Application note

Capacitive Charging Mode (CCM) for M0-9 standard HSD

Introduction

The M0-9 HSD Family includes some part numbers aiming at addressing the power distribution domain (suffix CAJ) which implement the CCM feature to drive capacitive loads.

1 General description

The maximum addressable capacitive load is specified into the device datasheet as the C_{MAX} parameter.

All other M0-9 HSD devices that do not implement this dedicated feature, with equal R_{DSON}, cannot drive such capacitive loads (C_{MAX}) because this would certainly trigger internal protections such as overcurrent and/or overtemperature, detecting a short circuit condition.

Nevertheless, for standard M0-9 HSD devices, it is still possible to charge some capacitive load, but with a much longer time compared to CCM devices, as they must manage the restart of the channel after the short circuit condition is detected.

For this reason, the CCM dedicated feature is introduced, allowing large capacitive loads to be charged within a shorter time, avoiding the intervention of current and thermal protections that would otherwise stop or delay the charging process.

The capacitive charging mode (CCM) is an operative condition, available in normal operation (channel in on state).

The CCM charges capacitors with a burst of I_{LIMH} pulses, provided that the total impedance is low enough to reach I_{LIMH} when charging the capacitor. If I_{LIMH} is not reached, the capacitor is charged with a single continuous charging pulse.

If the ESR of the connected capacitor and the total output line impedance are low enough to allow the channel to reach its ILIMH value, the channel will turn off after the differential thermal threshold ΔT_{J_SD} is reached and will autonomously turn on again after the differential thermal hysteresis falls below a certain threshold.

Thanks to the lower values of ΔT_{J_SD} and ILIMH, compared to standard M0-9 HSD devices that do not implement this feature, all devices with CCM can sustain charging capacitors up to $\mathbf{C_{MAX}}$ even in high ambient temperature conditions.

Definitions:

- $\mathbf{C_{MAX}}$: maximum capacitive load that can be charged within the defined charging time
- **ESR**: Equivalent series resistance of the capacitor
- $\mathbf{t_{CMAX}}$: maximum charging time (50 ms)
- $\mathbf{t_{CLOAD}}$: load capacitor charging time
- $\mathbf{t_{D\_Restart}}$**:** latch-OFF delay time before automatic restart
- $\mathbf{\Delta T_{J\_SD}}$: dynamic temperature (differential thermal threshold 35°C typical for CAJ devices)
- $\mathbf{T_J}$: junction temperature
- $\mathbf{T_{TSD}}$: shutdown temperature
- $\mathbf{T_{HYST}}$: thermal hysteresis

To better explain the CCM mechanism, some examples are reported below, considering the VN9008CAJ as the Device Under Test (DUT).

The VN9008CAJ, as per the device datasheet, declares as typical C_{MAX} a value of 8 mF.

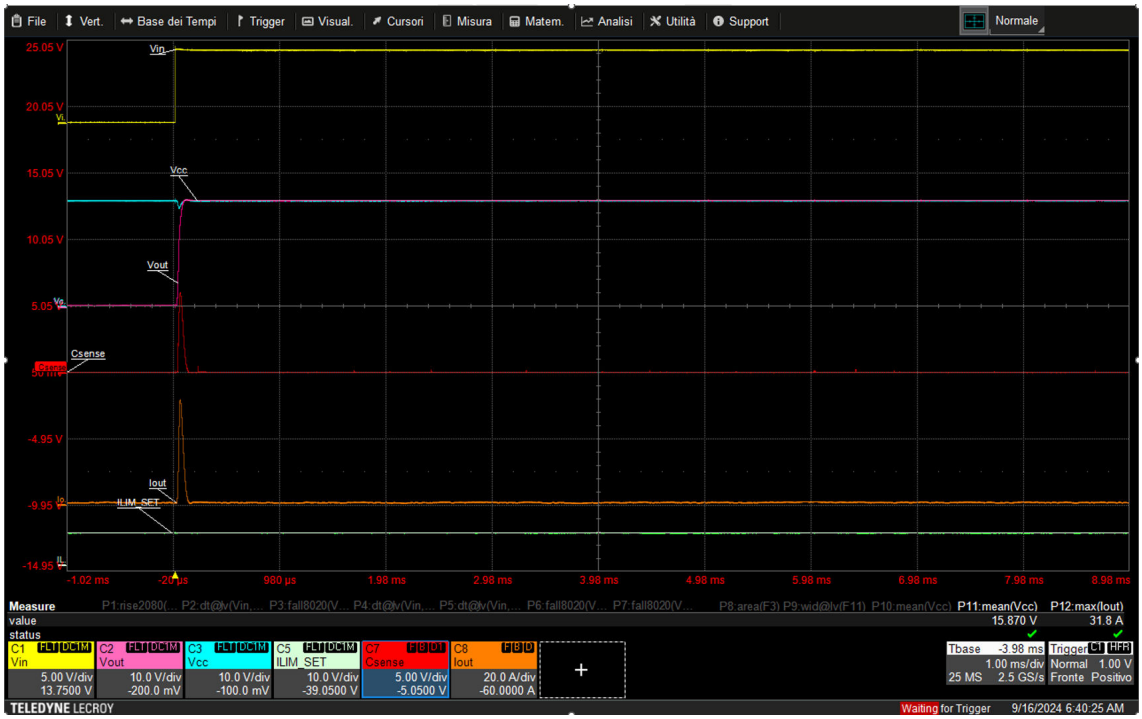
The following CCM examples consider two cases where different capacitor loads are charged within the t_{CMAX} time (50 ms).

General test conditions:

- V_{CC} = 16 V (supply voltage)
- T_J = 25 °C (starting junction temperature)
- FaultRST = 0 V (fault RESET pin)
- ILIM_SET = 0 V

Case 1: C_{LOAD} = 0.1 mF << C_{MAX} (capacitor charging time << t_{CMAX})

Figure 1. C_{LOAD} << C_{MAX}



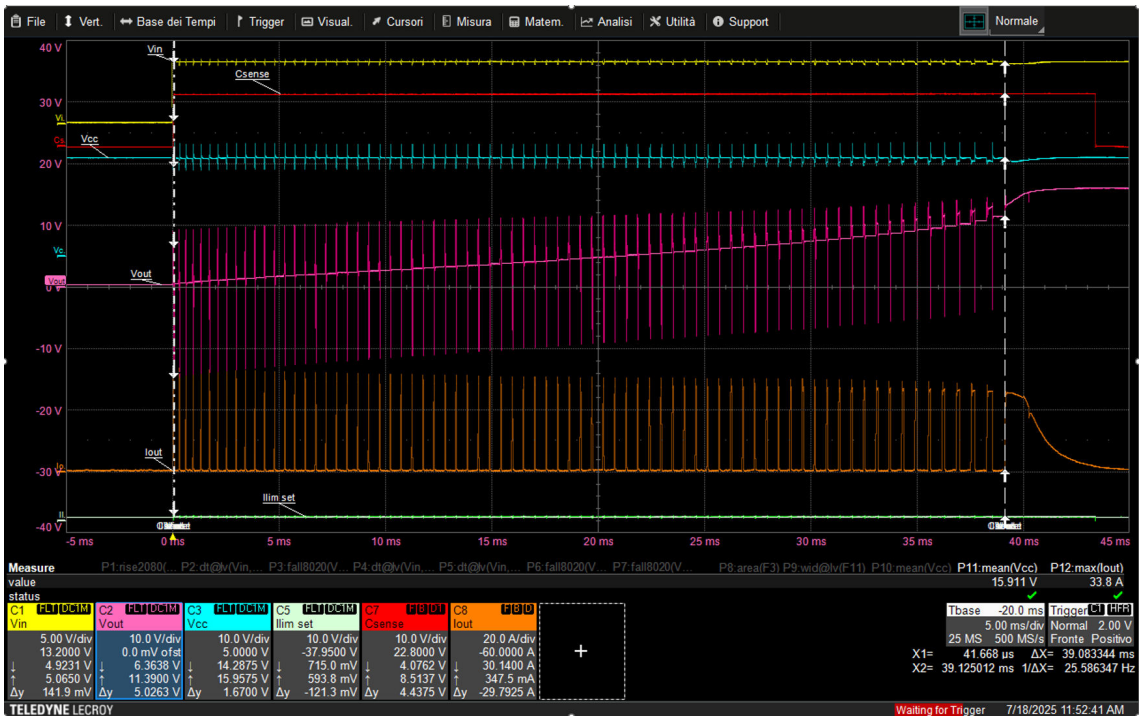
In this case, the device can charge the capacitor very quickly, and the output voltage (V_{OUT}) reaches the supply voltage (V_{CC}) in a very short time compared to t_{CMAX}.

Only one pulse is produced, the charging time is less than 0.5 ms and the maximum current peak is 31.8 A.

Case 2: C_{LOAD} = C_{MAX} (8 mF within 50 ms)

When the load capacitor value is in the range of C_{MAX} (in this case, C_{LOAD} = C_{MAX}), the CCM feature produces a consistent burst of ILIMH pulses capable of transferring the required energy to fully charge the load within $t_{CLOAD} \leq t_{CMAX}$ (see Figure 2).

Figure 2. C_{LOAD} = 8 mF (C_{MAX})



When the load capacitor exceeds C_{MAX}, the device may trigger its thermal protection (T_{TSD}), causing a latch-off of the channel. Once the junction temperature (T_J) falls below T_{TSD} - T_{HYST} (shutdown temperature minus thermal hysteresis), the channel restarts after $t_{D\_Restart}$ time, cycling until the load capacitor voltage reaches its final value (V_{CC}).

If an additional current load is present in parallel with the load capacitor, the charging attempts might be ineffective because the transferred energy may not be sufficient to fully charge the capacitor.

Note: For a given load capacitor, the charging time depends on battery voltage and junction temperature T_J:

- *The higher the battery voltage (VBATT), the longer the charging time (t_{CLOAD}).*
- *The higher the junction temperature (T_J), the longer the charging time (t_{CLOAD}).*
- *The higher the load capacitor (C_{LOAD}), the longer the charging time (t_{CLOAD}).*

Revision history

Table 1. **Document revision history**

Date	Version	Changes
20-Jan-2026	1	Initial release.