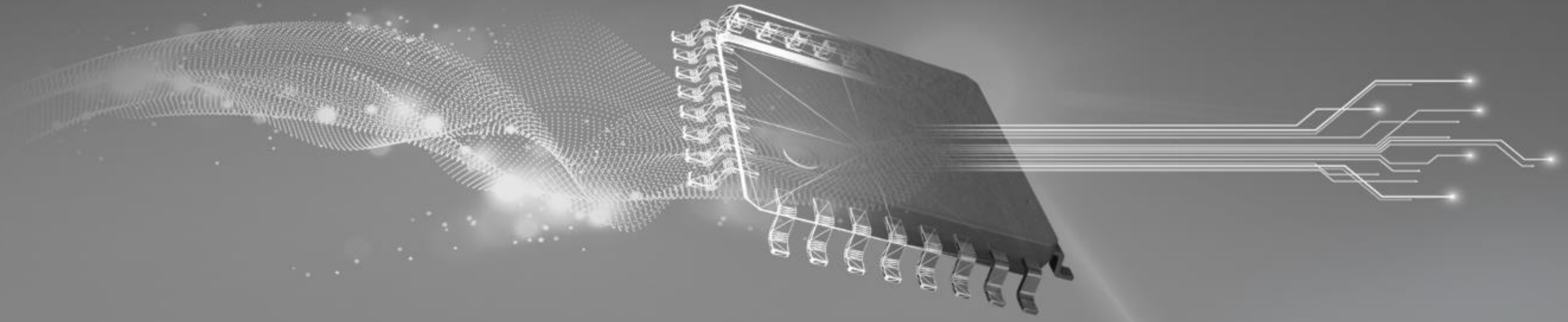
TI TECH DAYS



Low V_{IN} Buck Converters for SOC Power

Arthi Krishnamurthy & Tanvee Pandya

Low Voltage Buck Switching Regulators (BSR-LV)

Texas Instruments

Agenda

- Low voltage buck converters for SOC power — Arthi
  - Key products: **TPS62810-Q1 and TPS628501-Q1**

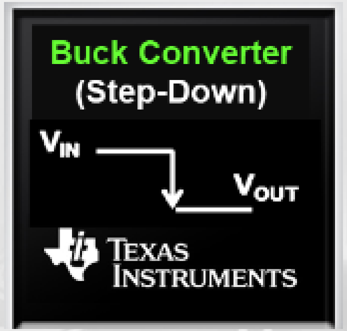
- Case study: Radar discrete power proposal — Tanvee

- Q & A

Low voltage buck converters for SOC power

Core voltage and Point-of-Load with V_{IN} <7V

- High efficiency
- Small solution size
- Easy & flexible



Processor

FPGA

SoC

Memory

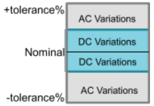
Presented by:

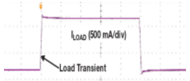
Arthi Krishnamurthy

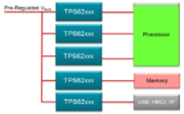
Product Marketing Engineer
Texas Instruments

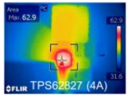
DC-DC buck converters for SOC power

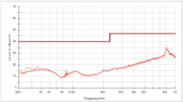
Trends & solutions

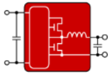












• Tight Accuracy	*1% over full Temperature Range, fixed V_{OUT}*
• Fast Transient Response	*DCS-Control Topology*
• High Output Current	*up to 6A single-phase, pin-2-pin scalable families*
• Dynamic Voltage Scaling	*I^2C Interface, V_{SELECT} Function*
• Multiple Supply Rails	*Pin-compatible families, PowerGood, Sequencing/Tracking*
• Thermal Performance	*High Efficiency, Power Save Mode, Power Packages*
• Small Solution Size	*Small packages, small & few external components, easy layout*
• Quiet Supply	*Fixed Frequency/Sync, Forced-PWM, Spread Spectrum to reduce EMI*
• Time-to-market	*Ease-to-use Modules w/ integrated Inductor*

Discrete (buck) Vs integrated (PMIC): Trade-offs

System design characteristic	System value proposition	Discrete DC/DC	Integrated PMIC
Design Flexibility	Scale power solution when core rail current changes	Easily scalable, pin2pin options for different output currents	Limited flexibility with multi-phase solution
Thermal Distribution	Managing heat & power dissipation on the PCB	Can be spread out across the discrete power tree (multiple ICs)	Concentrated in one IC
Solution Cost	Optimizing for lowest BOM cost (including passives) across different SOC variants	Use only as many rails as you need	More compact, but may contain more rails than you need or use
Functional Safety & Diagnostics (system specific)	Improve electrical safety and reliability and reduce failures by supporting system level Functional Safety requirements	Typically FS Capable (FIT, FMD, pin FMA documentation support) Device-level: OV, UV, Current Limit, PowerGood protection	Typically FS Compliant - ASIL B/C/D certified
Time to market	Balancing the fastest design cycle time with maximum re-use	Fast solution using “off-the-shelf” catalog (AEC-Q100) components	Fast when a PMIC-SOC attach is readily available

Focus markets and applications

ADAS

Camera (front, rear, surround view), ECU, Radar, Lidar

Body

Body Control Module, Gateway, Occupancy Detection, door-obstacle, trunk opener

Telematics

Telematics Control Unit (TCU), eCall, V2X

Car Access

Key fob & base stations (RKE, PEPS)

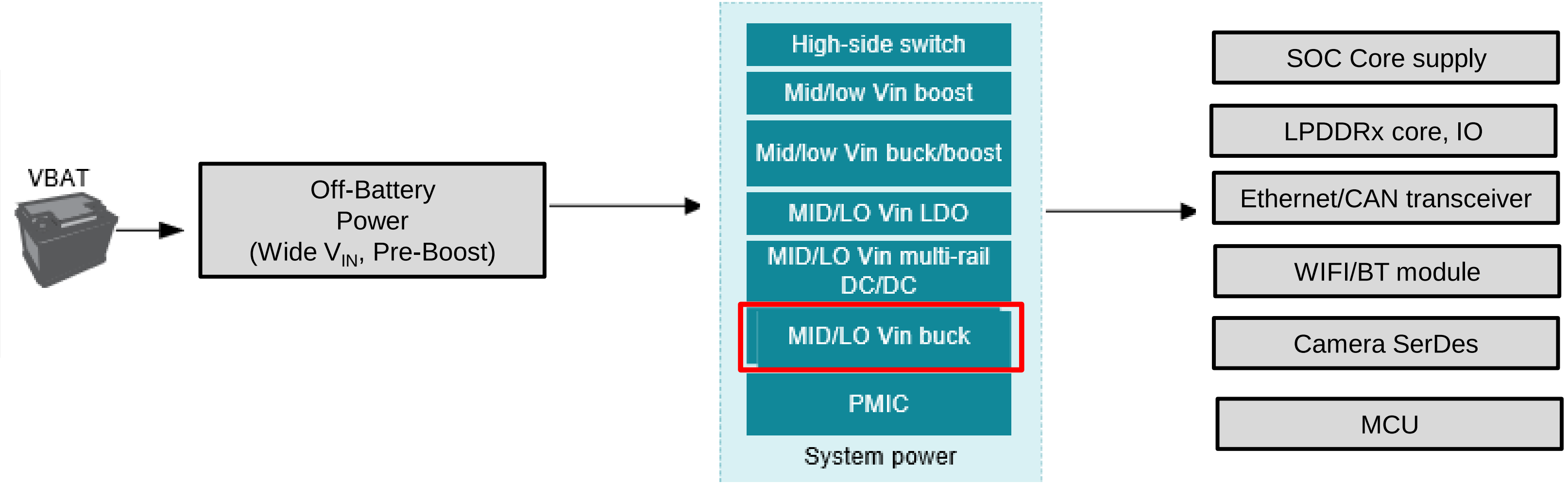
Infotainment

Head unit, digital cockpit, premium audio, external amplifier

Instrumentation

Cluster, navigation module, HUD

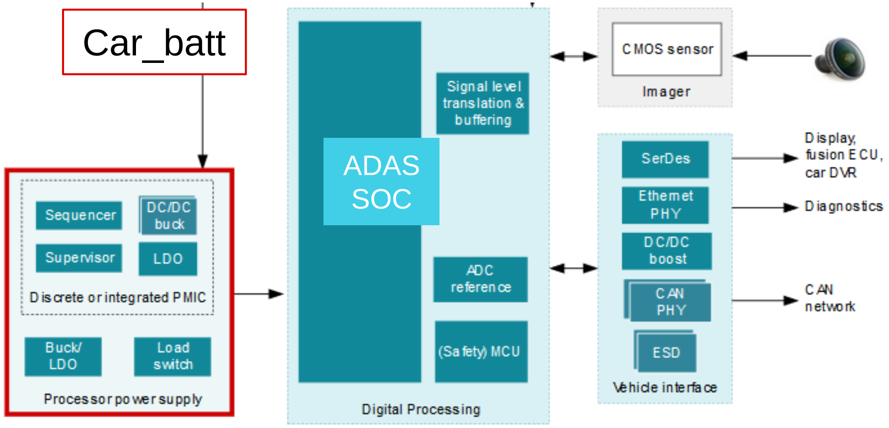
1) Infotainment SOC in head-unit, dig cockpit, premium audio block diagrams



Design challenges	Recommended DC-DC Bucks
- Variable output current - High fsw - Low EMI - Space & cost optimized	Low voltage DC-DC Converters: - TPS62810-Q1, 1-2-3-4 A in 2x3 mm QFN w/ Wettable-flanks (WF) - TPS628501-Q1, 1-2 A in smallest SOT583 – NEW - TPS54618C-Q1, 6 A in 3x3 mm QFN

2) ADAS SOC in front-camera block diagram

Discrete power: low-medium currents
- SoC aux rails
- Memory rails
- System aux rails:
  - SerDes
  - Ethernet, CAN, PHY, …
  - CMOS sensor

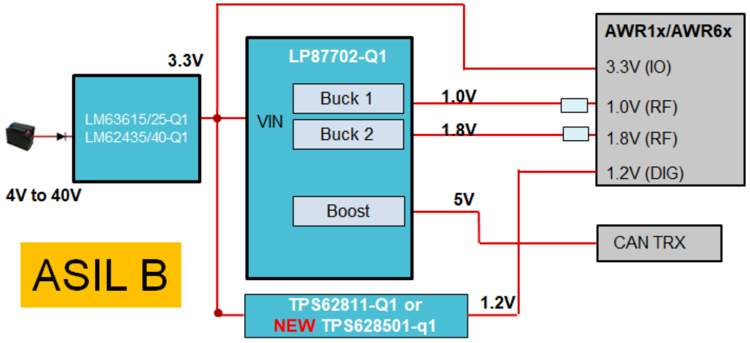


Design challenges	Recommended bucks for SoC and AUX rails
- Smallest sol-size - Good thermals - Functional Safety requirements - Competitive pricing	High-current DCDC: - DCDC controllers (eg. TPS59632-q1 + TPS59603-q1) - Multiphase converters (eg LP8756x-Q1) Low-current DCDC converters: - TPS54618C-Q1, 6 A in 3x3 mm QFN - TPS62810-Q1, 1-2-3-4 A in 2x3 mm QFN w/ Wettable-flanks (WF) - TPS628501-Q1, 1-2 A in smallest SOT583 – NEW

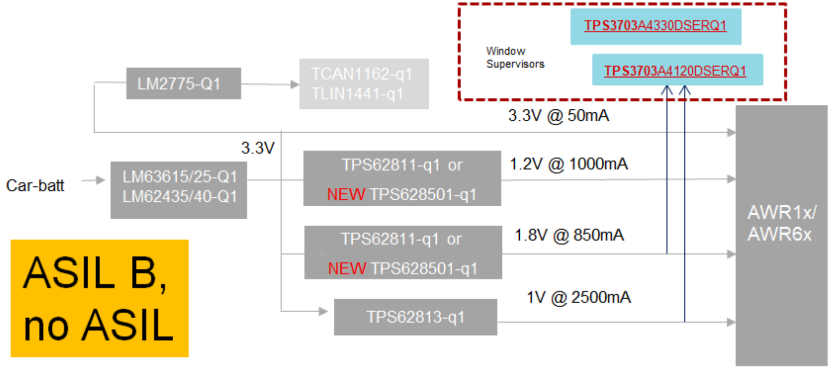
3) Radar SOC in ADAS and Body block diagrams

TI's AWR1642/1843/6843 Radar SOCs integrate DSP and MCU. Power solutions:

a) Semi-integrated supply:



b) Discrete supply:



(*) This power tree will be covered in the case study later

Design challenges	Recommended bucks
- High Fsw - Smallest sol-size - Competitive pricing - Functional Safety capable	- TPS62811-Q1, 1-2-3-4 A in 2x3mm QFN w/ wettable-flanks - TPS628501-Q1, 1-2 A in smallest SOT583 (1.6x2.1mm) – NEW Features include: optional Spread-Spectrum, 1% accuracy, 150 C Tj operating, up to 4MHz for easier noise filtering and 'functional-safety' capable documentation.

TPS62810/11/12/13-Q1

1/2/3/4 A Fixed frequency step-down converter

NEW

FEATURES

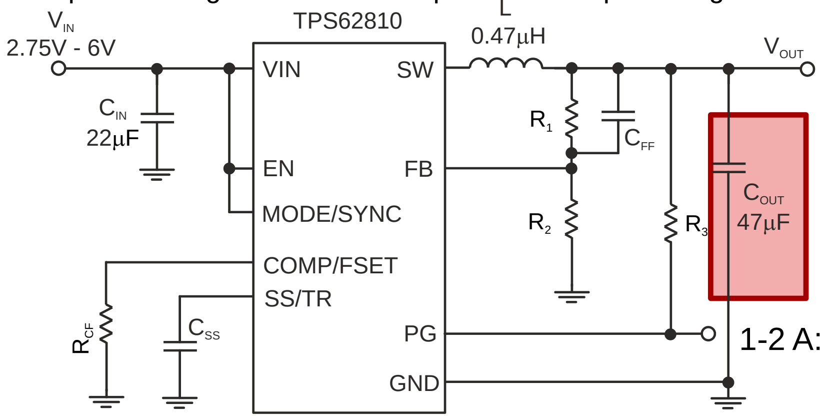
- 2.75 V to 6 V input voltage range
- **1 A/ 2 A/ 3 A / 4 A output current, all p2p**
- Adjustable output voltage from 0.6V to V_{IN}
- 10 uA Quiescent current
- Functional Safety CAPABLE **(#1)**
- 1% output voltage accuracy
- **- 40 ºC to 150 ºC junction temp range, grade 1 (#2)**
- Forced PWM or PWM/PFM operation using MODE
- Open drain power good output
- Adjustable switching frequency with R_{CF} resistor
- **Fixed frequency operation**, per default at 2.25 MHz
- External synchronization (1.8 MHz – 4 MHz) at MODE pin
- Spread spectrum clocking: optional **(#3)**
- QFN (HotRod) package with wettable flanks: 3x2 mm **(#4)**

APPLICATIONS

- Infotainment: Head Unit, Telematics Control Unit, Cluster
- Body Electronics: Body Control Module, Gateway
- ADAS: Camera System ECU, Sensor Fusion

BENEFITS

- **Small solution size with minimal external components for lowest total solution cost**
- Short min on-time of 50ns allows **direct conversion of 5 V to 0.6 V at f = 2 MHz**
- **Allows wide range of output capacitance** to meet requirements for input of FPGAs or MCUs
- Low EMI by spread spectrum clocking
- Output discharge for defined ramp-down of output voltage



1-2 A: 22uF

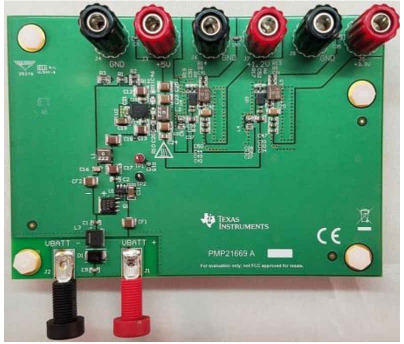
TPS6281x-Q1 family spins

Versatile family: Multiple fixed output voltage options with SSC on or off

Device	Iout	Adj Vout	Fixed Vout	SSC	Vout Discharge	Fold-back Ilim
TPS62811QWRWYRQ1	1 A	X		OFF	ON	OFF
TPS6281120QWRWYRQ1	1 A	X		ON	ON	OFF
TPS628110AQWRWYRQ1	1 A		1.2 V	OFF	ON	OFF
TPS628112AQWRWYRQ1	1 A		1.2 V	ON	ON	OFF
TPS628112MQWRWYRQ1	1 A		1.8 V	ON	ON	OFF
TPS62812QWRWYRQ1	2 A	X		OFF	ON	OFF
TPS6281220QWRWYRQ1	2 A	X		ON	ON	OFF
TPS6281208QWRWYRQ1	2 A		1.1 V	OFF	ON	OFF
TPS6281206QWRWYRQ1	2 A		1.0 V	OFF	ON	OFF
TPS628120MQWRWYRQ1	2 A		1.8 V	OFF	ON	OFF
TPS62813QWRWYRQ1	3 A	X		OFF	ON	OFF
TPS6281320QWRWYRQ1	3 A	X		ON	ON	OFF
TPS62810QWRWYRQ1	4 A	X		OFF	ON	OFF
TPS6281020QWRWYRQ1	4 A	X		ON	ON	OFF
TPS6281008QWRWYRQ1	4 A		1.1 V	OFF	ON	OFF

Automotive Reference designs with TPS62810-Q1

Instrumentation Cluster



Application Needs
- EMI meets CISPR25 class 5
- Reverse polarity protection
- Three output voltages: 5 V, 3.3 V, 1.2 V

Reference Design
- **TPS62810-Q1**

PMP21669

Cluster and display power

Application Needs
- Tree passing CISPR 25
- All switching DCDC above 2 MHz
- High light-load efficiency
- Less than 25°C temperature rise under full load current conditions

Reference Design
- **TPS62810-Q1**

PMP22063

Digital Cockpit design

Application Needs
- low-loss smart diode controller
- input filter to minimize ripple
- High efficiency across all rails
- Very good load transient

Reference Design
- **TPS62810-Q1**

PMP30670

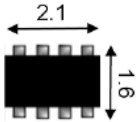
TPS628501/2-Q1

$6V_{IN}$, 1 A/2 A buck converter in leaded SOT583

Preview NOW
Release Nov '20

FEATURES

- 2.7 V to 6 V input voltage range
- **2 A / 1 A output current**
- **Fixed output voltage options**
- 15 uA Quiescent current
- Functional Safety CAPABLE **(#1)**
- 1% output voltage accuracy
- **- 40 °C to 150 °C junction temperature range (#2)**
- Forced PWM or PWM/PFM operation using MODE
- Open drain power good output
- Adjustable switching frequency with R_{CF} resistor
- **Fixed frequency operation**, per default at 2.25 MHz
- External synchronization (1.8 MHz – 4 MHz) at MODE pin
- Spread spectrum clocking: optional **(#3)**
- **SOT 583 package: 2.1 mm x 1.6 mm, 0.5 mm pitch (#5)**

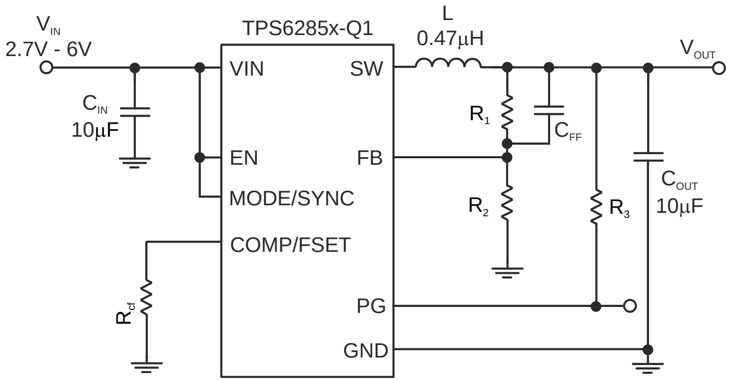


APPLICATIONS

- ADAS: Camera System ECU, Sensor Fusion
- Infotainment: Head Unit, Telematics Control Unit, Cluster
- Body Electronics: Body Control Module, Gateway

BENEFITS

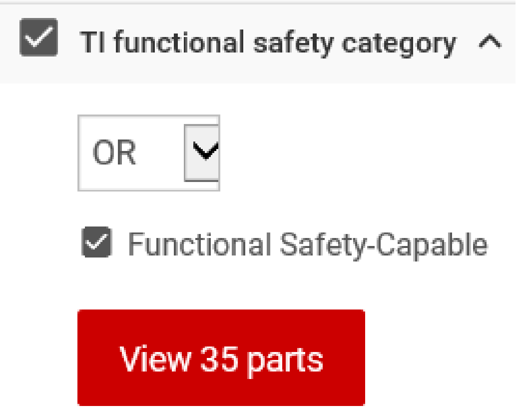
- **Small solution size with minimal external components for lowest total solution size and cost**
- Short min on-time of 50 ns allows **direct conversion of 5 V to 0.6 V at f = 2 MHz**
- **Allows wide range of output capacitance** to meet requirements for input of FPGAs or MCUs
- 1% accuracy allows larger headroom during transients



#1) Functional safety capable (FSC)

- Applicable to discrete DC-DCs, enabling customers to achieve system level ISO26262 ASIL requirements and streamline the certification process.
- FIT, FMD and pin-FMEA Analysis Report available for TPS62810-Q1 and TPS628501-Q1.

Note: NEW on ti.com: FS-capable search



#2) AEC-Q100 qualification

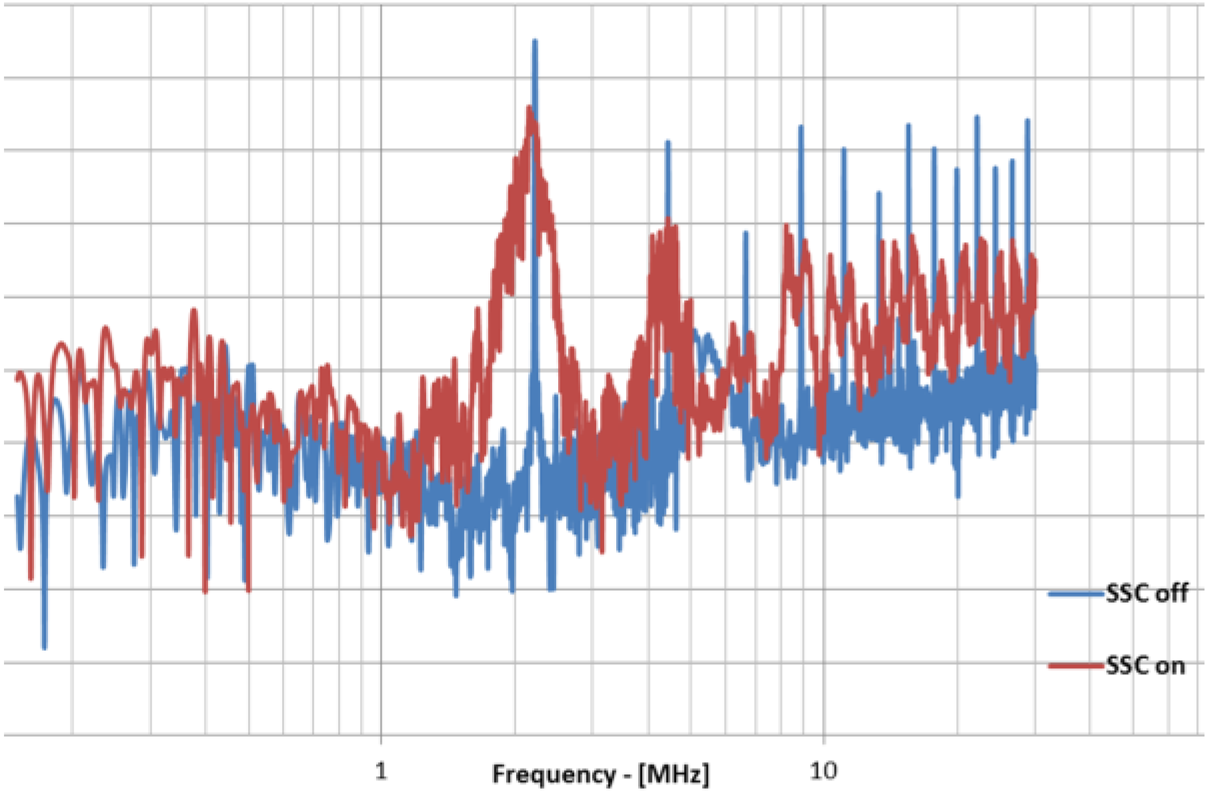
1.3.3 Definition of Part Operating Temperature Grade

The part operating temperature grades are defined below:

Grade 0: -40°C to +150°C ambient operating temperature range
Grade 1: -40°C to +125°C ambient operating temperature range
Grade 2: -40°C to +105°C ambient operating temperature range
Grade 3: -40°C to +85°C ambient operating temperature range
Grade 4: 0°C to +70°C ambient operating temperature range

- TPS62810-Q1 & TPS628501-Q1: Support Grade-1, 125 C Tambient -> up to 150 C Tjunction in operation.
- Qualification Report available upon request (TI NDA).

#3) Spread spectrum clock (SSC)



- Spread-Spectrum to improve EMI performance & pass CISPR 25 L5 system-level certification.
- We have a ref-design with measurements: PMP21669.

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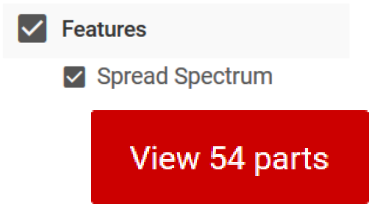
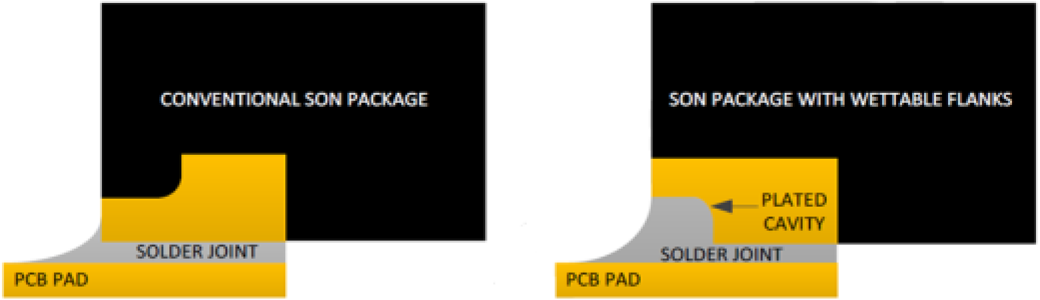
Note: also on ti.com, new search for SSC:



#4) Packages with wettable flanks (WF)

- Wettable flanks guarantee visible side-wetting at good solder joints.
- Enables 100% automotive visual inspection assembly processes.
- Dual plated punched process with notch on underside of the package.

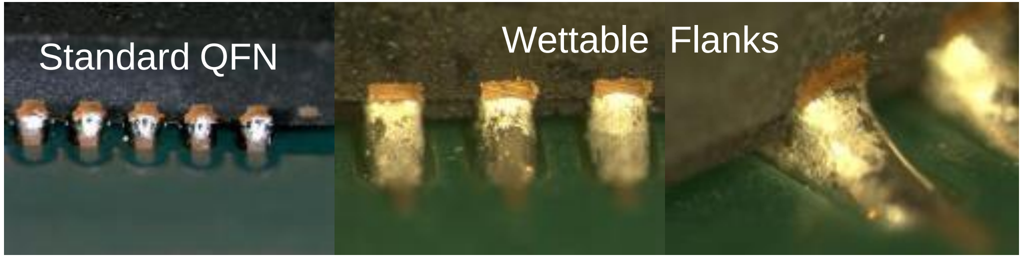


Note: also on ti.com, new search for WF:

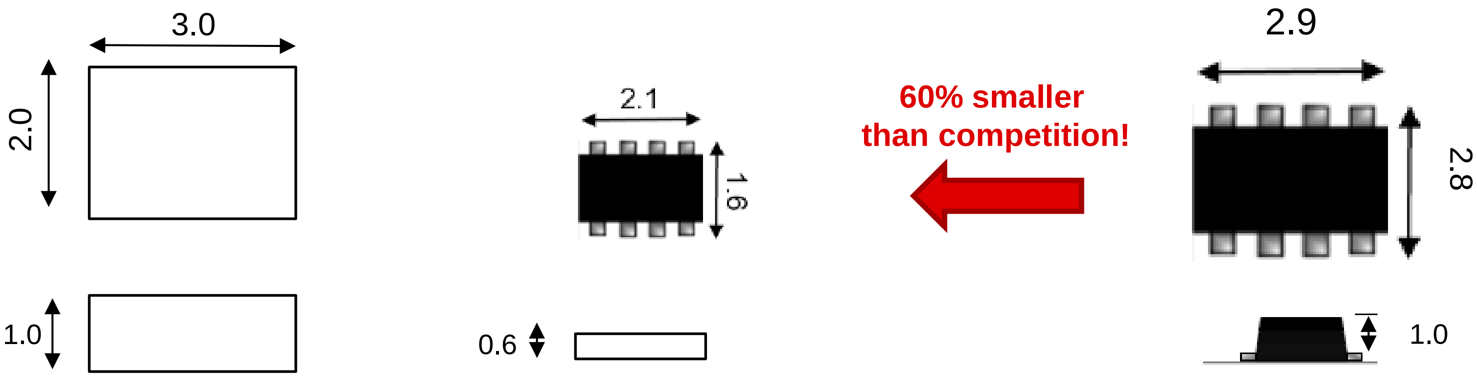
Features

Wettable Flanks Package

View 63 parts



#5) Smallest solution size for 1-2 A



3x2 QFN w/ wettable flanks	SOT583	SOT23-8
Package size: **6 mm2**	Package size: **3.36 mm2**	Package size: **8.12 mm2**
Solution size 1-2 A: **80 mm2**	Solution size 1-2 A: **31 mm2**	PN: *competition*
PN: TPS62810/1/2/3-Q1	PN: TPS628501/2-Q1	1-2 A
1-2-3-4 A	1-2 A	

Summary

Automotive SOC discrete power

- We reviewed key design trends & challenges for SOC power supplies in ADAS & Infotainment applications.

- We discussed trade-offs between discrete & integrated solutions.

- We demonstrated how TPS62810-Q1 and TPS628501-Q1 offer pin2pin scalable, high performance solutions to lower cost & simplify your power design for faster time to market.

- Next, we will present our discrete proposal for Radar SOC power….

Case study: Radar SOC discrete power supply

Presented by:
Tanvee Pandya

Applications Engineer
Texas Instruments

AWR18x Radar SOC power supply requirements

- AWR1843 Radar SOC requires **four low voltage power** rails:
  - 3.3 V (IO), 1.2 V (digital), 1.8 V (RF), 1.0 V* (RF)
- Critical parameters for the power rails are **load profile and output ripple.**
- There is no special sequencing spec.
- *1.0 V RF rail when the internal LDO is disabled (typical use case).

SUPPLY	DEVICE BLOCKS POWERED FROM THE SUPPLY
1.8 V	Synthesizer and APLL VCOs, crystal oscillator, IF Amplifier stages, ADC, LVDS
1.3 V (or 1 V in internal LDO bypass mode)(1)	Power Amplifier, Low Noise Amplifier, Mixers and LO Distribution
3.3 V (or 1.8 V for 1.8 V I/O mode)	Digital I/Os
1.2 V	Core Digital and SRAMs

AWR18x load profile

- **Load transient requirements** for rails:
  - 1.2 V (+10%, -5%)
  - 1.8 V (+/-5%)
  - 3.3 V (+/-5%)
  - 1.0 V (+/-5%)

AWR1843 load spec from datasheet

		MIN	NOM	MAX	UNIT
VDDIN	1.2 V digital power supply	1.14	1.2	1.32	V
VIN_SRAM	1.2 V power rail for internal SRAM	1.14	1.2	1.32	V
VNWA	1.2 V power rail for SRAM array back bias	1.14	1.2	1.32	V
VIOIN	I/O supply (3.3 V or 1.8 V): All CMOS I/Os would operate on this supply.	3.135	3.3	3.465	V
		1.71	1.8	1.89	
VIOIN_18	1.8 V supply for CMOS IO	1.71	1.8	1.9	V
VIN_18CLK	1.8 V supply for clock module	1.71	1.8	1.9	V
VIOIN_18DIFF	1.8 V supply for LVDS port	1.71	1.8	1.9	V
VIN_13RF1 VIN_13RF2	1.3 V Analog and RF supply. VIN_13RF1 and VIN_13RF2 could be shorted on the board	1.23	1.3	1.36	V
VIN_13RF1 (1-V Internal LDO bypass mode) VIN_13RF2 (1-V Internal LDO bypass mode)		0.95	1	1.05	V

AWR18x output ripple

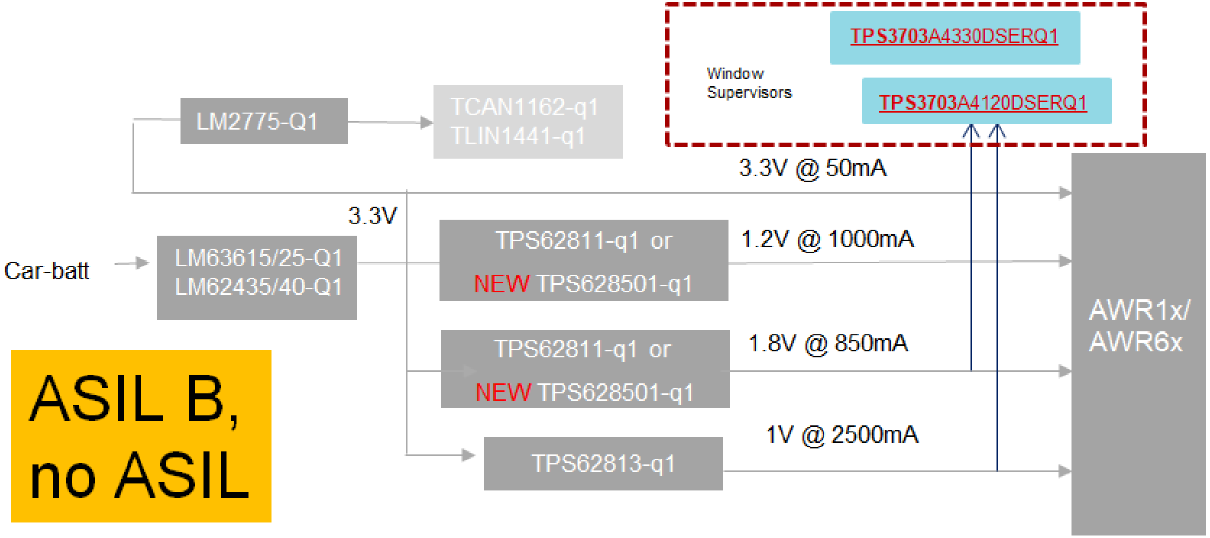
- AWR18x has a **tight spec** for output ripple on power rails.
- Noise on the output voltage rail of a buck regulator exhibits a **peak at its typical switching frequency** because of its inherent architecture. Power rails require noise reduction.
- The spec is suggested for RF rails but noise from the other rails can couple to RF rails. Optimize all power rails to avoid uncertain noise on RF rails.

FREQUENCY (kHz)	RF RAIL		VCO/IF RAIL
	1.0 V (INTERNAL LDO BYPASS) (μV_{RMS})	1.3 V (μV_{RMS})	1.8 V (μV_{RMS})
2200	11	82	13
4400	13	93	19

AWR18x discrete power supply proposal

Why discrete power?

- Optimize **cost**
- Improve **thermal** performance
- Increase **efficiency**

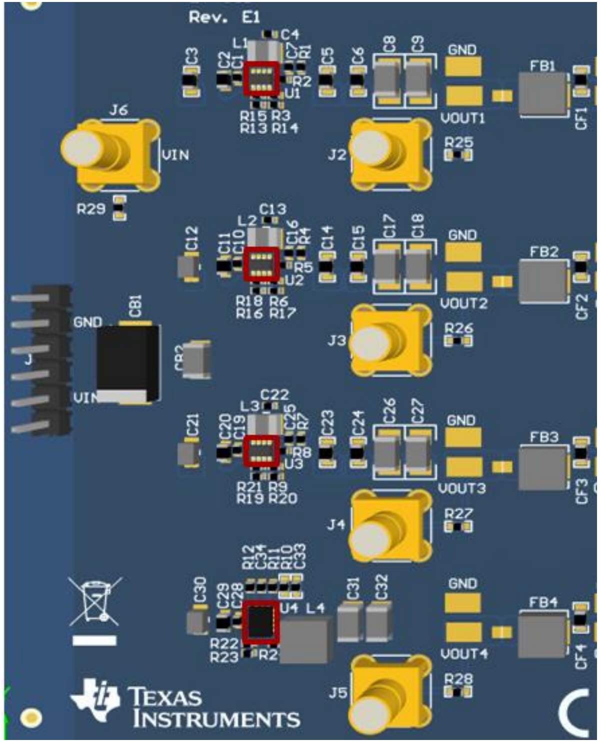


Discrete power proposal

Discrete power: evaluation board

- Power supply transient and noise requirements require an additional LC filter to optimize the performance of regulator.
- Good PCB layout needed to avoid additional noise coupling for RF sensitivity.

- Solution size with passive and LC converter: **6.7x7.3 mm^2.**

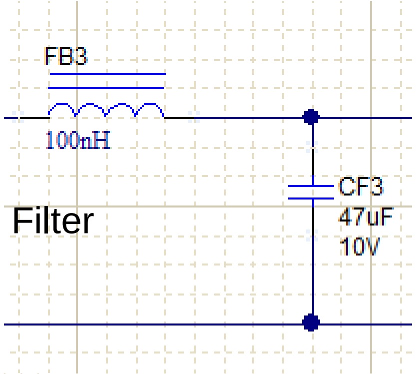


Evaluation Board

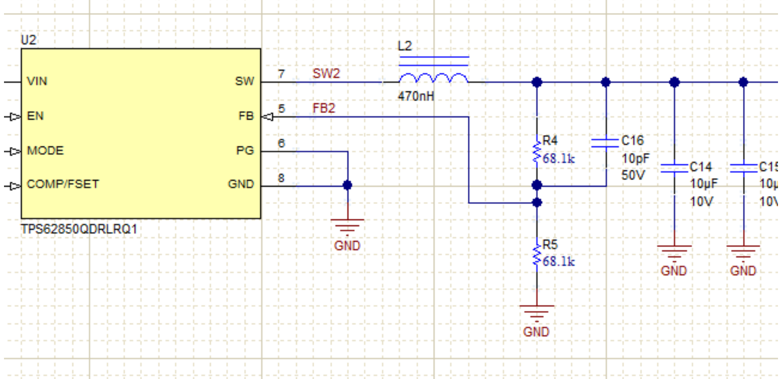
Discrete power: LC filter

- 100 nH **low impedance** ferrite bead inductor selected to balance output current & small BOM size.

- 47 uF capacitor selected to **suppress noise.**



LC- Filter

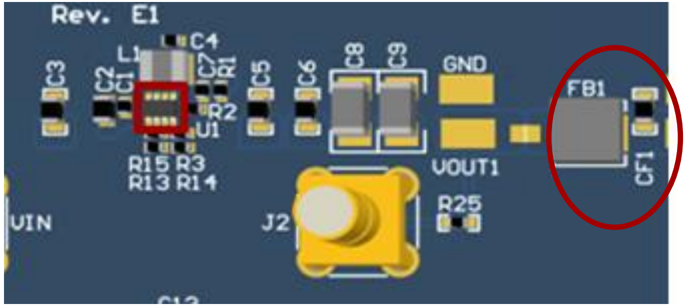


Regulator

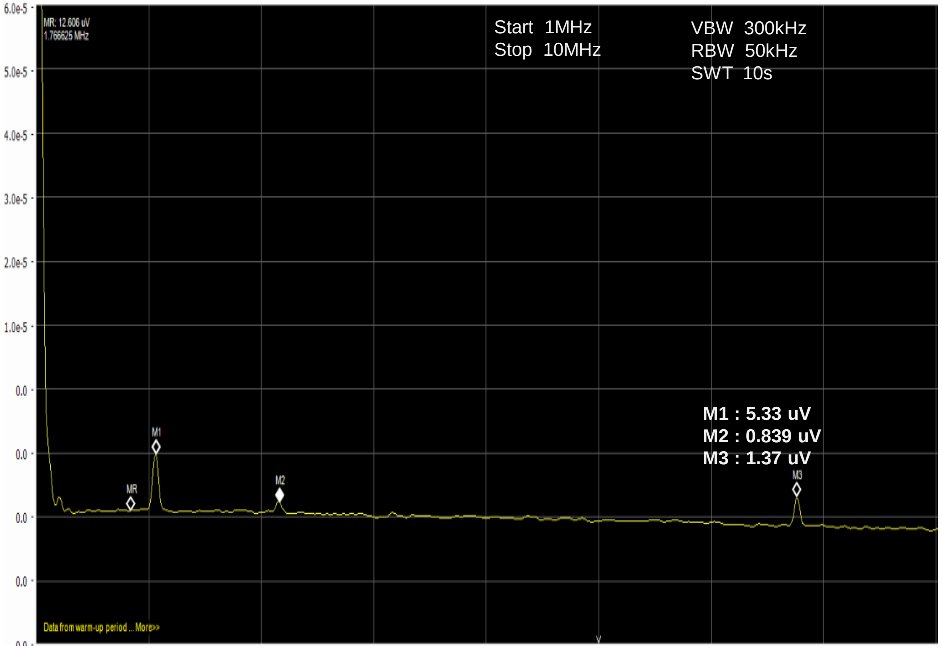
Discrete power: test setup

- Maximum load was applied externally to the output and ripple was measured on the decoupling caps of the LC filter with help of a Spectrum Analyzer.
- The recommended load profile (AWR User Guide) was used for load transient evaluation.
- The results show that Output Ripple is within the specification limits of AWR.

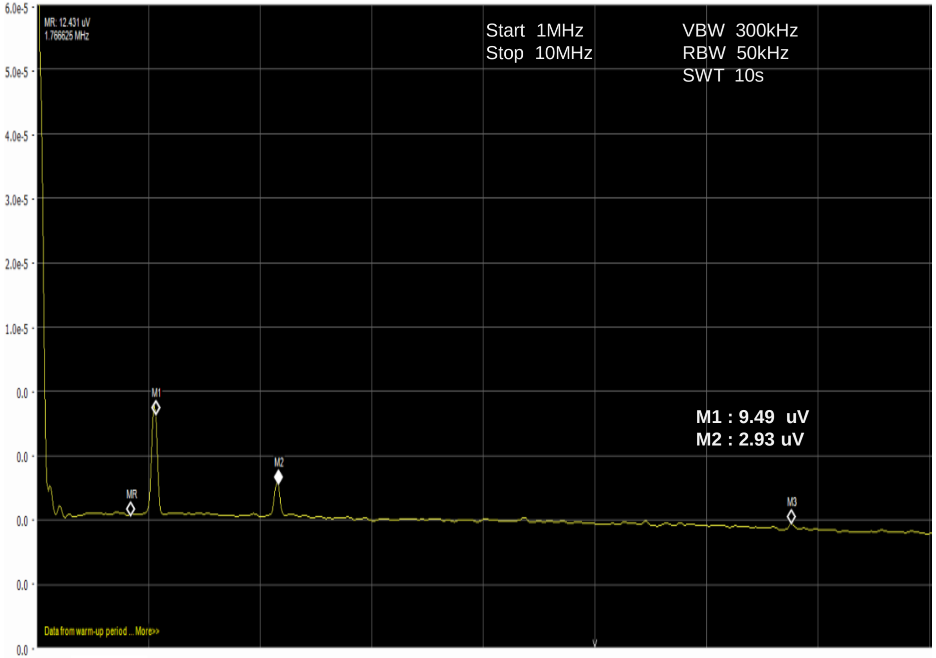
Ripple spec for RF rails (uVrms)			
Frequency	AWR1843 Ripple spec.	1.0V Rail	1.8V Rail
2.2 MHz	11.29	**9.49**	**5.33**
4 MHz	13.65	**7.93**	**2.65**



Output ripple measurements on RF rails @ 2.25 Mhz

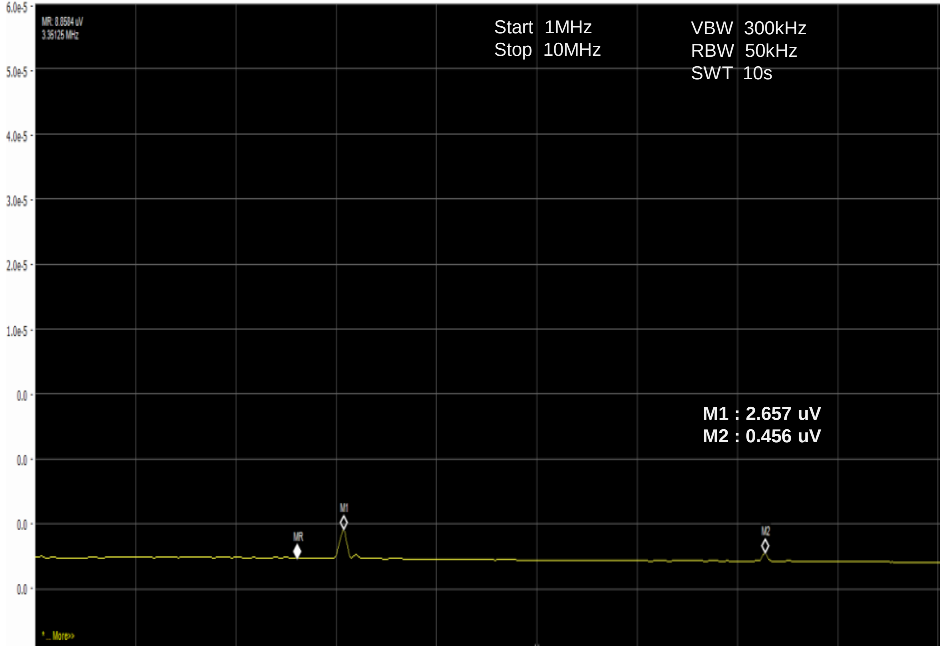


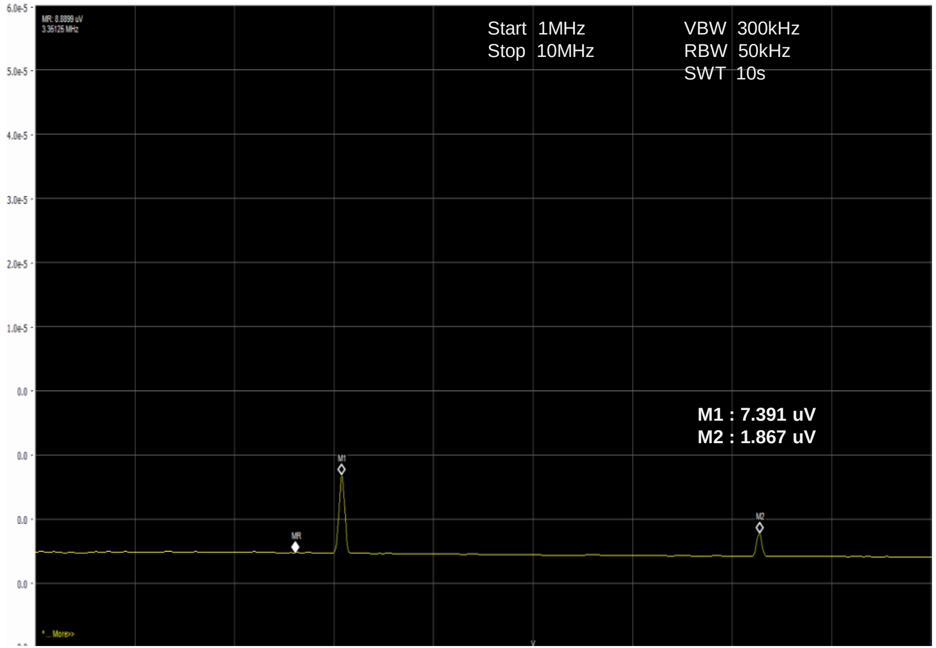
Test Conditions: 1.8 V @2.25MHz
TPS628502-Q1



Test Conditions: 1.0 V @2.25MHz
TPS62810-Q1

Output ripple measurements on RF rails @ 4 Mhz

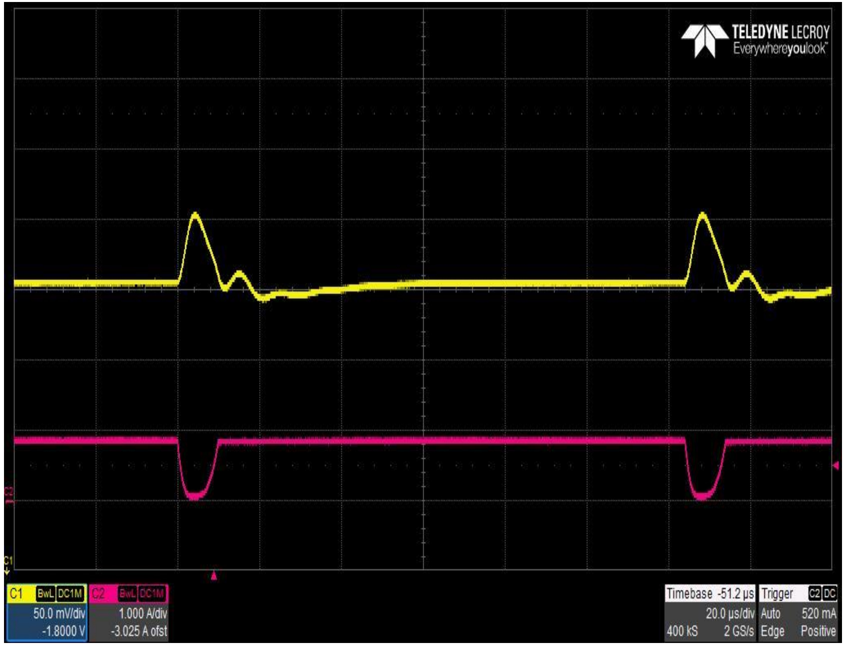




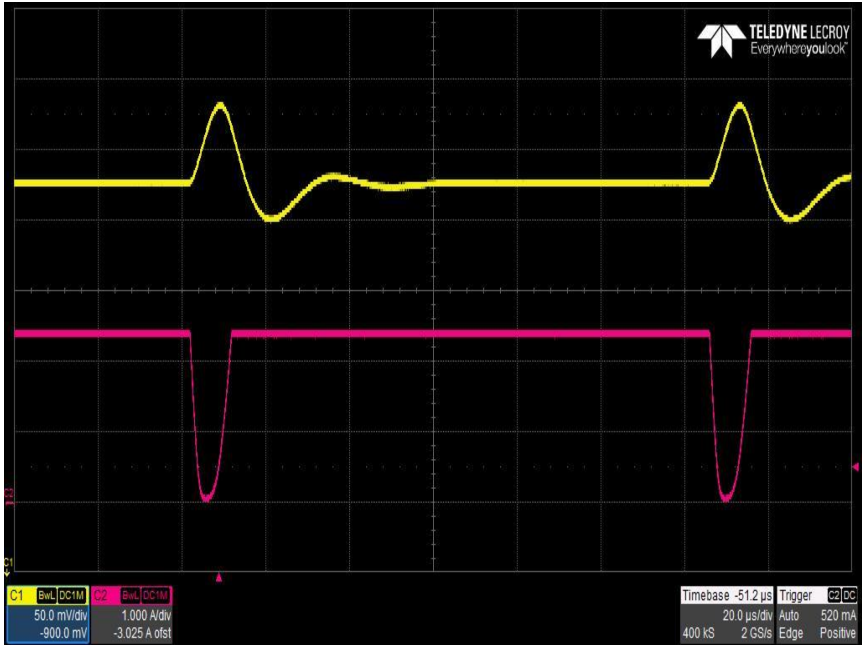
Test Conditions: 1.8 V @4MHz
TPS628502-Q1

Test Conditions: 1.0 V @4MHz
TPS62810-Q1

Transient measurements @ 1.8 V/1.0 V



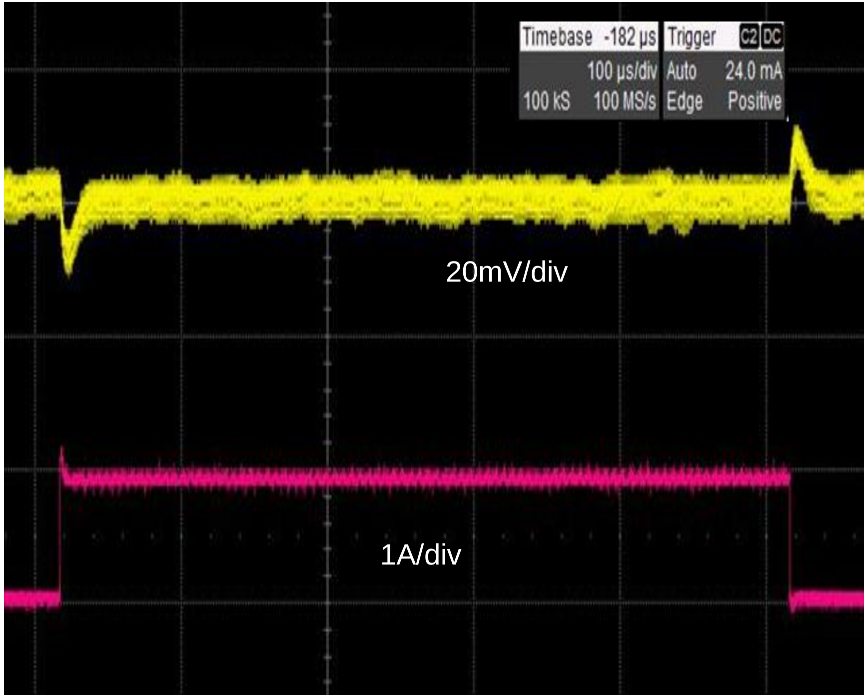
Test Conditions: 1.8 V @4MHz
TPS628502-Q1



Test Conditions: 1.0 V @4MHz
TPS62810-Q1

Transient measurements @ 1.2 V/3.3 V

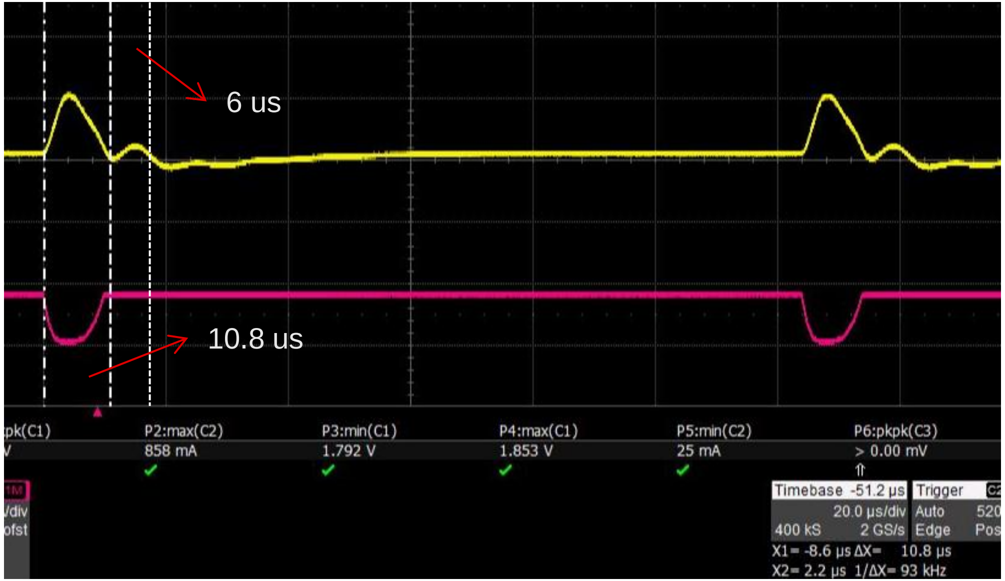
Test Conditions: 1.2 V @4MHz
TPS628502-Q1



Test Conditions: 3.3 V @4MHz
TPS628502-Q1

Time period @ 1.8 V

- Additional LC filter affects the settling time of the device.
- Ideal settling time after the load transient before the start of 1st chirp >11 us.



TPS628502-Q1 (1.8 V) + LC filter. Settling time before chirp is 10.8 us and requires 6 us to turn on ADC.

Summary

Case study: Radar AWR18x discrete power supply

- We demonstrated how the discrete power solution (TPS62810-Q1 and TPS628502-Q1) successfully meets the critical output ripple & load transient specification of AWR1843 Radar SOC.
- We shared best practices to optimize layout and filter design for best results.
- Further evaluation is ongoing, contact TI for more information.

Power resources at every stage of the design cycle

Easy part selection

- ti.com/power

Design and development

webench® POWER DESIGNER

- Power Stage Designer™ Tool
- Reference designs

Training

- Power Supply Design Seminars (PSDS)
- Battery Management Deep Dive
- High Volt Interactive
- Local Tech Days

Power fundamentals

- Power Topologies Handbook
- training.ti.com
  - Power tips video series
  - Power topology video series
- Short technical articles at ti.com/powerhouse
- “Fundamentals of power supply design”

Online support

- e2e.ti.com
- Power management forum for expert answers to technical questions

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