Using the XC9131H in parallel with an external power supply

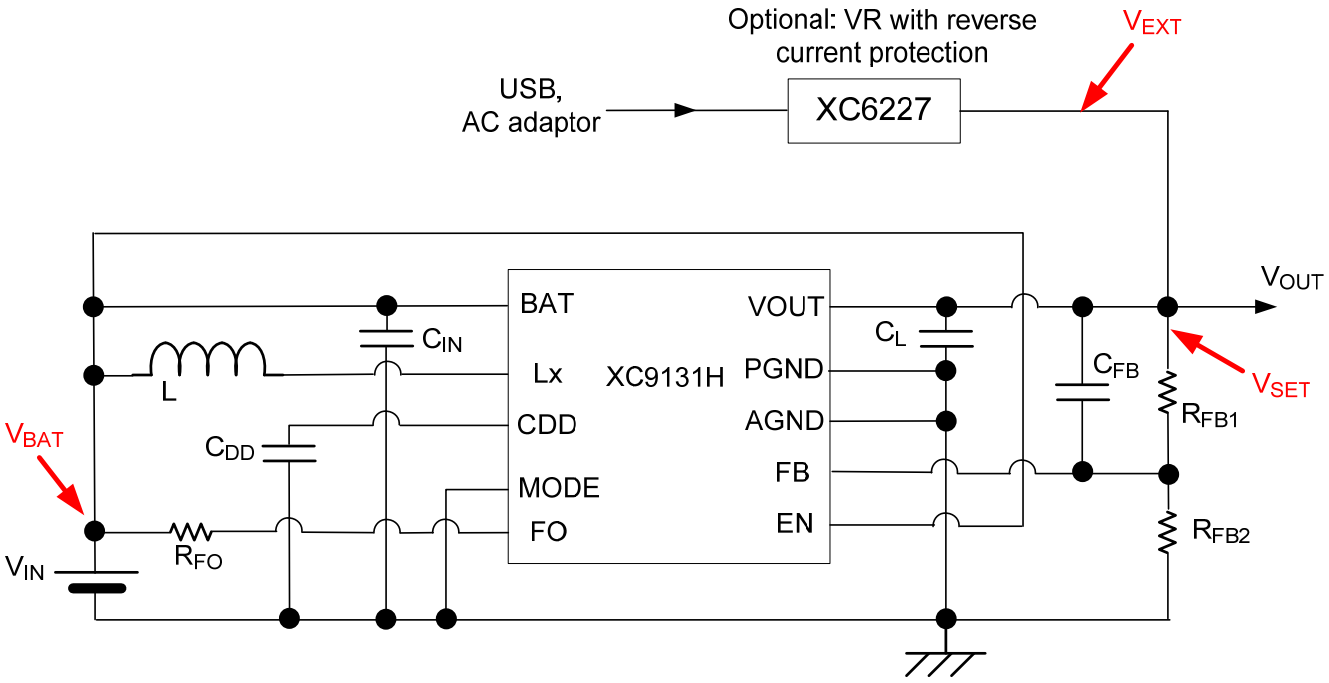
This document will explain how you can use the XC9131H in parallel with an external power supply, a configuration still referred to as an “OR circuit”. The proposed solution is **very simple**, because:

- ➔ The amount of external components is small (if your application permits it, **you can even discard the LDO**, as explained later).
- ➔ In order to switch between the two supplies, **you don’t have to adjust the signals at the EN and MODE pins** of the XC9131H.

For this explanation, we will be using the XC9131H, but all remarks apply to the XC9135C, XC9135K and XC9136N. We will refer a lot to V_{SET}, V_{BAT}, V_{EXT} and V_{OUT}. Here is how they are defined:

- **V_{SET}:** Voltage to which the XC9131H “tries to set” its output, with the help of resistors R_{FB1} and R_{FB2} and its internal reference voltage V_{REF}.
- **V_{BAT}:** Voltage of the battery that supplies the XC9131H via its BAT pin.
- **V_{EXT}:** Voltage coming from the external supply rail. If an LDO is used, it is the output voltage of this LDO.
- **V_{OUT}:** Voltage at the output of the “OR circuit”. It is as well the ACTUAL output voltage of the XC9131H circuit – whereas V_{SET} is only the TARGETED output voltage of the XC9131H. V_{SET} is equal to V_{OUT} when the external battery is disconnected and when $V_{SET} > V_{EXT}$.

All four voltages can be seen on the circuit diagram that follows.



On the circuit diagram above, you can see that EN = ‘High’ (the IC is enable) and MODE = ‘Low’ (the IC operates in PWM/PFM mode). As mentioned previously, these voltage levels won’t have to be adjusted while the circuit is operating.

We have got three main situations:

A) The external supply (USB, AC/DC adaptor, etc) is disconnected

In this case, the XC9131H will be supplying current to the output circuit and set the voltage of the output circuit.

B) The external supply is connected and its voltage is higher than V_{SET} of the XC9131H

In this case, the output of the circuit will be supplied by the external supply. As mentioned previously, the EN pin of the XC9131H is 'High', so the XC9131H is operating. However, the voltage fed back to the XC9131H informs this IC that the output voltage is high enough, so the IC basically stops oscillating (no more pulses are sent to turn 'ON' the two integrated FETs) and the output is supplied by the XC6227.

C) The external supply is connected and its voltage is lower than V_{SET} of the XC9131H

In this case, the XC9131H detects via its feedback network that the output voltage is much lower than the targeted V_{SET}. So the XC9131H starts operating and supplies current to the output.

Because of that, the voltage at the external supply (if you use an LDO, this is not V_{EXT} but the voltage BEFORE the LDO) will be lower than V_{OUT}, which means reverse current can flow. If you use an LDO such as the XC6227 that includes reverse current protection, you won't have to worry about this current, because both the LDO and external supply will be protected from it.

However, if your external supply can accept a small amount of reverse current (and if you consider that your external supply regulates its voltage well enough), you don't even require an LDO.

FAQ (Design restrictions):

Why is it not possible to use the XC9131F with this OR circuit?

For applications where the XC9131 circuit is on its own (i.e. no external power supply in parallel with it), the XC9131F is recommended instead of the XC9131H because of the additional advantages that offers its CL discharge function.

However, for applications where the XC9131 circuit is paralleled with an external power supply, while in PFM mode, the XC9131F is operating in an unwanted way when its output voltage (V_{SET}) is lower than V_{EXT} (Please note as well that we always assume that $V_{BAT} < V_{SET}$, because V_{BAT} is always well below V_{OUT} – see last question of this FAQ). Under these conditions, there is a risk that the P-ch driver transistor will be 'ON', permitting reverse current to flow from the external supply to the XC9131F. This reverse current can easily damage the XC9131F.

Under the same conditions (PFM mode, $V_{BAT} < V_{SET} < V_{EXT}$), the P-ch transistor of the XC9131H will always be 'OFF', which means that reverse current is never permitted to flow within the IC via its VOUT pin. This safe behavior justifies the use of the XC9131H with the OR circuit.

Why is it not possible to set the MODE pin to 'High'?

By setting the MODE pin to 'High', the XC9131H will operate in synchronous full time PWM mode. In this mode, there is always one of the two integrated FET's that will be turned on. And this is why this configuration is not recommended.

Indeed, when V_{EXT} is higher that the output voltage set by the XC9131H (remember, we call the latter V_{SET}), the IC will reduce its duty cycle to as low as possible so that the output voltage can decrease to the same value as V_{SET}. Reducing the duty cycle means turning the N-ch transistor 'OFF' most of the time and, since both transistors can't be 'OFF' at the same time, the P-ch transistor will remain 'ON'. As a consequence, reverse current can penetrate the XC9131H via its VOUT pin, flow through the P-ch transistor and damage internal circuits of the XC9131H.

In order to circumvent this issue, the MODE pin is set to 'Low', so that the XC9131H operates in PWM/PFM mode, where both integrated transistors can be turned 'OFF' at the same time. That way, reverse current is prevented from entering the XC9131H via its VOUT pin.

We can sum up the situation in a few sentences by realizing that, when V_{SET} is less than V_{EXT}, the XC9131H hardly supplies any current, so its load current is small. So, in shorter terms:

- When the MODE pin is 'Low', if the load current is small, the IC will operate in PFM mode. Since it is in PFM mode and since $V_{SET} < V_{EXT}$, the P-ch driver transistor is always 'OFF' and this protects the IC from reverse current.
- When the MODE pin is 'High', if the load current is small, the IC will operate in PWM mode. In this mode, the IC oscillates at 1.2MHz and its P-ch driver transistor is often 'ON', so some reverse current flows from V_{OUT} to V_{BAT}.

REMARK: Of course, the reverse current will no longer be an issue when the XC9131H (with its MODE pin set to 'Low') switches from PFM to PWM mode when the load current increases. This is because the XC9131H will be operating in continuous conduction mode by the time it switches to PWM mode, so reverse current will no longer be present.

What if V_{BAT} of the XC9131H can sometimes be higher than its V_{OUT}, or very close to it?

The above configuration typically applies to circuits such as a USB supply paralleled with a XC9131 circuit with a Lithium-Ion battery. In such cases, the V_{OUT} of the XC9131H will be about 5V, while its input voltage (V_{BAT}) will be 4.2V or lower. The fact that V_{BAT} is always well below V_{OUT} greatly simplifies the design. If your design requires V_{BAT} to sometimes be very close to (or higher than) V_{OUT}, please contact us so that we can advise about its feasibility.