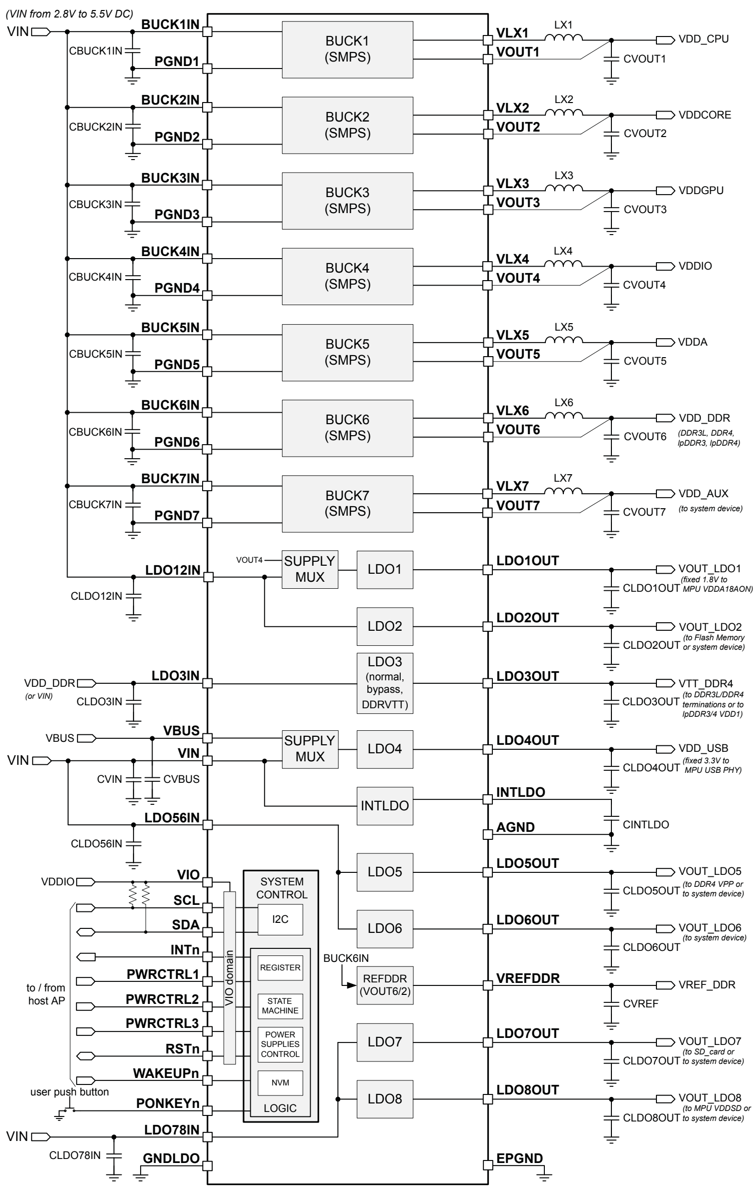
1 STPMIC25 passive external components

This AN is intended to guide the customer in the selection of the external passive components for the BUCK and LDO regulators of STPMIC25 device.

A typical application schematic is shown in below figure

Figure 1. STPMIC25 Typical application schematic



1.1 Buck converters

The STPMIC25 is provided with 7 buck converters optimized to supply circuits with high current consumption and comply with fast transient response requirements. The input supply range of all BUCK converters goes from 2.8V to 5.5V, and they are featured with soft-start and DVS ramp for system power optimization.

The switching frequency of the converters is typically 2 MHz in a steady-state CCM condition.

In details:

Table 1. BUCK converters general description

Regulator	Output voltage (V)	Programming step (mV)	Rated output current (mA)	Application use (typical MCU application)
BUCK1, BUCK6	0.5 – 1.5	10	2000, 1500, 1000, 500	Buck1 = VDDCPU Buck6 = VDD_DDR (DDR3L, DDR4, lpDDR3, lpDDR4)
BUCK2, BUCK3	0.5 – 1.5	10	2000, 1500, 1000, 500	Buck2 = VDDCORE Buck3 = VDDGPU
BUCK4, BUCK5	1.5 – 4.2	100	500, 250	Buck4 = VDD (VDDIO) Buck5 = VDDA18x
BUCK7	1.5 – 4.2	100	2500, 2000, 1500, 1000	General Purpose

Following sections show the recommended values of the inductors and output capacitors that have been defined for STPMIC25A,B and D to fulfill the expected performances for STM32MP2s MPUs, such as the output voltage ripple and the load transient response in all operating conditions (DCM, CCM and temperature).

Table 2. STPMIC25A/B/D BUCK converters description

Regulator	Input voltage max (V)	Default output voltage (V)	Rated output current (A)	OCP threshold I_{BCKLIM} (A)	Typical MPU application
BUCK1	5.5V	0.8	1	2.1	VDDCPU
BUCK2		0.82	2	3.3	VDDCORE
BUCK3		0.8	2	3.3	VDDGPU
BUCK4		1.8 (B) 3.3 (A & D)	0.5	1.5	VDDIO
BUCK5		1.8	0.5	1.5	VDDA18x
BUCK6		1.1	1.5	2.8	VDD_DDR
BUCK7		3.3	2.5	3.6	General purpose

Note: For battery applications (with STPMIC25B), the max input voltage could be reduced to 4.2V (maximum battery voltage) to optimize IL ripple computation. Nevertheless, that will no change significantly the IL max

1.1.1 Inductor selection for buck converters

The inductors must be rated for their DC resistance and saturation current. The DC resistance of the inductance directly influences the efficiency of the DC-DC converter. For this reason, an inductor with the lowest DC resistance should be selected to reach a higher efficiency.

Equation 1. Peak-to-peak inductor current (CCM mode)

$$\Delta I_L = \frac{(Vinmax - Vout) * D_{max}}{L\ x\ f} = Vout * \frac{1 - \frac{Vout}{Vinmax}}{L\ x\ f}$$

Equation 2. Maximum inductor current (CCM mode)

$$I_{Lmax} = I_{out\_max} + \frac{\Delta I_L}{2}$$

Equation 1 and equation 2 show how to calculate the maximum inductor current under static load conditions. The saturation current of the inductor then must be rated higher than the maximum inductor current as calculated with Equation 2. This is needed because during heavy load transient the inductor current rises above the calculated value.

Where:

- D_{max}= maximum duty cycle
- f = Switching frequency (2 MHz typical in CCM mode)
- L = Inductor value
- ΔIL = Peak-to-peak inductor ripple current
- IL_{max} = Maximum inductor current

The highest inductor current occurs at maximum Vin.

For BUCK1, BUCK2, BUCK3, BUCK6 and BUCK7 a 0.68 µH output inductor must be used, while for BUCK4 and BUCK5 a 2.2 µH output inductor must be used.

Regulator	Typical MPU application	Input voltage max	Default output voltage	Rated output current	OCP threshold	Switching frequency (CCM mode)	Recommended output coil	Peak-to-peak inductor current (CCM mode)	Maximum inductor current (CCM mode)
		(V)	(V)	(A)	$I_{BUCKLIM}$ (A)	(MHz)	(µH)	ΔI_L (A)	I_{Lmax} (A)
BUCK1	VDDCPU	5.5	0.8	1	2.1	2	0.68	0.50	1.25
BUCK2	VDDCORE		0.82	2	3.3	2	0.68	0.51	2.25
BUCK3	VDDGPU		0.8	2	3.3	2	0.68	0.50	2.25
BUCK4	VDDIO		1.8 (B)	0.5	1.5	2	2.2	0.28	0.64
			3.3 (A & D)				2.2	0.30	0.15
BUCK5	VDDA18x		1.8	0.5	1.5	2	2.2	0.28	0.64
BUCK6	VDD_DDR		1.1	1.5	2.8	2	0.68	0.65	1.83
BUCK7	General purpose		3.3	2.5	3.6	2	0.68	0.97	2.98

Following inductor part numbers were chosen in the final application:

Table 3. **Buck converters - recommended Inductors**

BUCK	Component	Vendor	Part number	(1)Value [µH]	Size	(2) DCR [mΩ]	(3)Isat [A]
BUCK1, BUCK6	LX1, LX6	Murata	DFE201610E-R68M	0.68	0806	36	4.3
BUCK2, BUCK3	LX2, LX3	Murata	DFE252012F-R68M	0.68	1008	25	5.4
BUCK4, BUCK5	LX4, LX5	Murata	DFE201610E-2R2M	2.2	0806	117	2.4
BUCK7	LX7	Murata	DFE201610E-R68M	0.68	0806	36	4.3

1. *The inductance value should not be lower than -50% when the peak current on the inductor reaches the OCP threshold ($I_{BUCKLIM}$) in case of an overload or short circuit. In fact, if the inductance value is too low, if the IL is very near to $I_{BUCKLIM}$ (i.e. the inductor is near the saturation), the IL will increase faster than the OCP circuitry loop is able to detect, causing the destruction of the high-side MOS.*
2. *Selecting inductors with similar DCR values will help to limit power efficiency losses and also reduce the self-heating of the coils.*
3. *Please refer to the inductor's datasheet for the Isat value specification.*

Different PN can be used compared to table 3, but keeping the same characteristic (value, DCR) and selecting the saturation current higher than the maximum expected inductor peak current (IBUCKLIM) indicated in the datasheet.

The inductors package size should be small enough to allow good PCB placement around the STPMIC25 (not too far from the STPMIC25 on PCB)

Shielded inductors are recommended to reduce possible electromagnetic interferences.

1.1.2 Output capacitor selection for buck converters

Table 4 shows the recommended output capacitor part numbers.

Table 4. Buck converters - recommended output capacitors

BUCK	Component	Vendor	Part number	Value [µF]	DC voltage [V]	Size	ESR [mΩ] @ f=2MHz, T=25°C (for 1 cap.)
BUCK1, BUCK6	CVOUT1, CVOUT6	Murata	GRM188R60J226MEA0D	3x22	6.3	0603	6
BUCK2, BUCK3	CVOUT2, CVOUT3	Murata	GRM188R60J226MEA0D	4x22	6.3	0603	6
BUCK4, BUCK5	CVOUT4, CVOUT5	Murata	GRM21BR61A226ME51L	3x22	10	0805	5
BUCK7	CVOUT7	Murata	GRM21BR61A226ME51L	4x22	36	0805	5

The X5R capacitors are indicated if the temperature does not exceed +85°C (combination of PCB temperature plus self-heating). If there is need to work at temperatures higher than +85°C, X7R ceramic capacitors with similar characteristics of X5R should be used.

Table 5 shows the recommended output capacitance ranges to meet the ripple and dynamic performance requirements of the buck converters for satisfying the power needs of STM32MP2x microprocessors.

Table 5. Output capacitance range of buck converters and max ESR

BUCK	Component	Output capacitance			
		(1) MIN effective [µF]	TYP [µF]	MAX [µF]	(2) Max ESR [mΩ]
BUCK1, BUCK6	CVOUT1, CVOUT6	23.2	3x22	106	106
BUCK2, BUCK3	CVOUT2, CVOUT3	34.8	4x22	106	2
BUCK4, BUCK5	CVOUT4, CVOUT5	21.7	3x22	80	2
BUCK7	CVOUT7	20.4	4x22	106	1.5

1. *The MIN effective capacitance is obtained considering all the derating factors that can affect the recommended capacitors shown in table 3, such as: nominal tolerance, worst case operating temperature, the highest voltage DC bias for each buck converter and the aging.*
2. *Using multiple output capacitors in parallel instead of one will help to reduce the ESR value, improving electrical dynamic performance such as ripple and load transient response.*

1.1.3 Input capacitor selection for buck converters

The table below shows the minimum values of the input capacitors required to stabilize the input voltage of the BUCK converters, which can be affected by the input peak current due to the DC-DC switching activity.

Table 6. Buck converters – recommended input capacitors

BUCK	Component	Vendor	Part number	Value [µH]	DC voltage [V]	(1) Size	Dielectric
BUCK1,BUCK2, BUCK3,BUCK4, BUCK5,BUCK6, BUCK7	CBUCK1,2,3,4,5,6,7_IN	Murata	GRM188R61A106ME69D	10	10	0603	X5R

1. *For each buck converter, we recommend using a minimum of a 10 µF ceramic input capacitor. The 0603 size is suggested as the best compromise between capacitance value and component placement on the PCB.*
   In fact, while larger value and dimension capacitors would help to have better filtering on the input pins, limiting ringing effects, on the other hand, it would be necessary to place such capacitors further away from the input pins of the PMIC25, significantly increasing the parasitic inductance values between the VIN and GND pins.

1.2 LDO regulators

The STPMIC25 is provided with 8 LDOs and 1 reference voltage LDO for DDR memories. In details:

- LDO1 is a fixed 1.8 V low drop regulator typically used to supply the VDDA18 MPUs applications domain;
- LDO2, LDO5, LDO6 and LDO7 are general purpose LDOs suitable to supply MPU application peripherals. All these LDOs are provided with bypass mode function. In case a LDO is used in bypass mode, no output capacitor is required.
- LDO3 has three different operating modes:
  - Normal mode: used as general purpose LDO
  - Sink-source mode: for DDR3, DDR3L, DDR4 memory termination
  - Bypass mode: for lpDDR3 or lpDDR4 memory
- LDO4 is a fixed 3.3 V regulator designed to supply 3V3 USB PHY circuit.
- LDO8 is a general-purpose regulator with extended voltage range. It supports bypass mode.
- VREFDDR is a sink-source LDO dedicated to providing the voltage reference for lpDDR/DDR memory.

Table 7. LDO general description

Regulator	Output voltage (V)	Programming step (mV)	Rated output current (mA)	Application use (typical MCU application)
LDO1	1.8	-	20	VDDA18AON
LDO2, LDO5, LDO6, LDO7	0.9 V to 4.0 V or bypass mode	100	400/200/100/50	General purpose (eMMC, DDR4 VPP, SD card, LCD camera)
LDO8	0.9 V to 4.0 V or bypass mode	100	150	General purpose (low voltage peripheral)
LDO3 normal mode	0.9 V to 4.0 V	100	120	General purpose/lpDDR VDD1
LDO3 sink-source mode	$\frac{V_{OUT6}}{2}$	-	+/-120 (rms) +/-230 (peak)	DDR3L/DDR4 terminations (VTT)
LDO3 bypass mode	VINLDO3	-	80	lpDDR VDD1
LDO4	3.3	-	40	VDD33USB VDD33UCPD
VREFDDR	$\frac{V_{OUT6}}{2}$	-	+/-5 (rms) +/-10 (peak)	Reference voltage for DDR memories

1.2.1 Output capacitor selection for LDOs

The output capacitor is essential to maintain the stability of a voltage linear regulator. It stores charge to manage sudden changes in load current, thereby reducing output voltage ripple and noise. Additionally, it creates a pole with the LDO's output impedance, which can influence the phase margin and the overall stability of the regulator. The value and type of the output capacitor can greatly affect the transient response and the stability of the LDO.

Below table shows the minimum effective output capacitance that must be guaranteed for each LDO:

Table 8. Output capacitance range of LDOs

LDO	Component	Output capacitance		
		* MIN effective [µF]	TYP [µF]	MAX [µF]
LDO1	CLDO1OUT	2	4.7	10
LDO2	CLDO2OUT	2	4.7	10
*LDO3 (normal mode)	CLDO3OUT	2	10	15
*LDO3 (sink-source mode)	CLDO3OUT	6	10	15
LDO4	CLDO4OUT	2	4.7	10
LDO5	CLDO5OUT	2	4.7	10
LDO6	CLDO6OUT	2	4.7	10
LDO7	CLDO7OUT	2	4.7	10
LDO8	CLDO8OUT	2	4.7	10
VREFDDR	CVREF	0.5	1	2.2
INTLDO	CINTLDO	2	4.7	10

*The MIN effective capacitance is obtained considering all the derating factors that can affect the recommended capacitors shown in Table 8, such as: nominal tolerance, worst case operating temperature, the highest voltage DC bias for each LDO and the aging.

Table 9 shows the recommended part numbers.

Table 9. LDOs - recommended output capacitors

LDO	Component	Vendor	Part number	Value [µF]	DC voltage [V]	Size	ESR [mΩ] @ f=1MHz, T=25°C
LDO1	CLDO1OUT	Murata	GRM155R60J475ME47D	4.7	6.3	0402	6
LDO2	CLDO2OUT	Murata	GRM155R60J475ME47D	4.7	6.3	0402	6
(1) LDO3 (normal mode)	CLDO3OUT	Murata	GRM155R60J106ME05D	10	6.3	0402	6
(1) LDO3 (sink-source mode)	CLDO3OUT	Murata	GRM155R60J106ME05D	10	6.3	0402	6
LDO4	CLDO4OUT	Murata	GRM155R60J475ME47D	4.7	6.3	0402	6
LDO5	CLDO5OUT	Murata	GRM155R60J475ME47D	4.7	6.3	0402	6
LDO6	CLDO6OUT	Murata	GRM155R60J475ME47D	4.7	6.3	0402	6
LDO7	CLDO7OUT	Murata	GRM155R60J475ME47D	4.7	6.3	0402	6
LDO8	CLDO8OUT	Murata	GRM155R60J475ME47D	4.7	6.3	0402	6
VREFDDR	CVREF	Murata	GRM155R61E105KA12D	1	25	0402	20

LDO	Component	Vendor	Part number	Value [µF]	DC voltage [V]	Size	ESR [mΩ] @ f=1MHz, T=25°C
INTLDO	CINTLDO	Murata	GRM155R60J475ME47D	4.7	6.3	0402	6

1. We suggest using 10µF/6.3V capacitor either for LDO3 working in normal and sink-source mode.

1.2.2 Input capacitor selection for LDOs

The main function of an input capacitor in a LDO is to supply high-frequency current that cannot be obtained from the power source because of the inductance in the power supply line. It aids in minimizing the ripple voltage from the power supply and stops the LDO from oscillating by offering a low impedance path to ground for high-frequency noise. The input capacitor's value is determined by the LDO's input impedance and the highest input ripple voltage that the application can handle.

Below table shows the recommended input capacitor for each LDO

Table 10. LDOs - recommended input capacitors

LDO	Component	Vendor	Part number	Value [µF]	DC voltage [V]	Size
LDO1, LDO2	CLDO12IN	Murata	GRM155R61E105KA12D	1	25	0402
LDO3	CLDO3IN	Murata	GRM155R60J106ME05D	10	6.3	0402
LDO4	CVIN	Murata	GRM155R60J475ME47D	4.7	6.3	0402
	CVBUS	Murata	GRM188R61C475KE11D	4.7	16	0603
LDO5, LDO6	CLDO56IN	Murata	GRM155R61E105KA12D	1	25	0402
LDO7, LDO8	CLDO78IN	Murata	GRM155R61E105KA12D	1	25	0402
VREFDDR	CVREF	Murata	GRM155R61E105KA12D	1	25	0402

1.3 Recommended BOM

The below table summarize all the suggested BOM part numbers also used on the STPMIC25 evaluation board (STEVAL-PMIC25V1).

Table 11. STPMIC25 recommended BOM list

Component	Manufacturer	Part number	Value	Size
CVIN, CLDO1,2,3,4,5,6,7,8_OUT, CINTLDO	MURATA	GRM155R60J475ME47D	4.7 µF 6.3V	0402
CBUCK1,2,3,4,5,6,7_IN		GRM188R61A106ME69D	10 µF 10V	0603
CVOUT1, CVOUT6		GRM188R60J226MEA0D	3 x 22µF 6.3V	0603
CVOUT2, CVOUT3			4 x 22µF 6.3V	
CVOUT4, CVOUT5		GRM21BR61A226ME51L	3 x 22µF 10V	0805
CVOUT7			4 x 22µF 10V	
CLDO12IN, CLDO56IN CLDO78IN, CVREF		GRM155R61E105KA12D	1µF 25V	0402
CLDO3IN, CLDO3OUT		GRM155R60J106ME05D	10µF 6.3V	0402
CVBUS		GRM188R61C475KE11D	4.7µF 16V	0603
LX1, LX6, LX7		DFE201610E-R68M=P2	0.68 µH	0806
LX2, LX3		DFE252012F-R68M=P2	0.68 µH	1008
LX4, LX5		DFE201610E-2R2M=P2	2.2µH	0806

Note: *All the recommended part numbers are X5R guaranteed with Tpcb ≤85 °C.*
Consider using X7R or better dielectric capacitors if the whole application works in an environment with Tpcb >85 °C.

Table 12 shows the alternative STPMIC25 part numbers that can be used in an environment with Tpcb>85°C

Table 12. Alternative X7R capacitor part numbers

Component	Manufacturer	Part number	Value	Size
CVIN, CLDO1,2,3,4,5,6,7,8_OUT,	MURATA	GRM21BR71A475ME51	4.7 µF	0805
CINTLDO			10 V	
CBUCK1,2,3,4,5,6,7_IN		GRM21BR71A106MA73	10 µF	0805
			10 V	
CVOUT1, CVOUT6		GRM31CR70J226ME19	3 x 22 µF	1206
			6.3 V	
CVOUT2, CVOUT3			4 x 22 µF	
			6.3V	

<table>
<tr><th>Component</th><th>Manufacturer</th><th>Part number</th><th>Value</th><th>Size</th></tr>
<tr><td rowspan="2">CVOUT4, CVOUT5</td><td rowspan="10">MURATA</td><td rowspan="4">GRM31CR71A226ME15</td><td>3 x 22 µF</td><td rowspan="4">1206</td></tr>
<tr><td>10V</td></tr>
<tr><td rowspan="2">CVOUT7</td><td>4 x 22 µF</td></tr>
<tr><td>10 V</td></tr>
<tr><td rowspan="2">CLDO12IN, CLDO56IN CLDO78IN, CVREF</td><td rowspan="2">GRM219R71E105KA88</td><td>1 µF</td><td rowspan="2">0805</td></tr>
<tr><td>25 V</td></tr>
<tr><td rowspan="2">CLDO3IN, CLDO3OUT</td><td rowspan="2">GRM21BR70J106MA73</td><td>10 µF</td><td rowspan="2">0805</td></tr>
<tr><td>6.3 V</td></tr>
<tr><td rowspan="2">CVBUS</td><td rowspan="2">GRM21BR71C475ME51</td><td>4.7µF</td><td rowspan="2">0805</td></tr>
<tr><td>16 V</td></tr>
</table>

Revision history

Table 13. Document revision history

Date	Version	Changes
14-June-2024	1	Initial release.
08-Jul-2025	2	Updated: Buck converters, Section 1.2, Section 1.2.1

Contents

List of figures