill of Material

11 Revision history

Table 1. Document revision history

Date	Revision	Changes
06-Oct-2015	1	Initial release

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