Attracting Tomorrow

µPOL Chip-Embedded DC-DC Power Modules

Power for Altera FPGA/SoC Series

New: TDK power for Agilex 5E and Agilex 7/9/11/13

Tony Ochoa
Director
TDK µPOL Group

www.us.tdk.com/POL

TDK Corporation
Communication Devices Business Group • µPOL
Q2 2025

µPOL Chip-Embedded DC-DC Power Modules

Completely Integrated Solution

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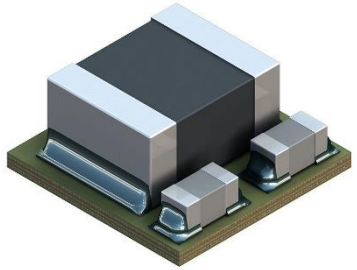

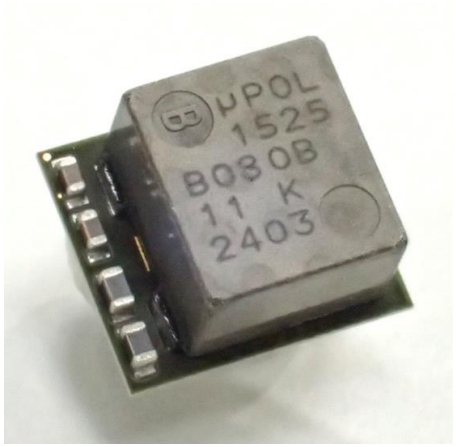

- ✓ TDK Component Quality
  - Entire BOM supplied by TDK

IC+Driver+ MOSFET

Controller, driver, MOSFETs and digital core are monolithically integrated within a single IC. Short signal paths enable high frequency operation and minimize parasitic inductance

+

Inductor

Custom inductor to exactly match the Q requirements of FETs and drivers which lowers interconnect and power losses

+

Local Bypass

Boot and Vcc capacitors are integrated as part of the total power solution

+

Embedded Package (SESUB)

Semiconductor **E**mbedded in **SUB**strate package reduces size, eliminates wire bonds & enhances thermal performance

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Quick Power Selection Guide

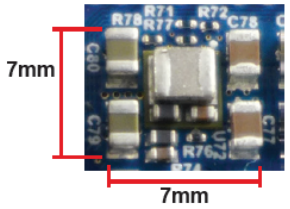
TDK's μPOL Chip Embedded Technology provides endless opportunities to save space, design time without compromising in performance. These power modules contain matching MOSFET, Driver, Inductor and thermally enhanced package make it possible to provide the most optimum solution without comprising performance, while reducing the number of external components to reduce the overall system cost.

Ease of Design
Small Size
Low BoM

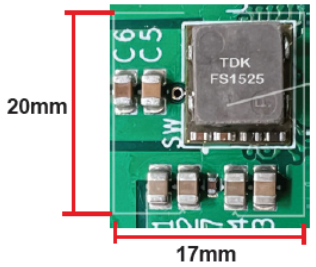
Excellent
Thermal Performance

Scalable:
1A to 200A

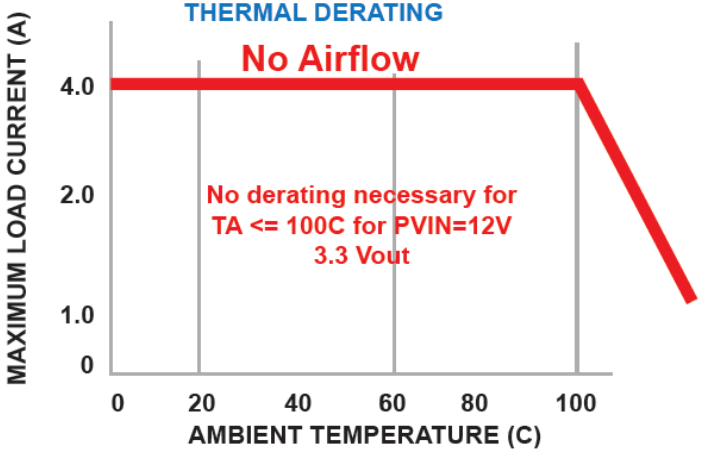
FS1406
6A



FS1525
25A



FS1604
4A (13W)
THERMAL DERATING



TDK μPOL	Vout / Iout	Current sharable
FS1525	0.6V to 1.8V, 15A to 25A	25A to 200A
FS1412	0.6V to 1.8V, 6A to 12A	
FS1606/1406	0.6V to 2.5V, 6A	
FS1604/1404	2.5V & 3.3V, 4A	
FS1603/1403 FS1703 (3.3V)	3.3V & 5.0V, 3A	
FS1003	0.6V to 5V, 3A	
FS1006	3.3V & 5.0V, 6A	
FS3303	0.4V to 3.3V, 3A	

Minimal External Components

Enhanced Thermal Design

Complete POL DC-DC Power

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Best in Size and Performance
Leading solutions for Vertical Power

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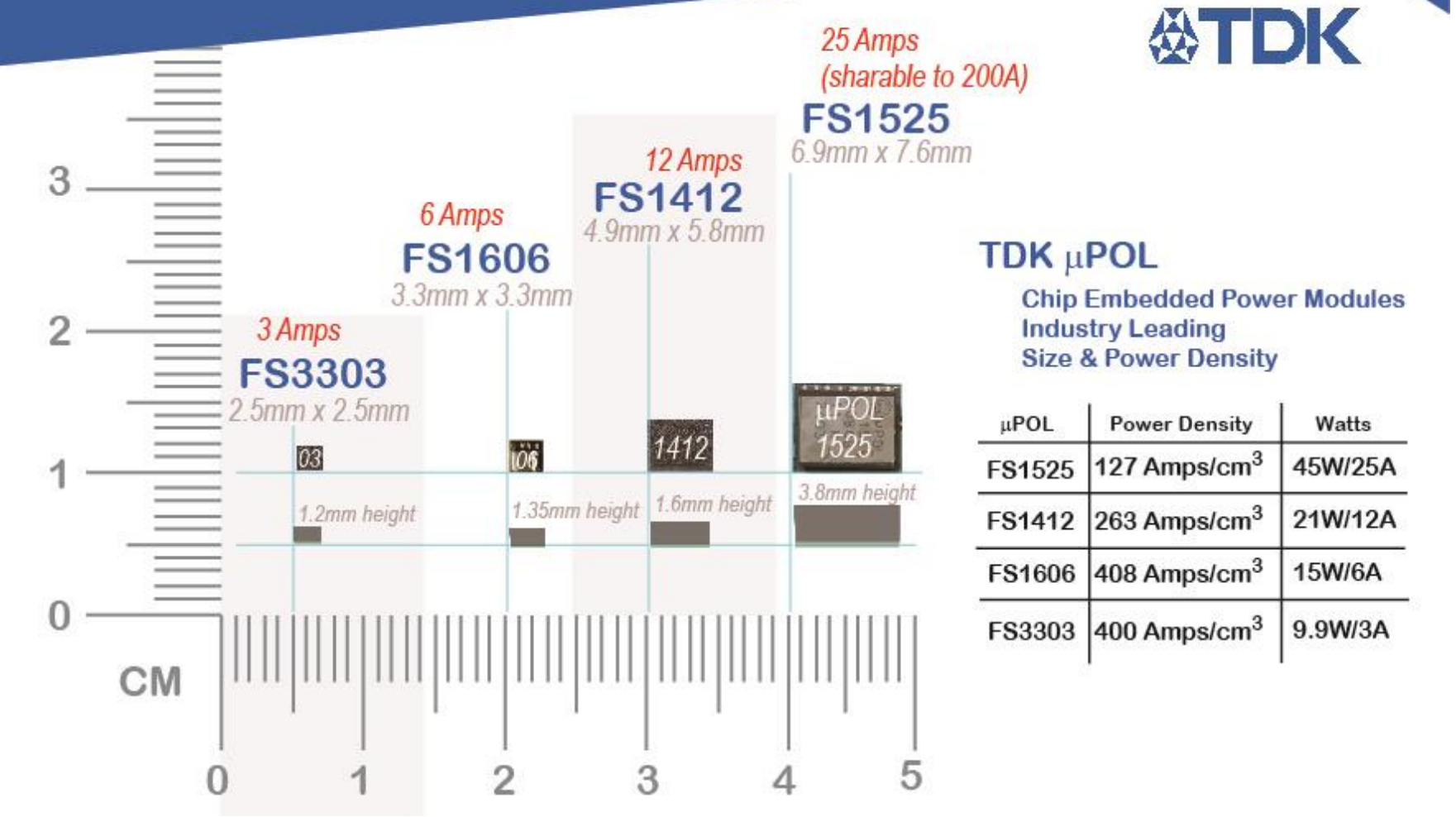

TDK µPOL

Chip Embedded Power Modules
Industry Leading
Size & Power Density

µPOL	Power Density	Watts
FS1525	127 Amps/cm^3	45W/25A
FS1412	263 Amps/cm^3	21W/12A
FS1606	408 Amps/cm^3	15W/6A
FS3303	400 Amps/cm^3	9.9W/3A

x2 to x4
Higher power density
Over competitors

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TDK μPOL Chip Embedded Power Modules

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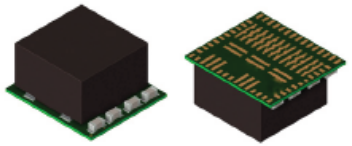
FS1525

45 Watts

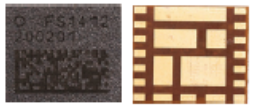


- 25A Power module
- Current sharable:
  n=1 to 8 phase: 25A to 200A
- Vout: 0.6V to 1.8V
- Vin: 4.5V to 16V
- Analog, I2C/PMBus plus Telemetry

6.8 mm x 7.6 mm x 3.8 mm height

FS1412

21 Watts

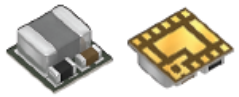


- 12A Power Module
- Vout: 0.6V to 1.8V
- Vin: 4.5V to 16V
- Analog, I2C/PMBus plus Telemetry

4.9 mm x 5.8 mm x 1.6 mm height

FS160x, FS140x, FS1703 Series

15 Watts



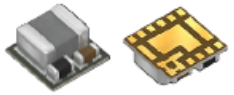
- 3A to 6A Power modules
- All same pinout
  - *FS1606 / FS1406: 0.6V to 2.5V Vout
  - *FS1603 / FS1403: 3.3V & 5.0V Vout
  - *FS1604 / FS1404: 2.5V & 3.3V Vout
  - FS1703 5V Vin to 3.3V Vout
- FS160x, I2C plus Telemetry

140x: 3.3mm x 3.3 mm x 1.5 mm height
160x: 3.3mm x 3.3 mm x 1.35 mm height

* Vin see datasheet

FS1006

30 Watts



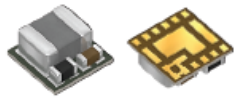
- 6A Power modules
- *FS1006 3.3V & 5.0V Vout @ 6A
- I2C plus Telemetry
- Same pinout as FS160x, FS140x

3.3mm x 3.3 mm x 1.35 mm height

* Vin see datasheet

FS1003

15 Watts



- 3A Power modules
- Vout: 0.6V to 5V
- Vin: 4.2V to 16V
- I2C plus Telemetry
- Same pinout as FS160x, FS140x

3.3mm x 3.3 mm x 1.35 mm height

FS3303 - Coming Soon

<10 Watts

- 3A Power modules
- 0.4V to 3.3V Vout @ 3A
- 2.7V to 5.5V Vin
- $I_{shutdown}$: <1uA max

2.5mm x 2.5 mm x 1.2 mm height

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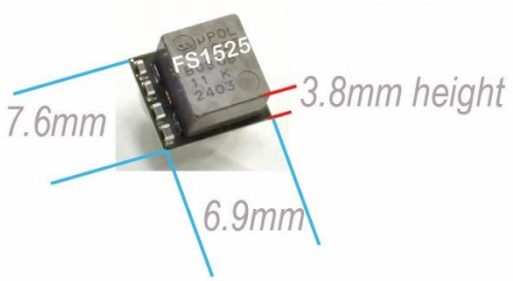
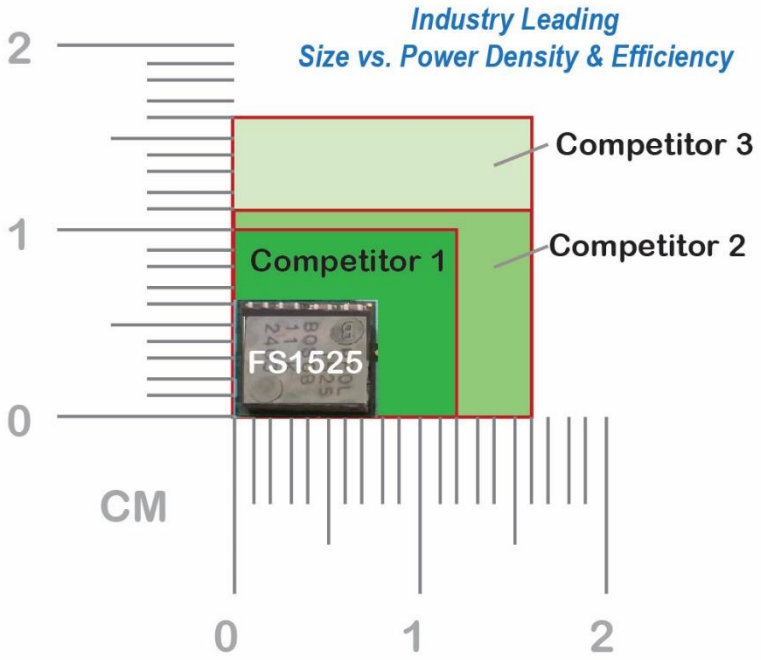
Leading Power Density & Size

TDK µPOL
Chip Embedded Power Modules

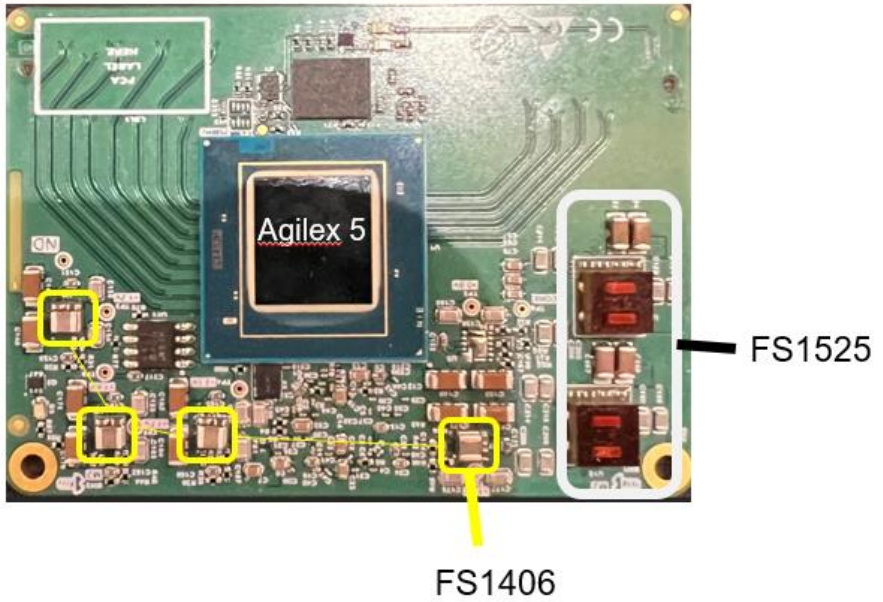
FS1525 *25 Amps (scalable to 200A)*





	TDK-FS1525 6.8mm x 7.6mm x 3.8mm	Competitor 1 10mm x 12mm x 4mm	Competitor 2 16mm x 16mm x 5mm	Competitor 3 11mm x 16mm x 4.2mm
Area	$52.6mm^2$	$120mm^2$ (2.25x larger)	$176mm^2$ (3.4x larger)	$256mm^2$ (5x larger)
Volume	$196mm^3$	$480mm^3$	$992mm^3$	$739mm^3$
Current Density, A/cm3	127.3	52.1	26.2	33.8
TDK is x-times better		2.4	4.9	3.8
Current Density, A/cm2	48.4	20.8	11.6	14.2
TDK is x-times better		2.3	4.2	3.4

Design Example: Altera Agilex SoM



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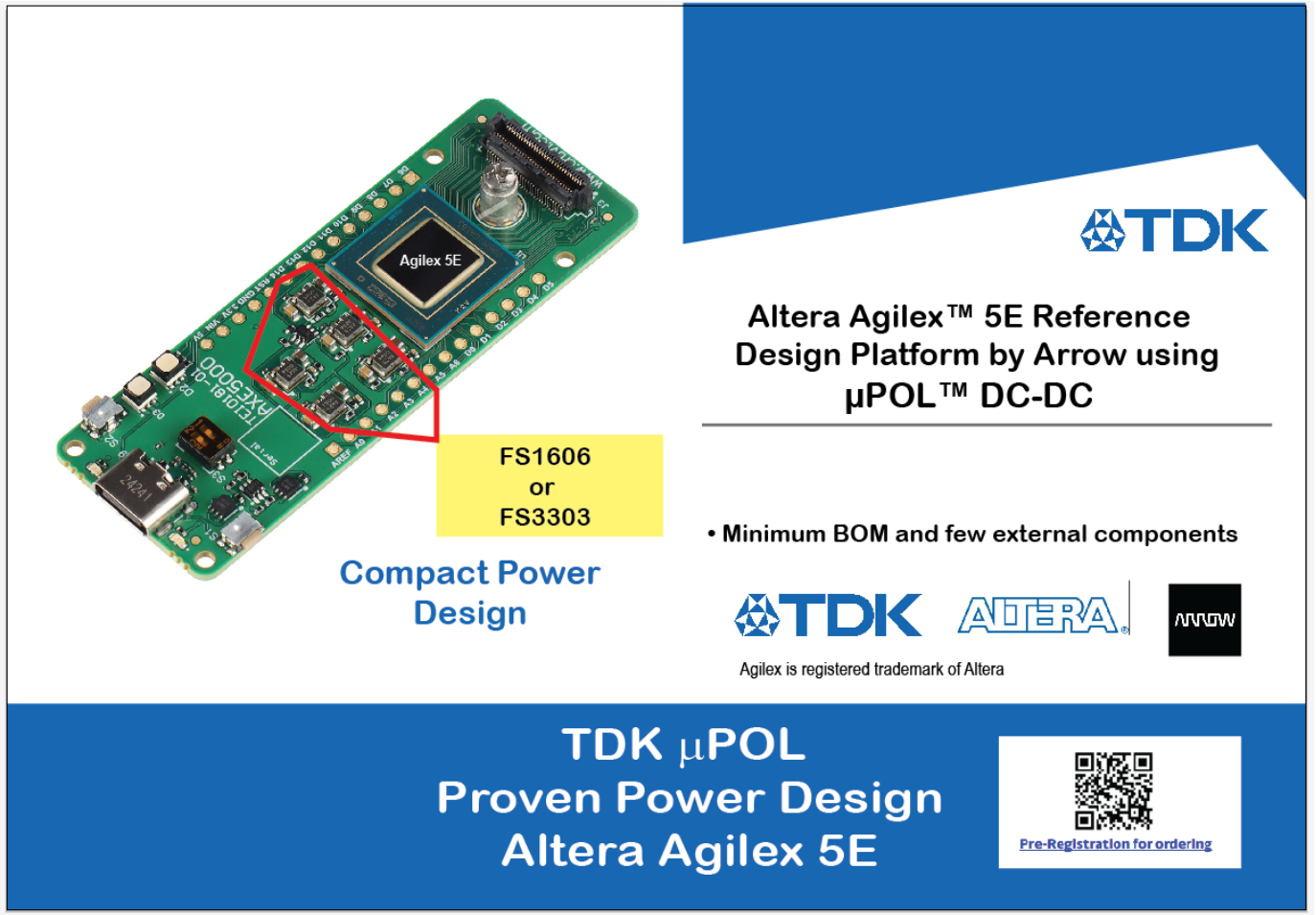
New – TDK FS1606 / FS1003 or FS3303 for Agilex 5E



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Key TDK μPOL devices to Power the Altera Agilex

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Device	Voltage	Current	Design Notes
FS1525	VID set: 0.8V default 0.7V to 0.9V in +/-10mV steps Fixed set: 0.75V, 0.78V, 0.8V	25A to 200A	FS1525 has PMBus to support Intel Quartus for SmartVID FS1525 Vout can be set • via PS (hardware pin / resistor) • Resistor divider • I2C/PMBus
FS1412	0.8V, 1.0V, 1.2V, 1.8V, 1.1V, 0.9V	6A to 12A	
FS1406/FS1606	0.8V, 1.0V, 1.2V, 1.8V, 1.1V, 0.9V	1A to 6A	
FS1003	0.6V to 5V	3A	
FS1404 / FS1604	3.3V	1A to 4A	
FS3303	0.4V to 3.3V	500mA to 3A	
Other System Power			
FS1006	3.3V	6A	For 10G to 40Gb Enet supplies 3.3V system supplies
FS1603	5.0V	3A	5V system supplies

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TDK μPOL devices to Power the Altera Agilex

Agilex 5 *Power Maps*

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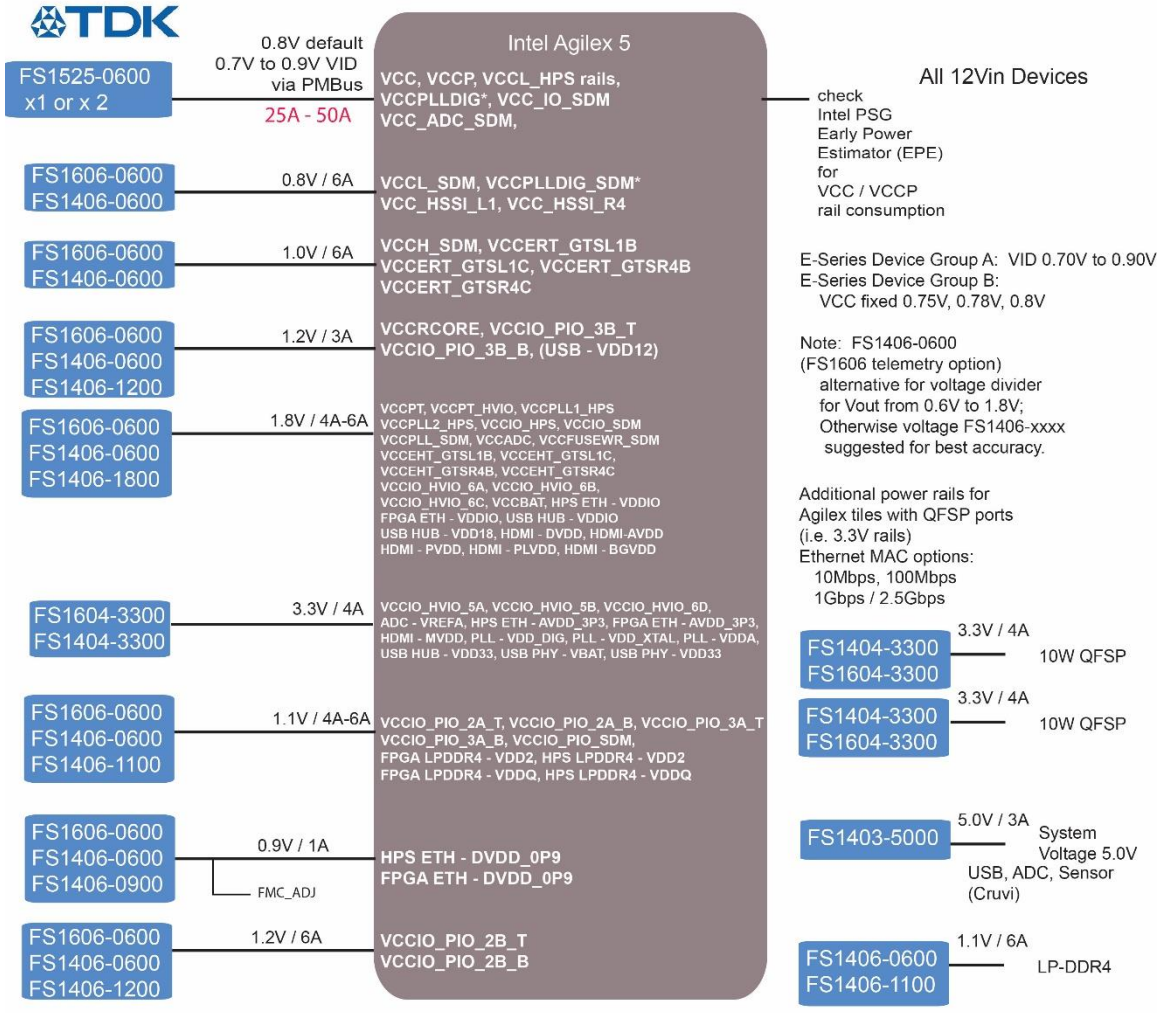

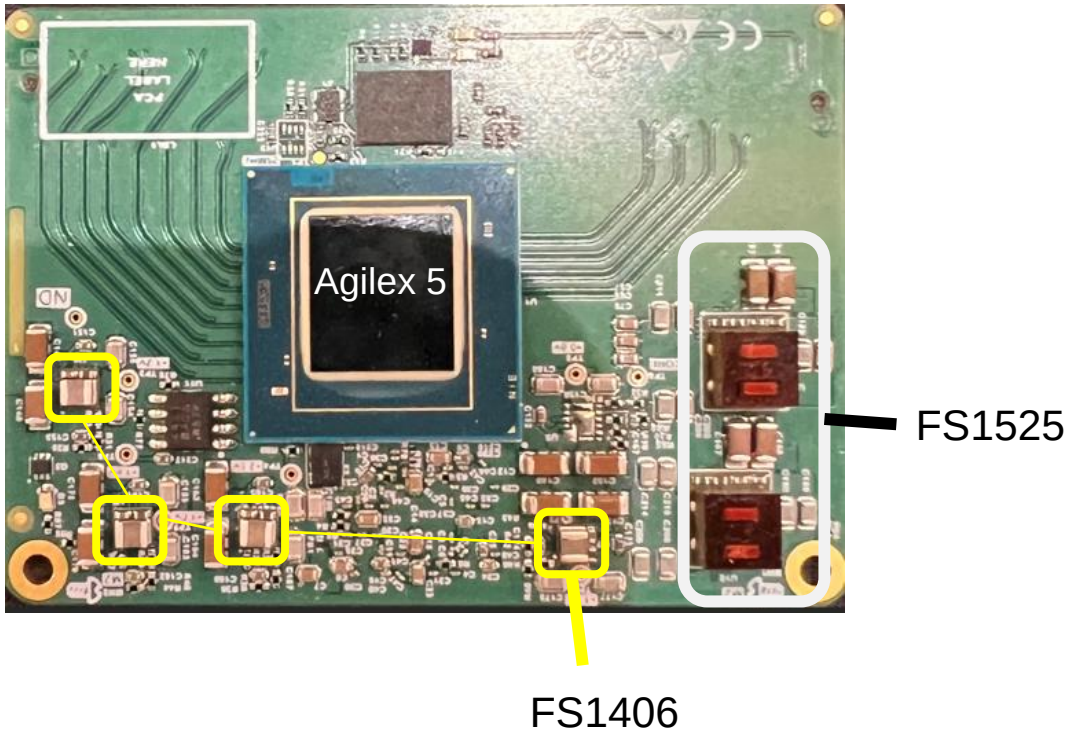

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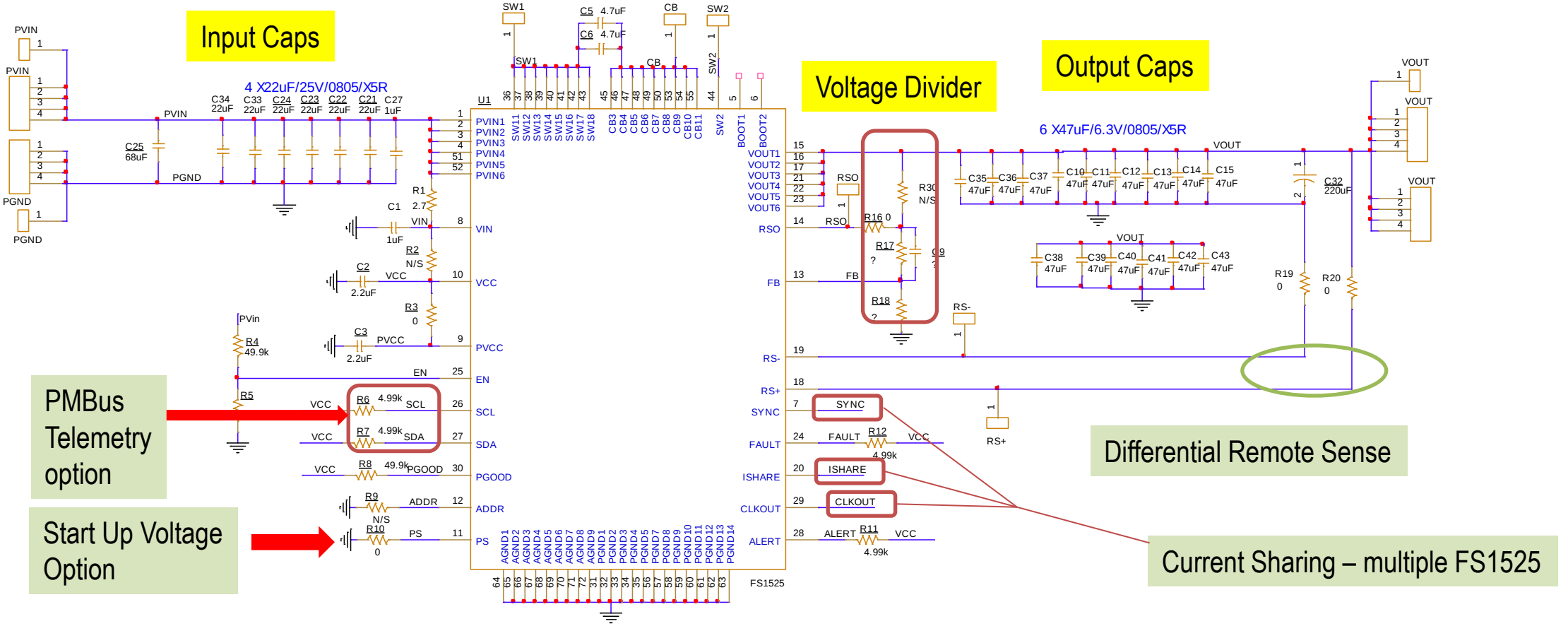
Vcore rail for Agilex 5 – Using the FS1525

FS1525 – 25A Design – Ease of Design

6.8mm x 7.6mm x 3.8mm



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TDK µPOL devices to Power the Altera Agilex Agilex 5 – VCC, VCCP voltage rail 25A

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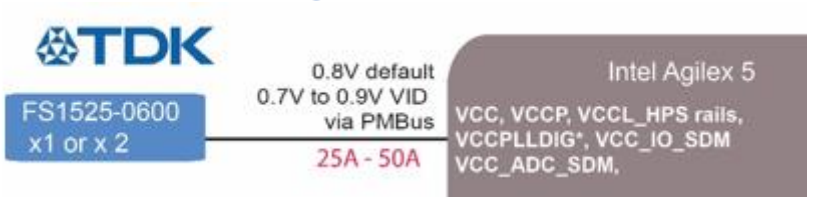
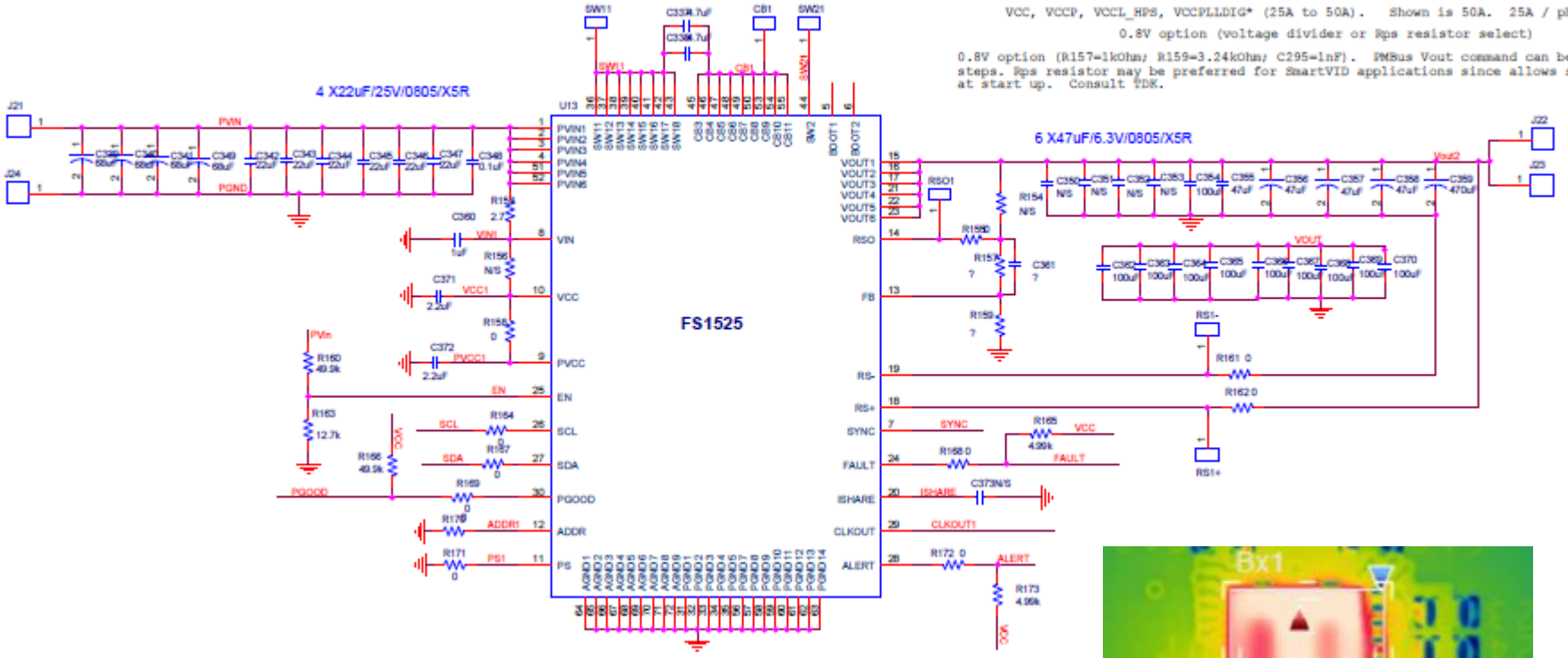
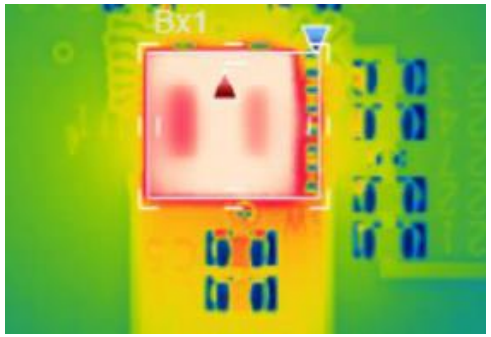
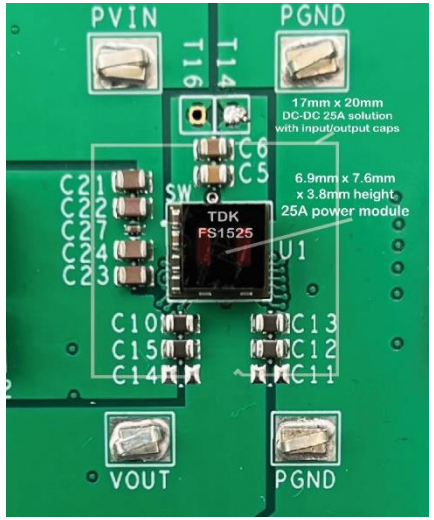


17mm x 20mm

TDK micro-POL Power Solution for Intel Agilex 5







PVin=12V, Vo= 0.8V,
Fsw=625 kHz,
Io=25A, no airflow.
+42C rise from room temp

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TDK – Altera Agilex 5 – Simplis Design Library

Agilex 5 – SIM Library SIMPLIS

Voltage rail name	Nom Vin	Max Iin	DC ripple	DC reg	AC reg	Load step	Slew rate	TDK µPOL	SIMPLIS model	Transient response plot
VCC, VCCP, VCCL_HPS, VCCPLLDIG*, VCC_IO_SDM VCC_ADC_SDM	0.70V	25A			±3%	20%	100A/µs	FS1525-0600	0V7 25A 20pc 100Aµs SIM.zip	Plot 0V7 25A 20pc 100Aµs SIM.pdf
	0.80V								0V8 25A 20pc 100Aµs SIM.zip	Plot 0V8 25A 20pc 100Aµs SIM.pdf
	0.90V								0V9 25A 20pc 100Aµs SIM.zip	Plot 0V9 25A 20pc 100Aµs SIM.pdf
VCCL_SDM, VCC_HSSI_L1, VCC_HSSI_R4	0.8V	12A			±3%	25%	10A/µs	FS1412-0600	0V8 12A 25pc 10Aµs SIM.zip	Plot 0V8 12A 25pc 10Aµs SIM.pdf
VCCPLLDIG_SDM*									0V8 12A 25pc 10Aµs SIM.zip	Plot 0V8 12A 25pc 10Aµs SIM.pdf
VCCL_SDM, VCC_HSSI_L1, VCC_HSSI_R4	0.8V	6A			±3%	25%	10A/µs	FS1406-0800	0V8 6A 25pc 10Aµs SIM.zip	Plot 0V8 6A 25pc 10Aµs SIM.pdf
VCCPLLDIG_SDM*									0V8 6A 25pc 10Aµs SIM.zip	Plot 0V8 6A 25pc 10Aµs SIM.pdf
VCCH_SDM, VCCERT_GTSL1B VCCERT_GTSL1C, VCCERT_GTSR4B VCCERT_GTSR4C	1.0V	6A			±3%	100%	1A/µs	FS1406-1000	1V0 6A 100pc 1Aµs SIM.zip	Plot 1V0 6A 100pc 1Aµs SIM.pdf

FS1525 Simplis performance guidelines data

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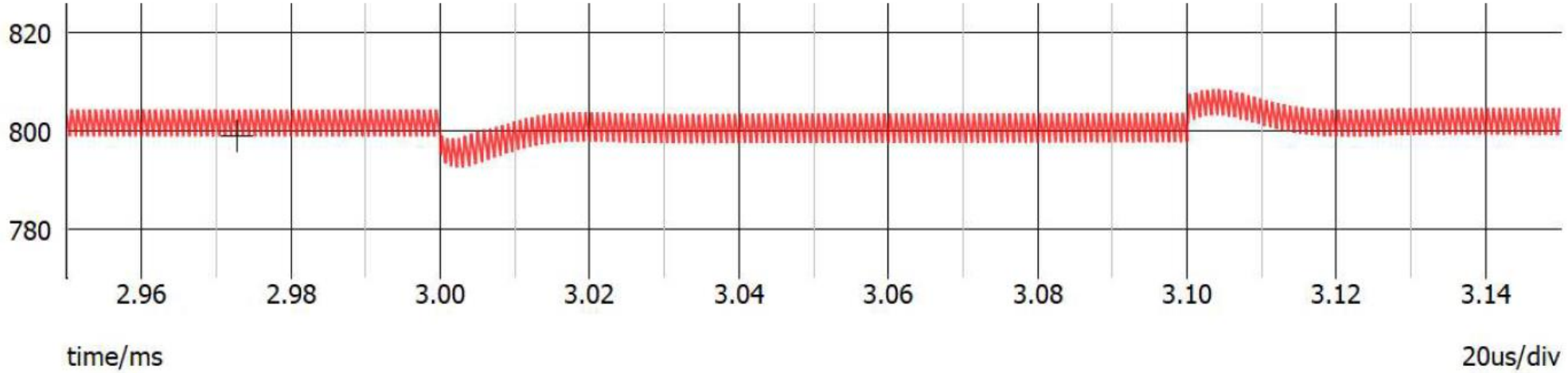
Design Example: VCC/VCCP (Vcore) of Altera Agilex 5

FS1525 – 25A / 0.8V. 20% step load. 100A/usec.

C_load = 1000µF AC Load regulation: ±1.36%, DC ripple = 5.4mV$_{pp}$.



Label	Legend
VOUT1	

Curve label	Name	Value
VOUT1	Peak To Peak	15.91449mV
VOUT1	Peak To Peak (2.96ms - 2.98ms)	5.4293438mV

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Design Example: VCC/VCCP (Vcore) of Altera Agilex 5

FS1525 – 25A / 0.8V. 20% step load. 100A/usec.

Part reference	Qty	Value	Description
C1,C48	2	1µF	0603/25V/X7R
C27,C40	2	1µF	0402/25V/X5R
C2,C3,C50,C51	4	2.2µF	0402/10V/X7R
C5,C6,C33,C34	4	4.7µF	0805/16V/X7R
C97,C*	2	330µF	1210/2.5V/X6S
C10,C13,C127,C130	4	47µF	0805/6.3V/X5R
C110,C111,C112	3	100µF	0805/4V/X6S
C107,C108,C109	3	47µF	0603/2.5V/X6S
C113,C126,C41	3	10µF	0402/6.3V/X5R
C21,C22,C23,C24,C37,C38,C39,C101	8	22µF	0805/25V/X5R
C35,C95	2	68µF	25V,poscap
C32,C93,C96	3	470µF	SP-CAP

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TDK μPOL devices to Power the Altera Agilex

Agilex 7, 9

Power Maps

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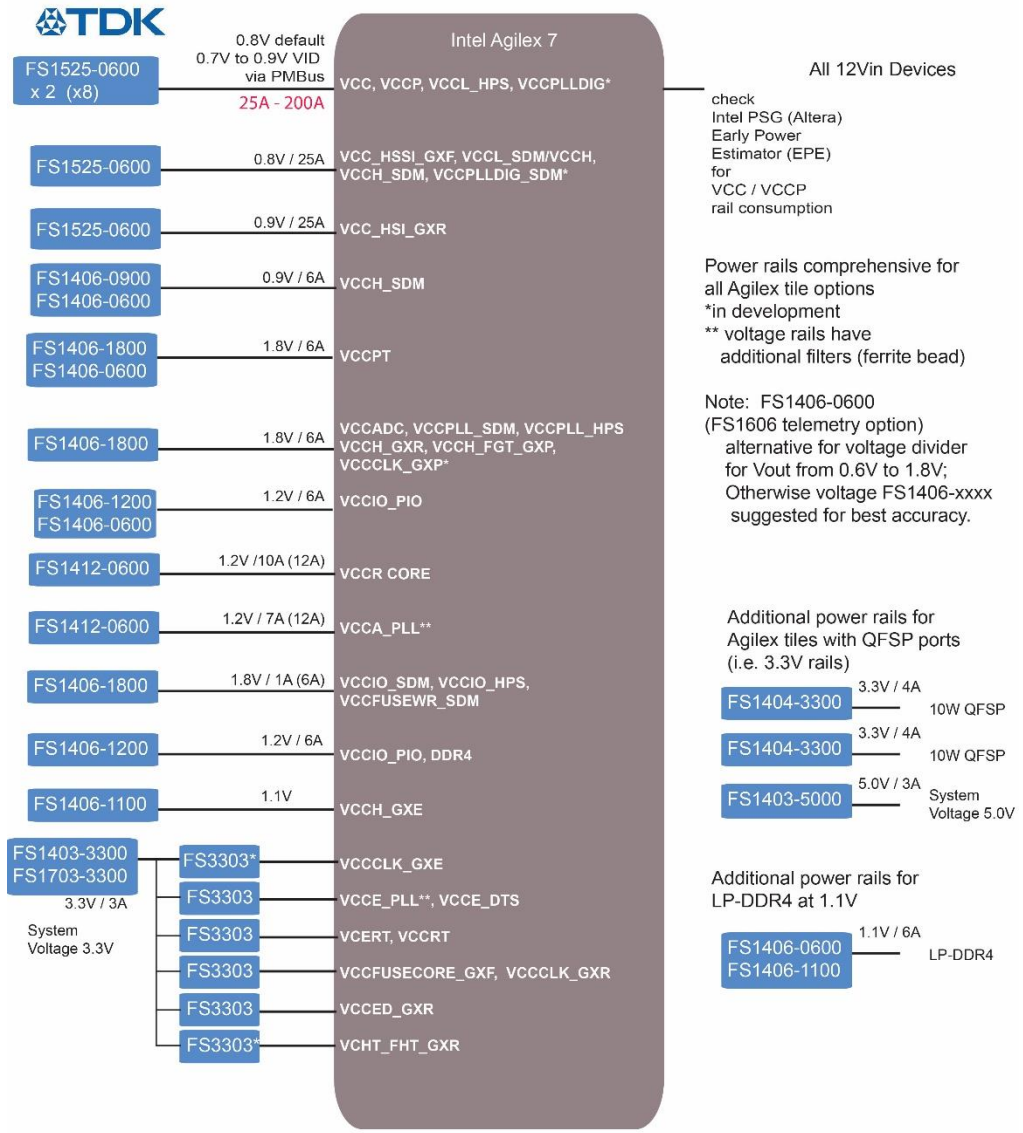

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TDK µPOL devices to Power the Altera Agilex

Agilex 5 – VCC, VCCP voltage rail 50A

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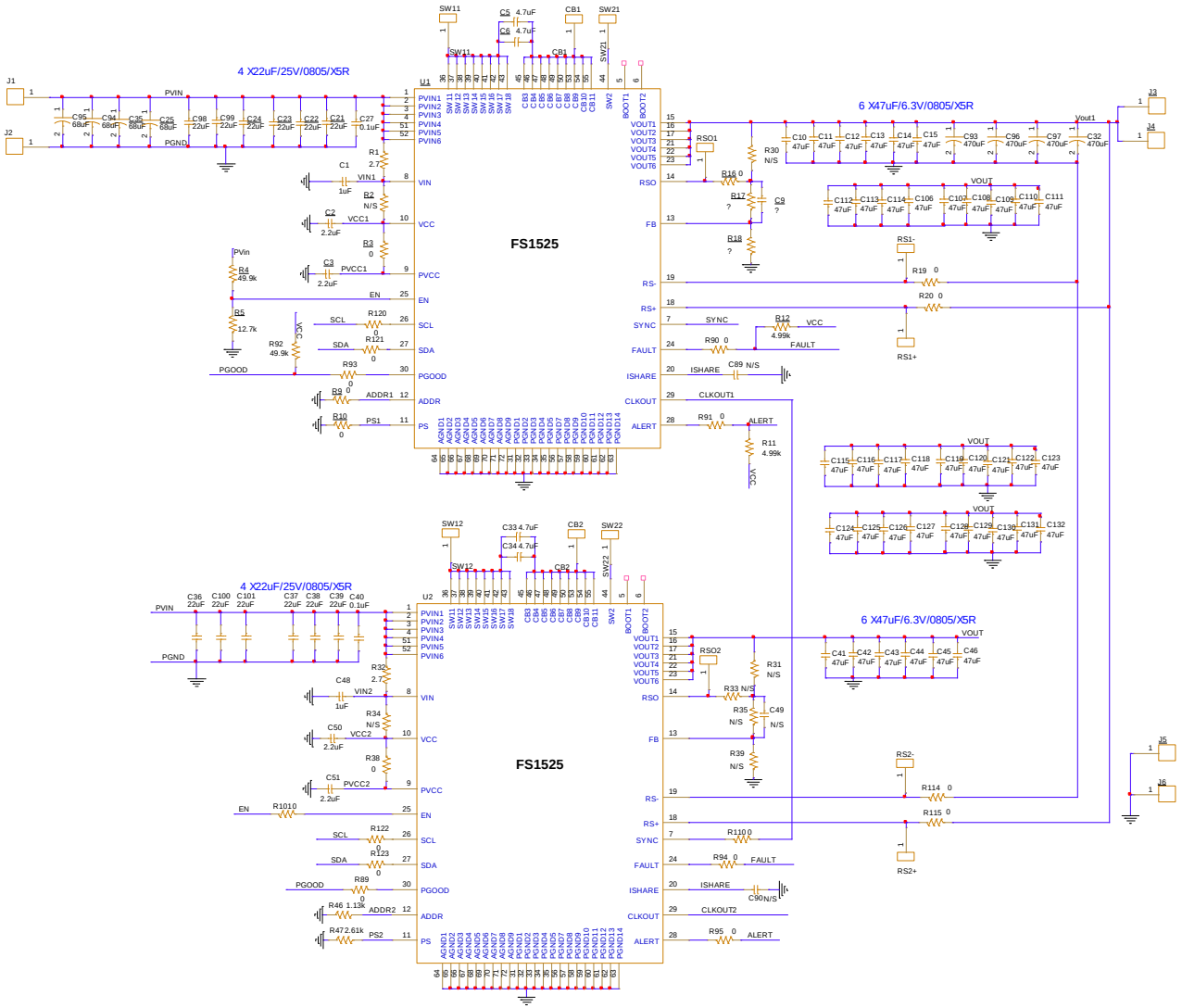
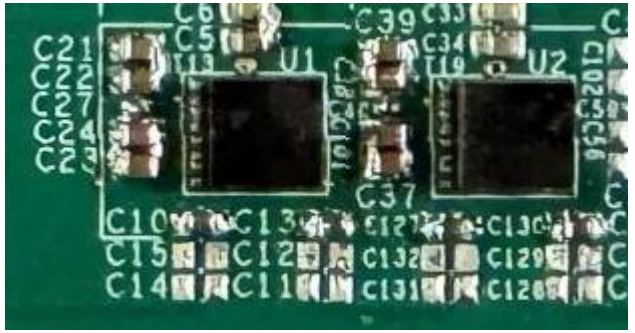


50A



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FS1525 – Using it for Agilex SmartVID

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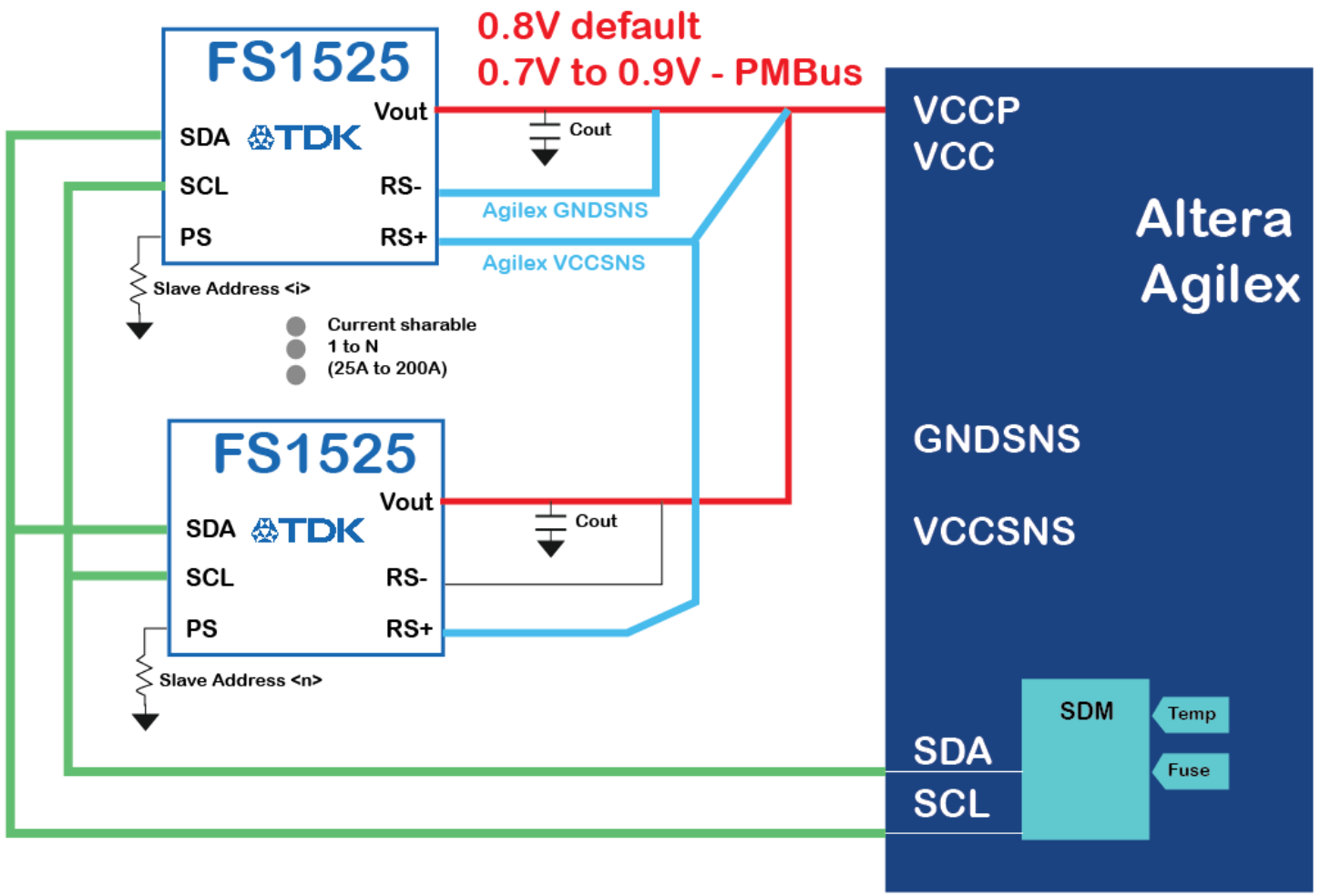
- Vcore Rail has two modes: Fixed or SmartVID
  VCCP, VCC
  - ➢ SmartVID: 0.8V default. 0.7V to 0.9V +/-10mV steps
  - ➢ Fixed: 0.75V, 0.78V, 0.8V
- FS1525 can used for either SmartVID or Fixed modes
- Altera uses PMBus to communicate to Slave Power Devices to set the VID voltages.
- Each FS1525 has a unique hardware address to be address by the Agilex SDM via Intel Quartus Software
- Design Configuration Tips for Quartus for FS1525 use case:
  1) Slave mode selected
  2) Linear mode selected
  3) Assign the slave hardware address for each FS1525
  4) FS1525 does not work in PAGE mode
  5) Each FS1525 must be address and programmed separately (Group mode is not available)



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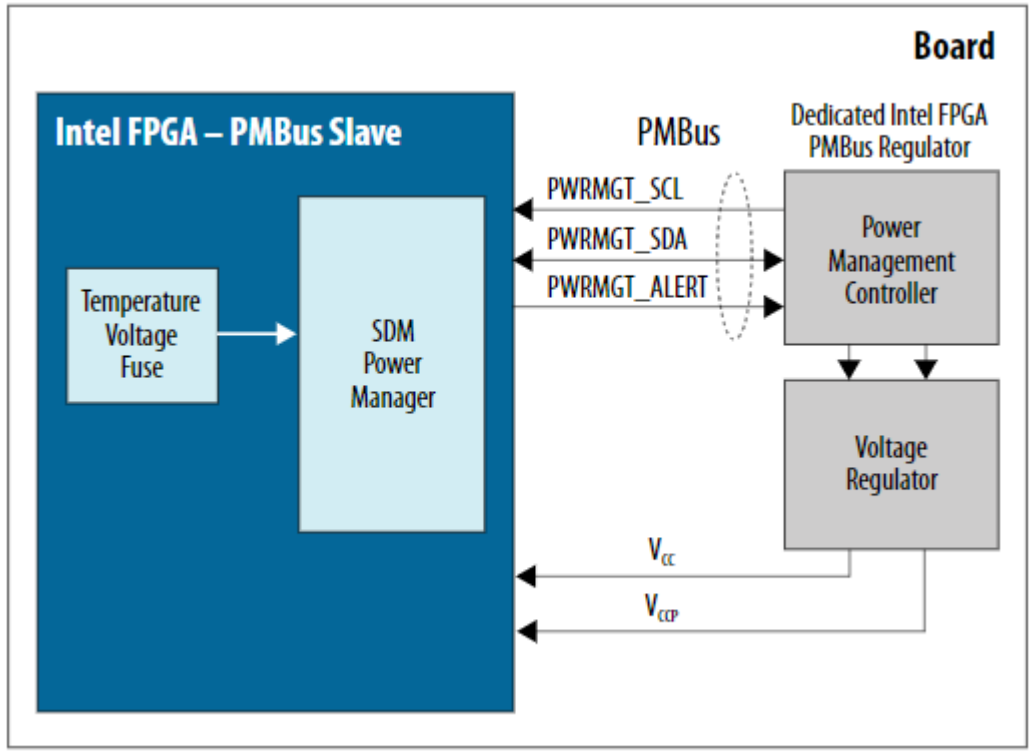
Supported Commands for the PMBus Slave Mode
FS1525 to Agilex

Command Name	Command Code	Default	PMBus Transaction Type	Number of Bytes
CLEAR_FAULTS	03h	—	Send byte	0
VOUT_MODE	20h	40h	Read byte	1
VOUT_COMMAND	21h	—	Read word	2
STATUS_BYTE	78h	00h	Read byte	1



FS1525 Quick PMBus Command Sets

Register	Name
40	I2C-base(6:0)
41	PMBus_base(6:0)
42	Operation[7:0]
43	On_off_config[7:0]
4C	Vout_command_lower[7:0]
4D	Vout_command_upper[7:0]

FS1525 also has Full telemetry command sets

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Other voltage rail for Agilex 5 – Using TDK μPOL

Other voltage rails for Agilex 5 Power Design

Attracting Tomorrow TDK

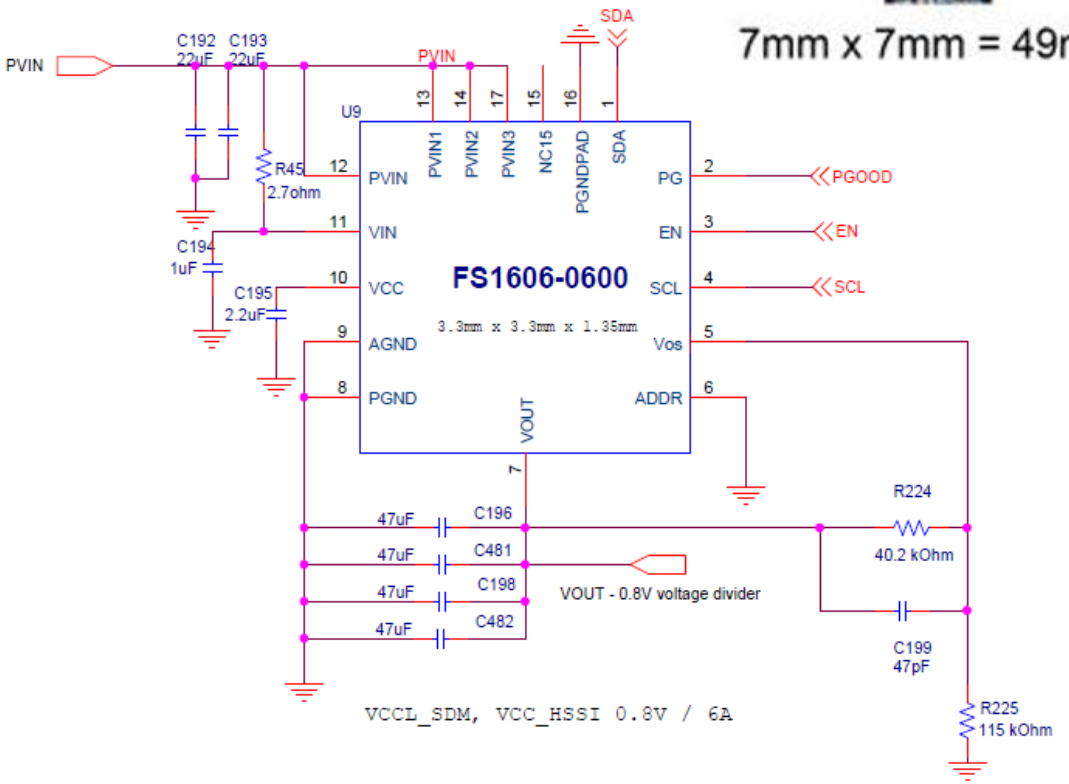
FS1606-0600
FS1406-0600

1.0V / 6A

VCCH_SDM, VCCERT_GTSL1B
VCCERT_GTSL1C, VCCERT_GTSR4B
VCCERT_GTSR4C

DC-DC Total Solution

7mm x 7mm = 49mm²



Transient load at Vo = 0.8V, Iout = 6A, Step load = 25% Slew rate = 10A/µs

C_load = 100µF AC Load regulation: ±1.23%, DC ripple = 5.4mV$_{pp}$.

C_load = 500µF AC Load regulation: ±0.63%, DC ripple = 3.3mV$_{pp}$.

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Other voltage rails for Agilex 5 Power Design

Attracting Tomorrow TDK

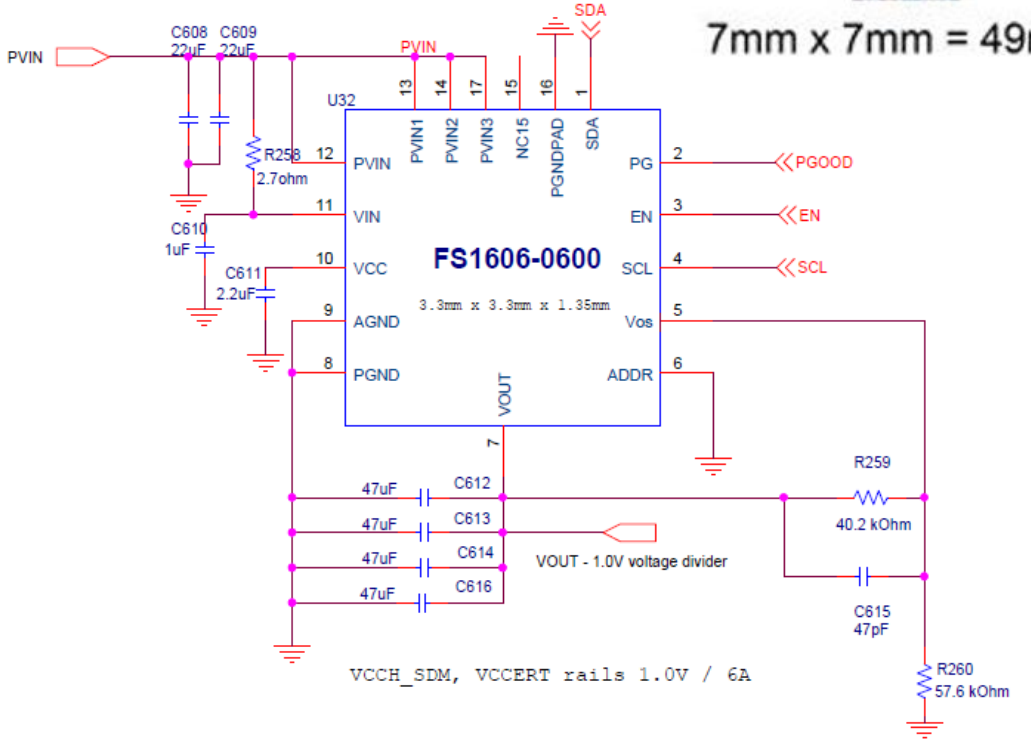
FS1606-0600
FS1406-0600

1.0V / 6A

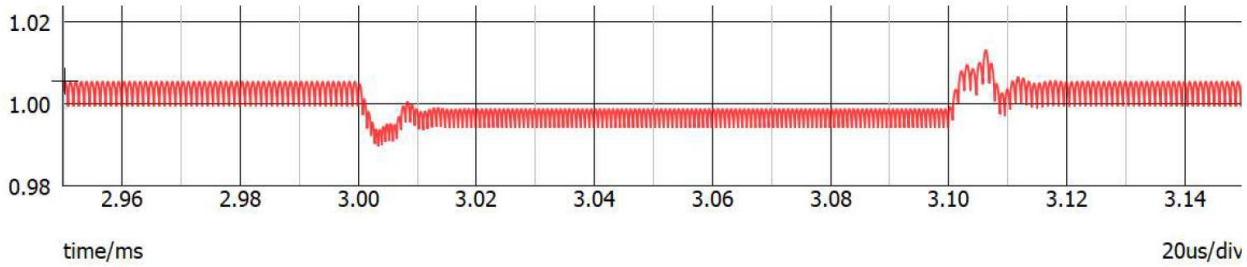
VCCH_SDM, VCCERT_GTSL1B
VCCERT_GTSL1C, VCCERT_GTSR4B
VCCERT_GTSR4C

DC-DC Total Solution

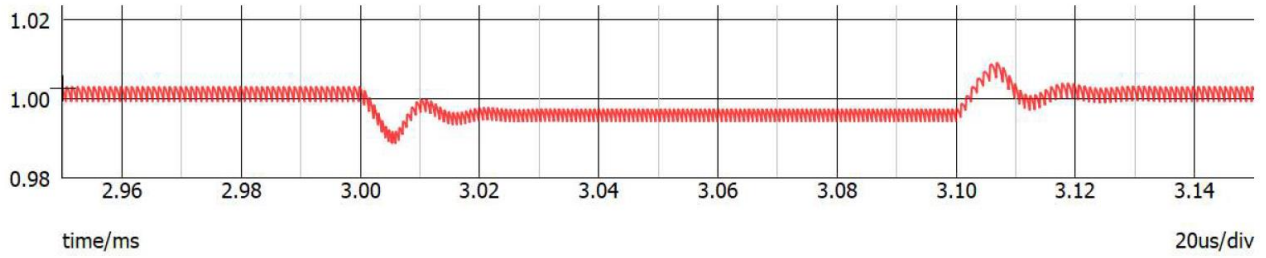
7mm x 7mm = 49mm²



Transient load at Vo = 1.0V, Iout = 6A,
Step load = 100% Slew rate = 1A/µs



C_load = 100µF AC Load regulation: ±1.18%, DC ripple = 6.1mV$_{pp}$.



C_load = 500µF AC Load regulation: ±1.03%, DC ripple = 3.8mV$_{pp}$.

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Other voltage rails for Agilex 5 Power Design

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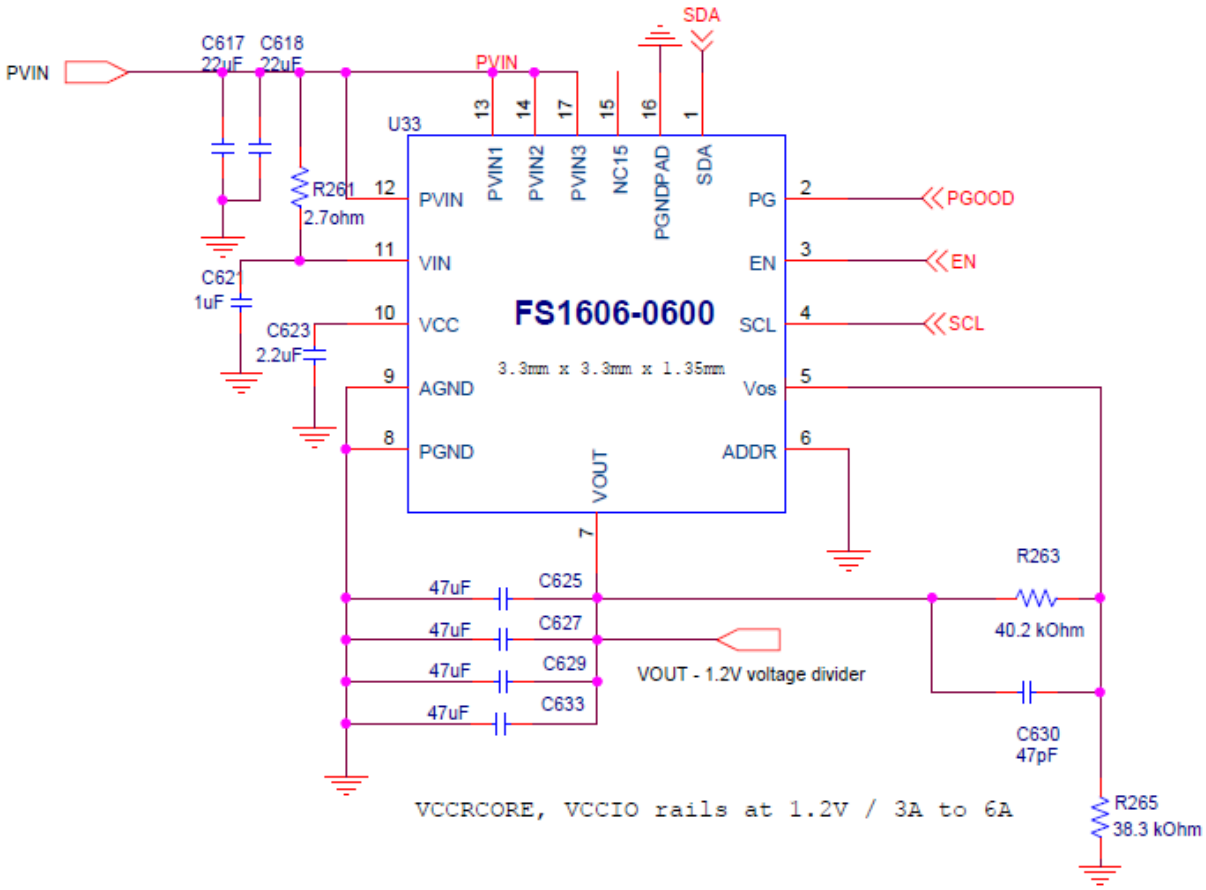
FS1606-0600
FS1406-0600
FS1406-1200

1.2V / 3A

VCCRCORE, VCCIO_PIO_3B_T
VCCIO_PIO_3B_B, (USB - VDD12)

DC-DC Total Solution

7mm x 7mm = 49mm^2



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Other voltage rails for Agilex 5 Power Design

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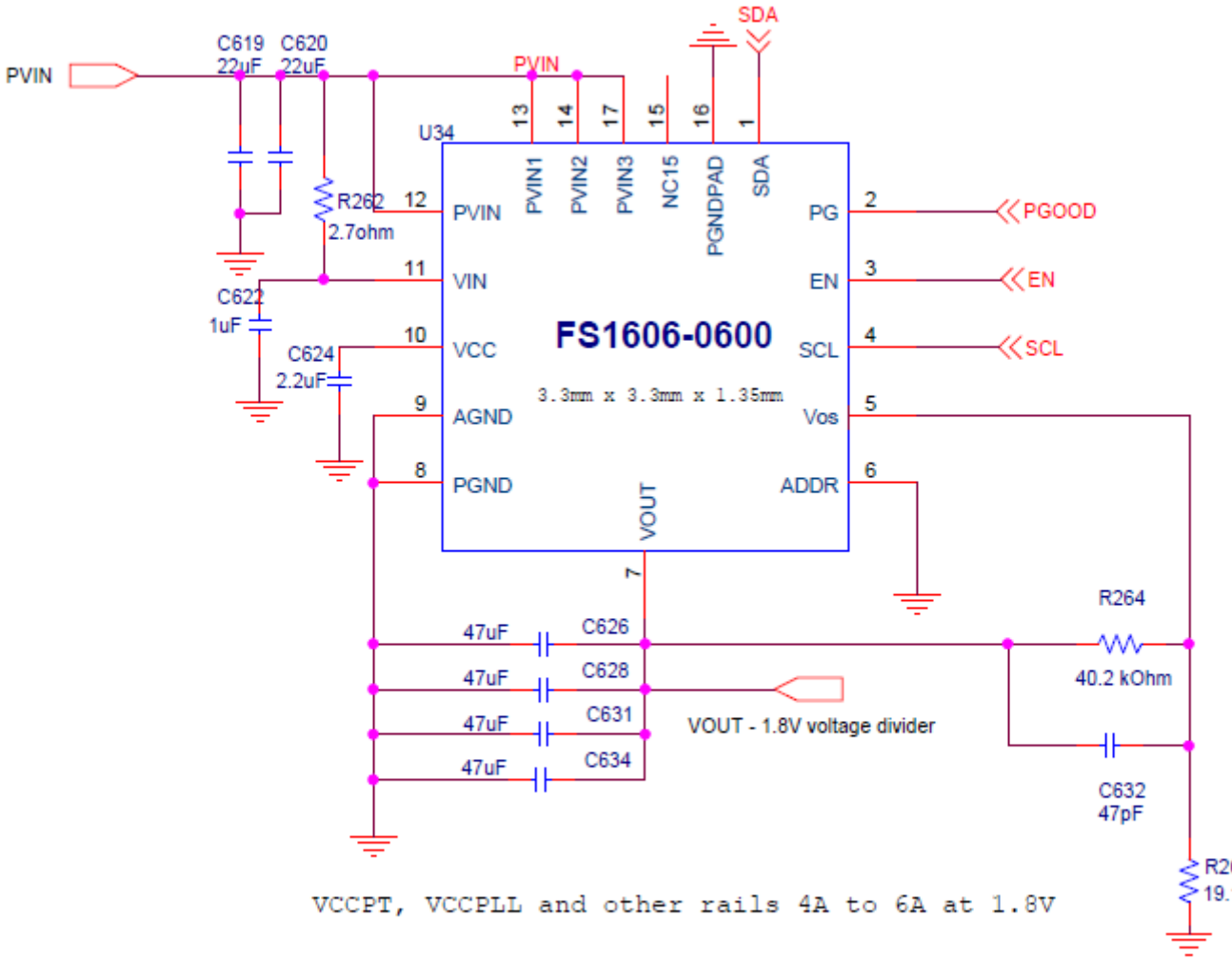
FS1606-0600
FS1406-0600
FS1406-1800

1.8V / 4A-6A

VCCPT, VCCPT_HVIO, VCCPLL1_HPS
VCCPLL2_HPS, VCCIO_HPS, VCCIO_SDM
VCCPLL_SDM, VCCADC, VCCFUSEWR_SDM
VCCEHT_GTSL1B, VCCEHT_GTSL1C,
VCCEHT_GTSR4B, VCCEHT_GTSR4C
VCCIO_HVIO_6A, VCCIO_HVIO_6B,
VCCIO_HVIO_6C, VCCBAT, HPS ETH - VDDIO
FPGA ETH - VDDIO, USB HUB - VDDIO
USB HUB - VDD18, HDMI - DVDD, HDMI-AVDD
HDMI - PVDD, HDMI - PLVDD, HDMI - BGVDD

DC-DC Total Solution

7mm x 7mm = 49mm^2



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Other voltage rails for Agilex 5 Power Design

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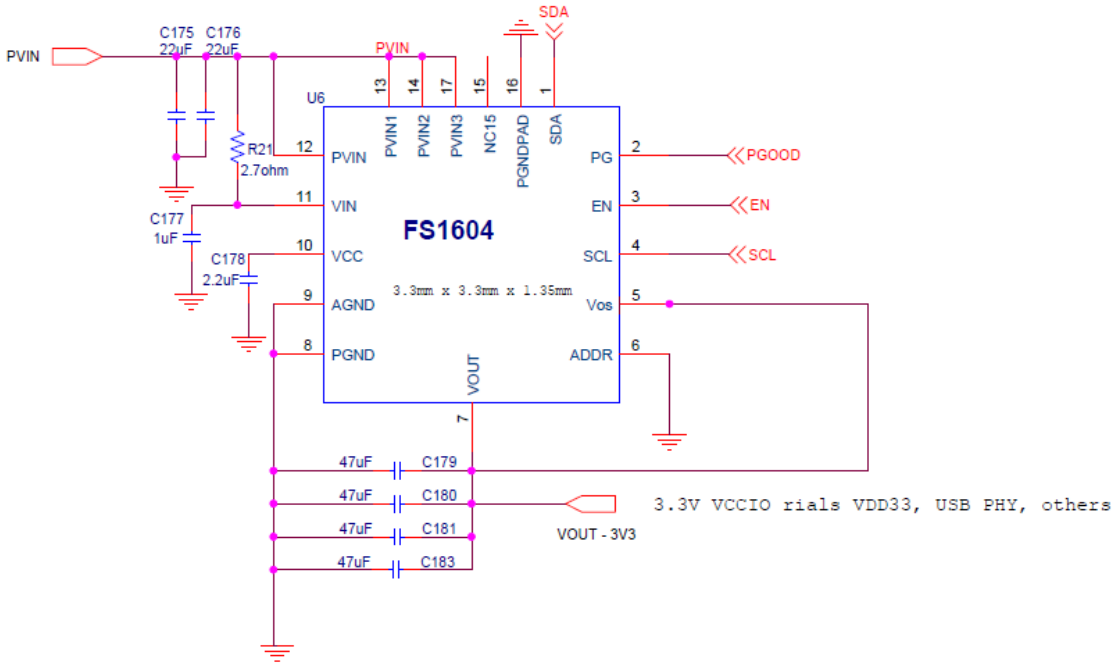
FS1604-3300
FS1404-3300

3.3V / 4A

VCCIO_HVIO_5A, VCCIO_HVIO_5B, VCCIO_HVIO_6D, ADC - VREFA, HPS ETH - AVDD_3P3, FPGA ETH - AVDD_3P3, HDMI - MVDD, PLL - VDD_DIG, PLL - VDD_XTAL, PLL - VDDA, USB HUB - VDD33, USB PHY - VBAT, USB PHY - VDD33

DC-DC Total Solution

7mm x 7mm = 49mm²



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Other voltage rails for Agilex 5 Power Design

Attracting Tomorrow

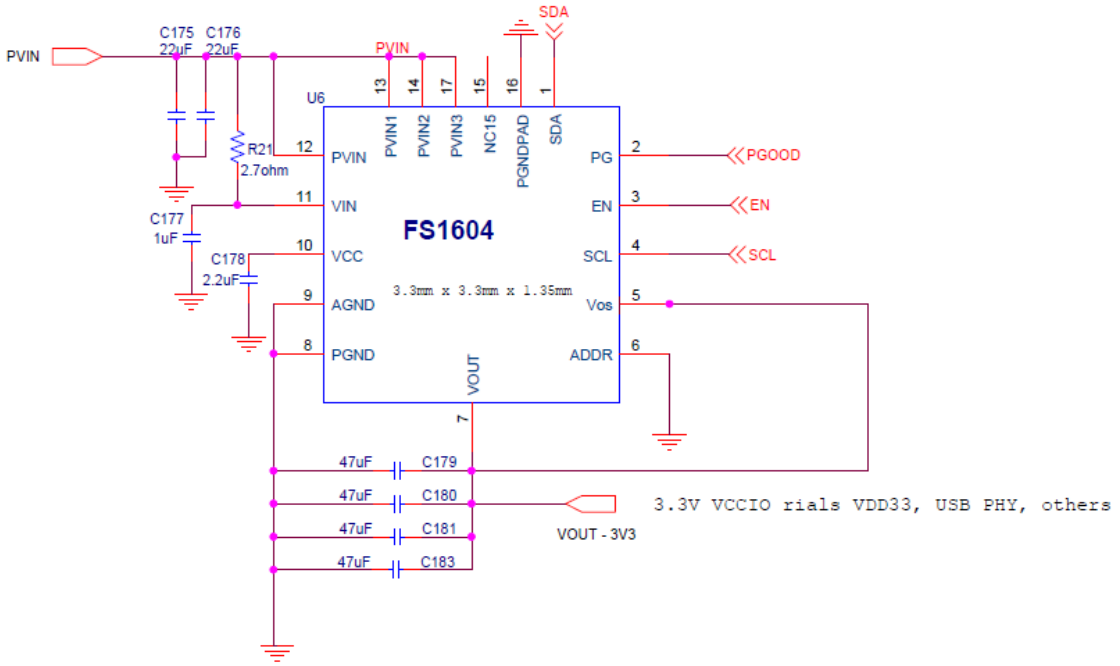
FS1604-3300
FS1404-3300

3.3V / 4A

VCCIO_HVIO_5A, VCCIO_HVIO_5B, VCCIO_HVIO_6D, ADC - VREFA, HPS ETH - AVDD_3P3, FPGA ETH - AVDD_3P3, HDMI - MVDD, PLL - VDD_DIG, PLL - VDD_XTAL, PLL - VDDA, USB HUB - VDD33, USB PHY - VBAT, USB PHY - VDD33

DC-DC Total Solution

7mm x 7mm = 49mm²



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Other voltage rails for Agilex 5 Power Design

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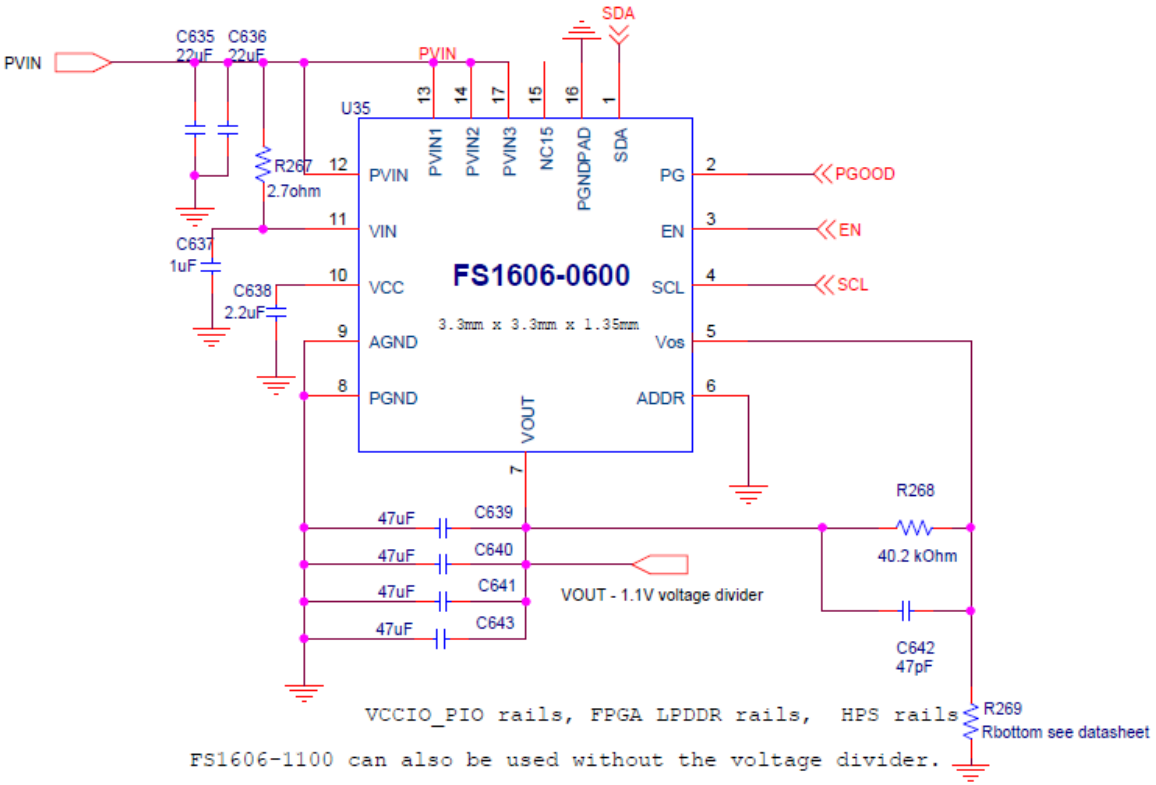
FS1606-0600
FS1406-0600
FS1406-1100

1.1V / 4A-6A

VCCIO_PIO_2A_T, VCCIO_PIO_2A_B, VCCIO_PIO_3A_T
VCCIO_PIO_3A_B, VCCIO_PIO_SDM,
FPGA LPDDR4 - VDD2, HPS LPDDR4 - VDD2
FPGA LPDDR4 - VDDQ, HPS LPDDR4 - VDDQ

DC-DC Total Solution

7mm x 7mm = 49mm²



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TDK μPOL:
Other Altera FPGA powered by TDK μPOL

Stratix, Arria 10, Cyclone, Max10

TDK μPOL: Altera Stratix and Arria 10

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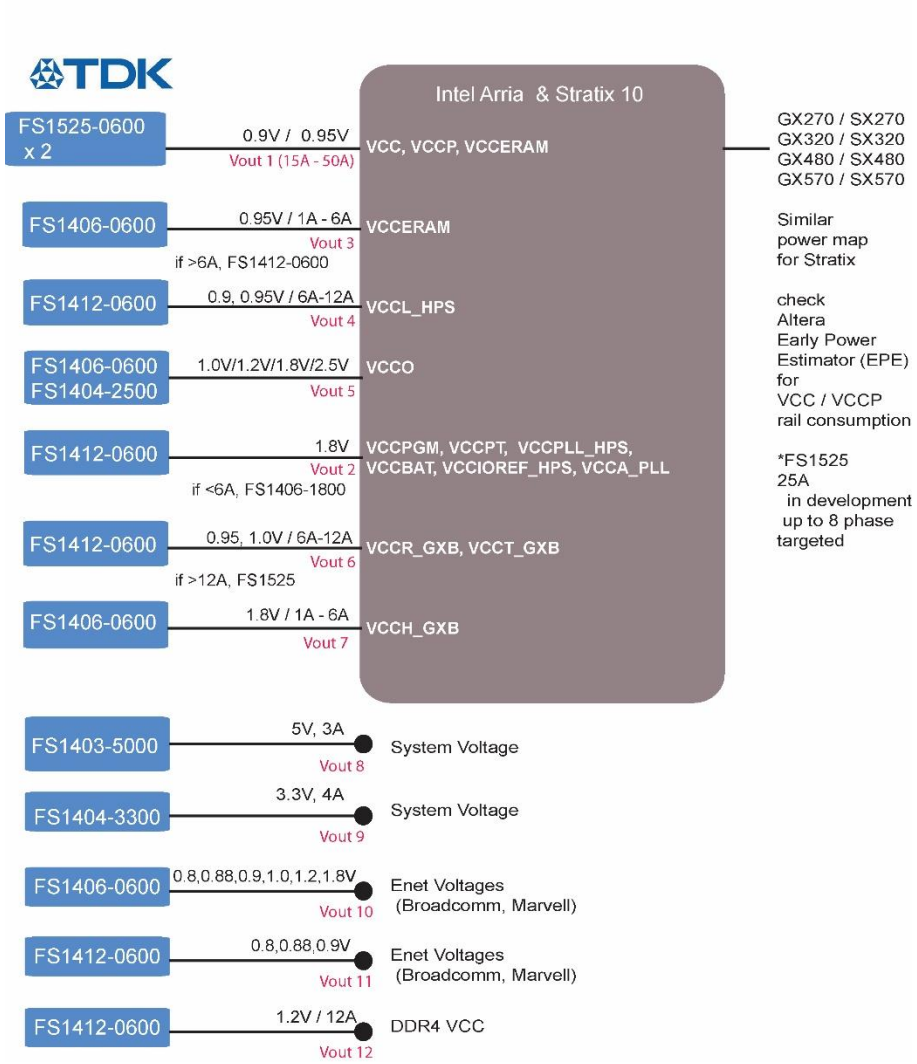

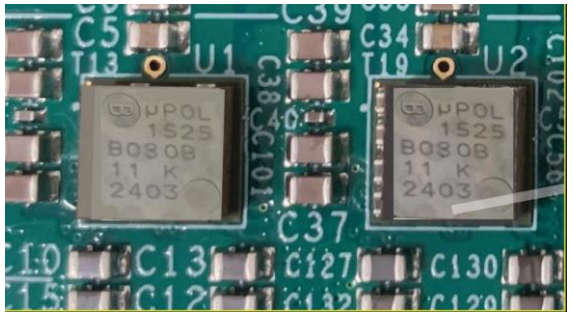

Shown 25A to 50A Vcore

FS1525 scalable for Stratix and Arria 10 from 25A to 200A

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TDK µPOL: Altera Cyclone

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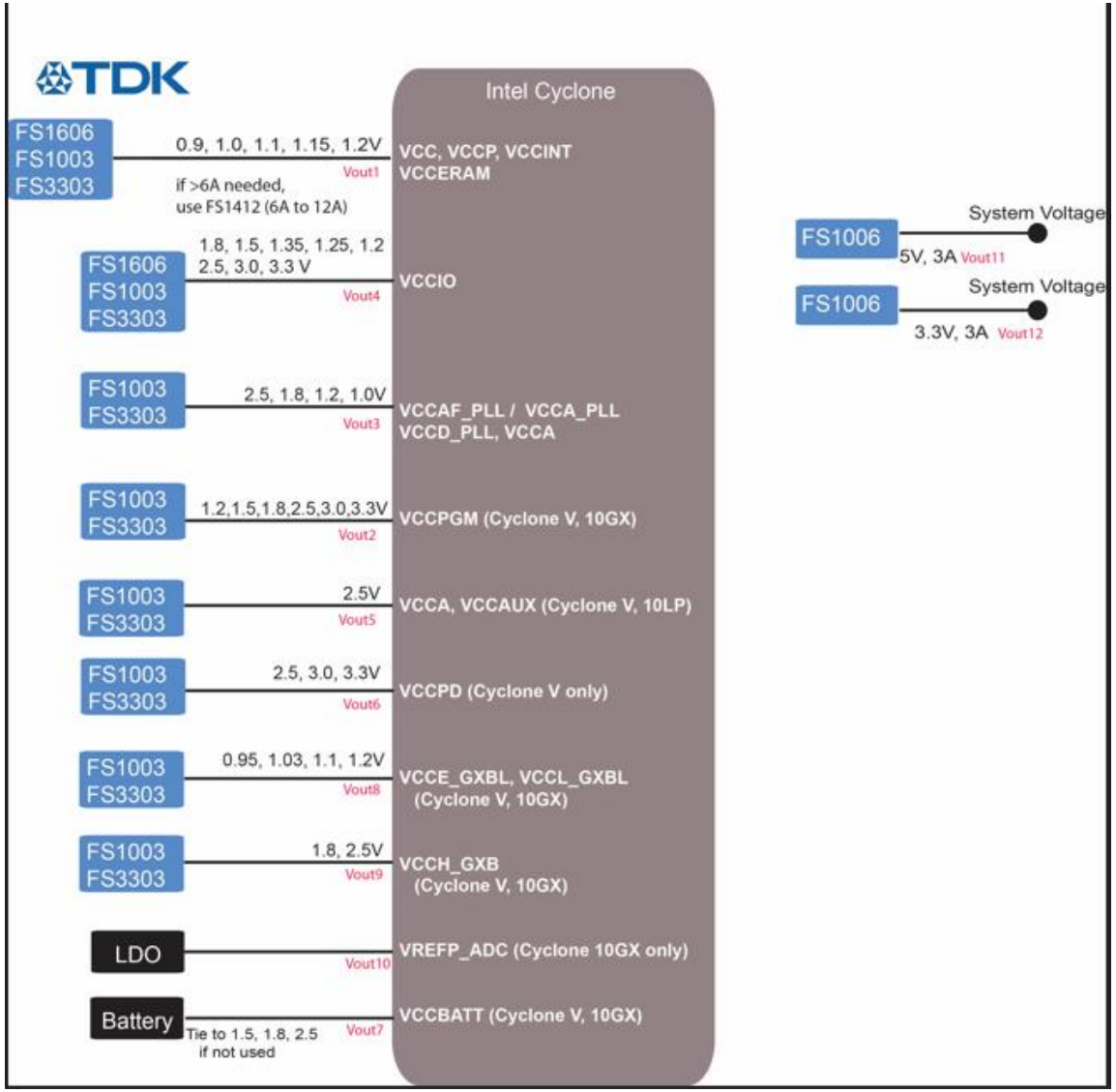

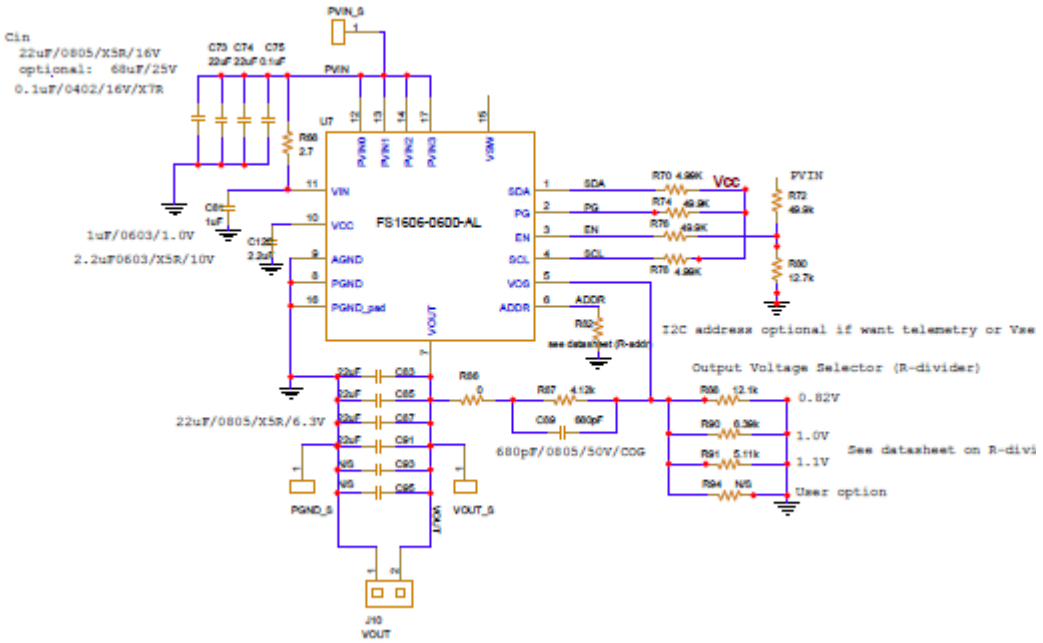

Designs Available for 12Vin and 5Vin

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TDK μPOL: Altera Cyclone

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		cyclone V	cyclone 10 LP	cyclone 10 GX
1	VCC, VCCINT, VCCP, VCCERAM	1.1, 1.15	1.0, 1.2	0.9
2	VCCPGM	1.8, 2.5, 3.0, 3.3	N/A	1.2, 1.5, 1.8
3	VCCAF_PLL, VCCA_PLL, VCCD_PLL	2.5	1.2, 1.0	1.8
4	VCCIO *	3.3, 3.0	3.3, 3.0	3.0, 2.5
		2.5, 1.8, 1.5, 1.35, 1.25, 1.2	2.5, 1.8, 1.5, 1.35, 1.25, 1.2	1.8, 1.5, 1.35, 1.25, 1.2
5	VCCA, VCCAUX	2.5	2.5	N/A
6	VCCPD	2.5, 3.0, 3.3	N/A	N/A
7	VCCBATT	BATT or 2.5V (not used)	N/A	Batt: 1.8, 1.2; connect to 1.5/1.8 if not used
10	VREFP_ADC	N/A	N/A	1.25 LDO
8	VCCE_GXBL, VCCL_GXBL	1.1, 1.2	N/A	1.03, 0.95
9	VCCH_GXBL	2.5	N/A	1.8

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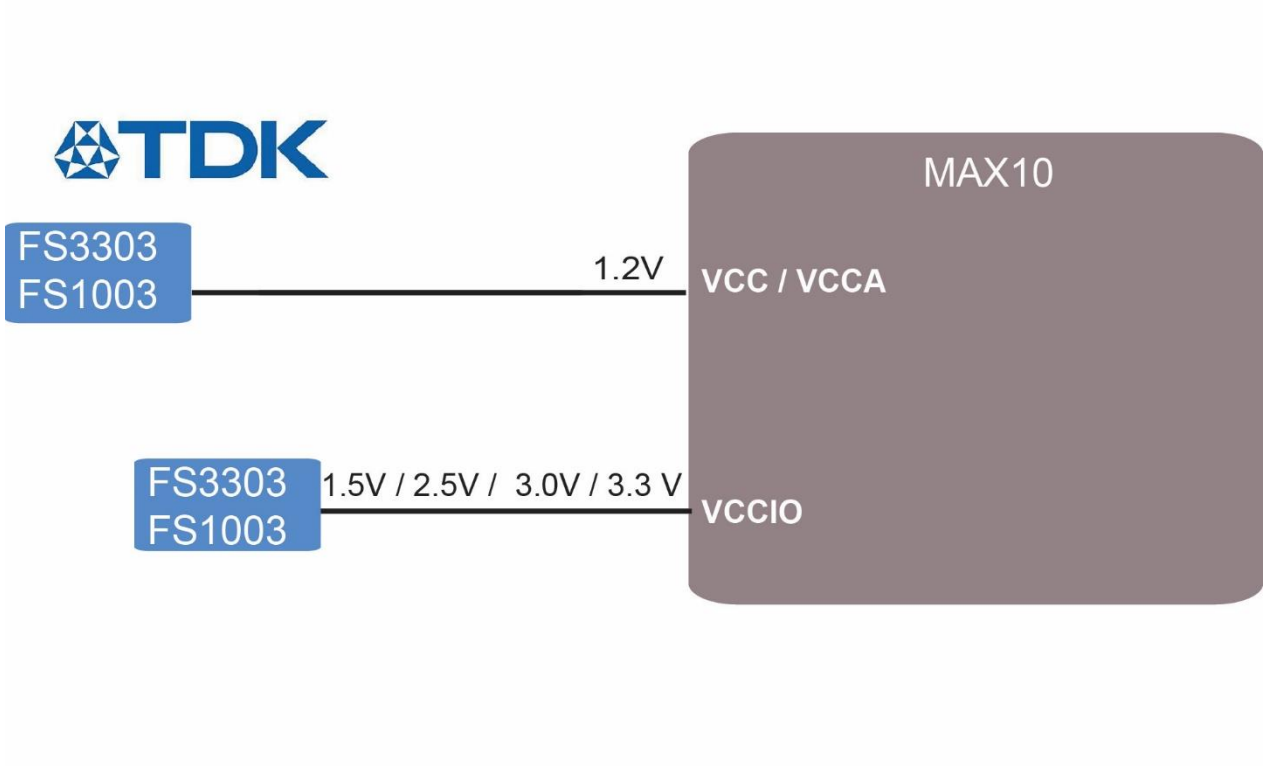
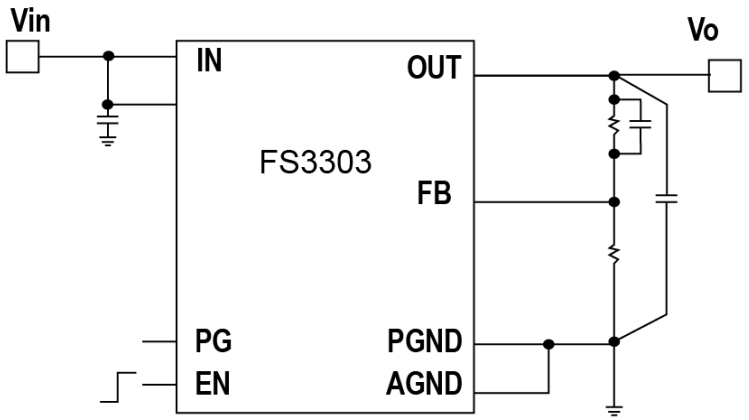
TDK μPOL: MAX10





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TDK μPOL:
FPGA/SoC power libraries on QSPICE and Simplis

FPGA / SoC Power Design Library (Coming Soon)

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(click manufacturer for details)

- Xilinx
- Broadcom
- NXP
- Intel - FPGA
- Intel
- Microchip
- Marvell

Power Tree / Map	Schematic/ BoM	Reference Design (DSN)	Power Design Guideline	QSPICE Models	Simplis Models
PDF	PDF	DSN (Cadence) schematic file in DSN format	PDF (Design Summary)	Zip File (FPGA power table with PDN power models by rail)	Zip File (FPGA power table with PDN power models by rail)

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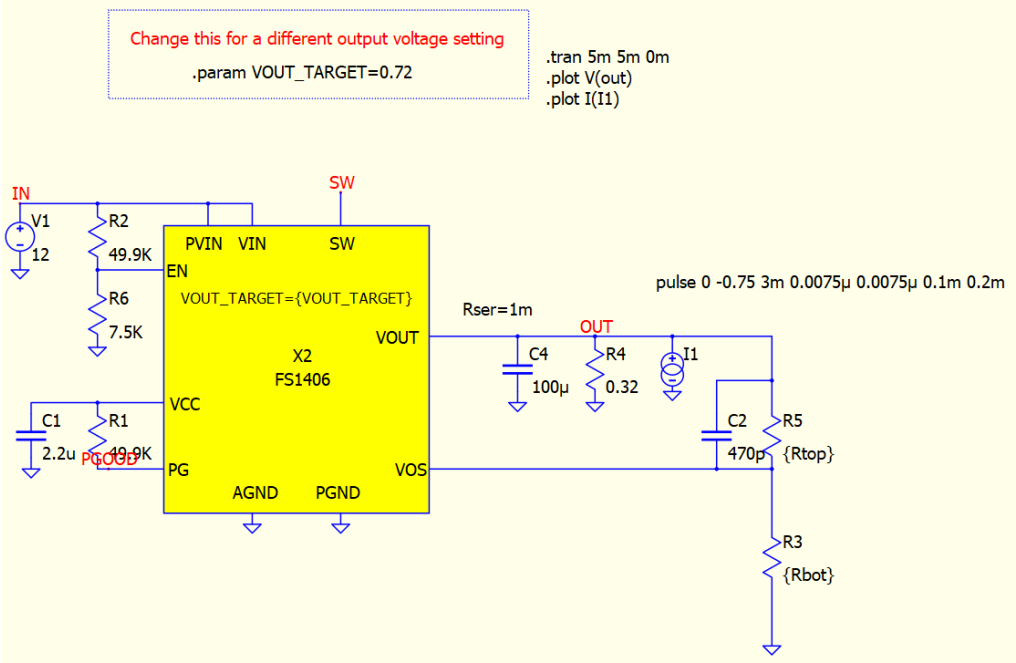
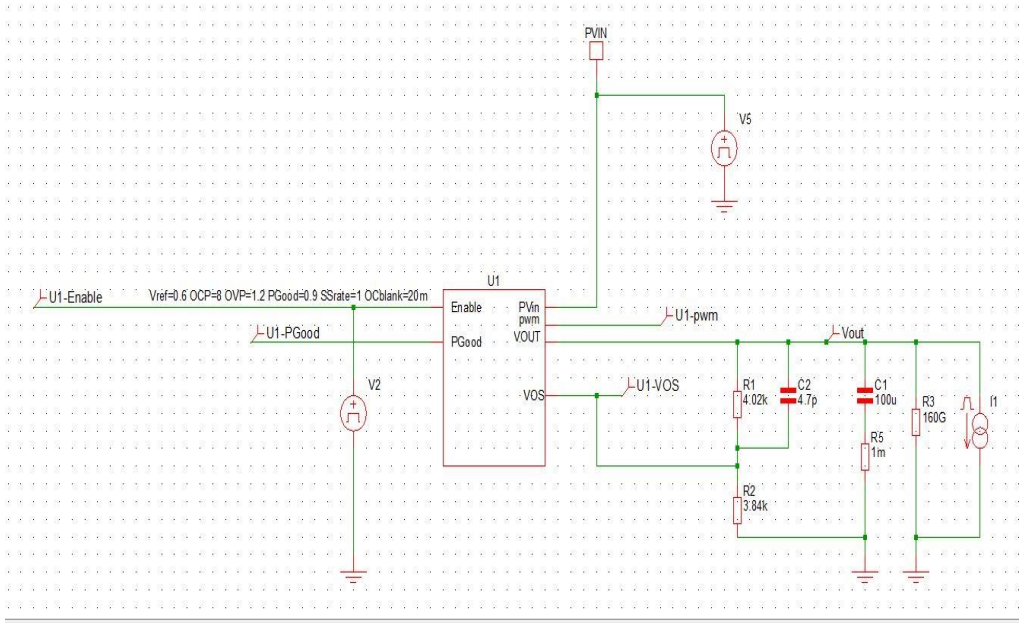
QSPICE



- New free circuit simulation software
- Runs much faster than LTSpice
- New models constantly being uploaded

SIMPLIS



- Powerful simulation software.
- Runs much faster than LTSpice
- Helps to analyze effect of parasitics

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Available TDK μPOL Power Design Libraries: QSPICE and Simplis (as of August 2024)

www.us.tdk.com/POL

QSPICE Libraries

- 10 – 40W Power Strip DCDC Board QSPICE FS160x Rev. 1
- Kintex Ultrascaleplus sim table Rev 1 QSpice
- Avant-E Sims Table Rev 1 QSPICE
- Versal Edge SIM Library Dbase QSPICE 1
- Zynq US LoCost Zu1-Zu2-Zu3 sim table QSPICE
- Artix 7 sim table rev2.0 QSPICE
- Intel Arria 10 sim table rev0.2 QSPICE
- Agilex 7 SIM Library QSPICE
- Artix UltraScale sim table rev1.0 QSPICE
- Intel Agilex 5 - sim table rev0.2 QSPICE

Simplis Libraries

- Agilex 5 SIM Library SIMPLIS
- Agilex 7 SIM Library SIMPLIS
- Arria 10 SIM Library SIMPLIS
- Artix UltraScale sim table rev1.0 SIMPLIS
- Avant-E Sims Table SIMPLIS
- Kintex UltraScaleplus sim table SIMPLIS
- Spartan 7 sim table SIMPLIS
- Versal Edge SIM Library Dbase SIMPLIS
- Zynq US LoCost Zu1-Zu2-Zu3 sim table SIMPLIS
- Zynq US+ Zu02-Zu04 sim table SIMPLIS
- Zynq Zu5-Zu19 sim table SIMPLIS

Availability:

Qspice:
- FS140x
- FS160x

Simplis
- FS140x
- FS1412
- FS1525 (single phase)

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Locations of Design collateral support

Other Design Collaterals

SCAN

www.us.tdk.com/POL

Package Design Guidelines

Tony Ochoa (Tony.Ochoa@tdk.com) is signed in

Symbols Schematic Layout 3D

Package Reel Info POL

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