Выбор понижающих DC/DC преобразователей в зависимости от особенностей архитектуры и применения

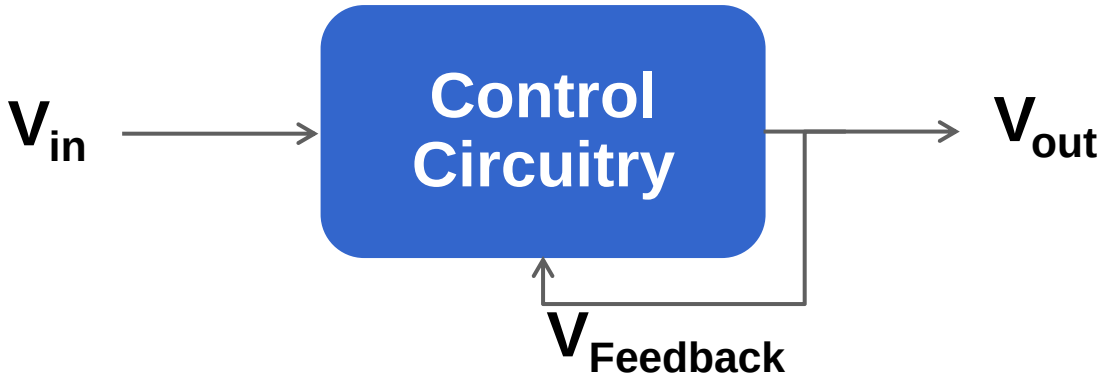
Ralf Regenhold

Dmitri Yablokov

Методы стабилизации (особенности петли ОС)

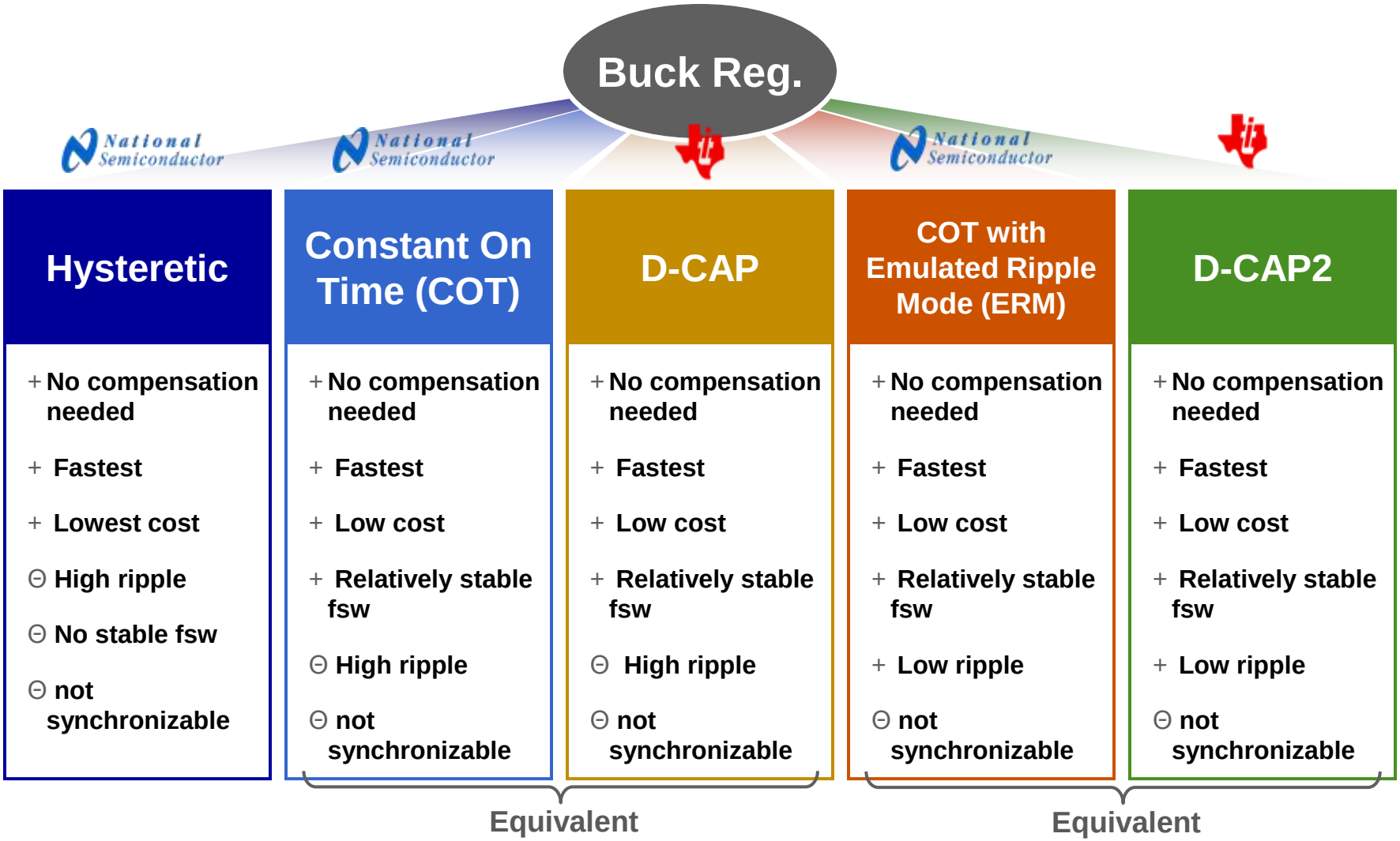
Методы достижения наилучшего результата при различных требованиях

На что влияют методы стабилизации?



- **Архитектура – метод стабилизации напряжения (тока)**
- **Качество стабилизации**
  - **Скорость реакции на переходные процессы (Transient performance)**
  - **Фиксированная/ плавающая частота (влияние на EMI)**
  - **Возможности синхронизации (in multi stage systems)**
  - **Пульсации и стабильность выходного напряжения**
- **Стоимость полного решения**
- **Сложность разработки**
  - **Стабильность петли ОС (compensation network)**

Hysteretic Control Architectures



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Fixed Frequency Control Architectures

Voltage Mode	Voltage Mode with Vin feed forward	Current Mode	Emulated Current Mode	DCS-Control
+ Stable fsw	+ Stable fsw	+ Stable fsw	+ Stable fsw	+ Fastest
+ Low ripple	+ Low ripple	+ Low ripple	+ Low ripple	+ Advanced Power Safe Mode
+ Synchronizable	+ Synchronizable	+ Synchronizable	+ Synchronizable	+ Low ripple
+ Wide duty cycle range	+ Medium cost	+ Fast Transient	+ Fast Transient	+ Relatively stable fsw
+ Medium cost	+ Compensates Vin changes	+ Simple compensation	+ Simple compensation	+ Low BOM cost
⊖ Slow Transient	+ Fast Transient	+ Compensates Vin changes	+ Compensates Vin changes	⊖ not synchronizable
⊖ Complex compensation needed	⊖ Complex compensation needed	⊖ No low duty cycle	+ Low duty cycle	
		⊖ Higher cost	⊖ No high duty cycle	
			⊖ Higher cost	

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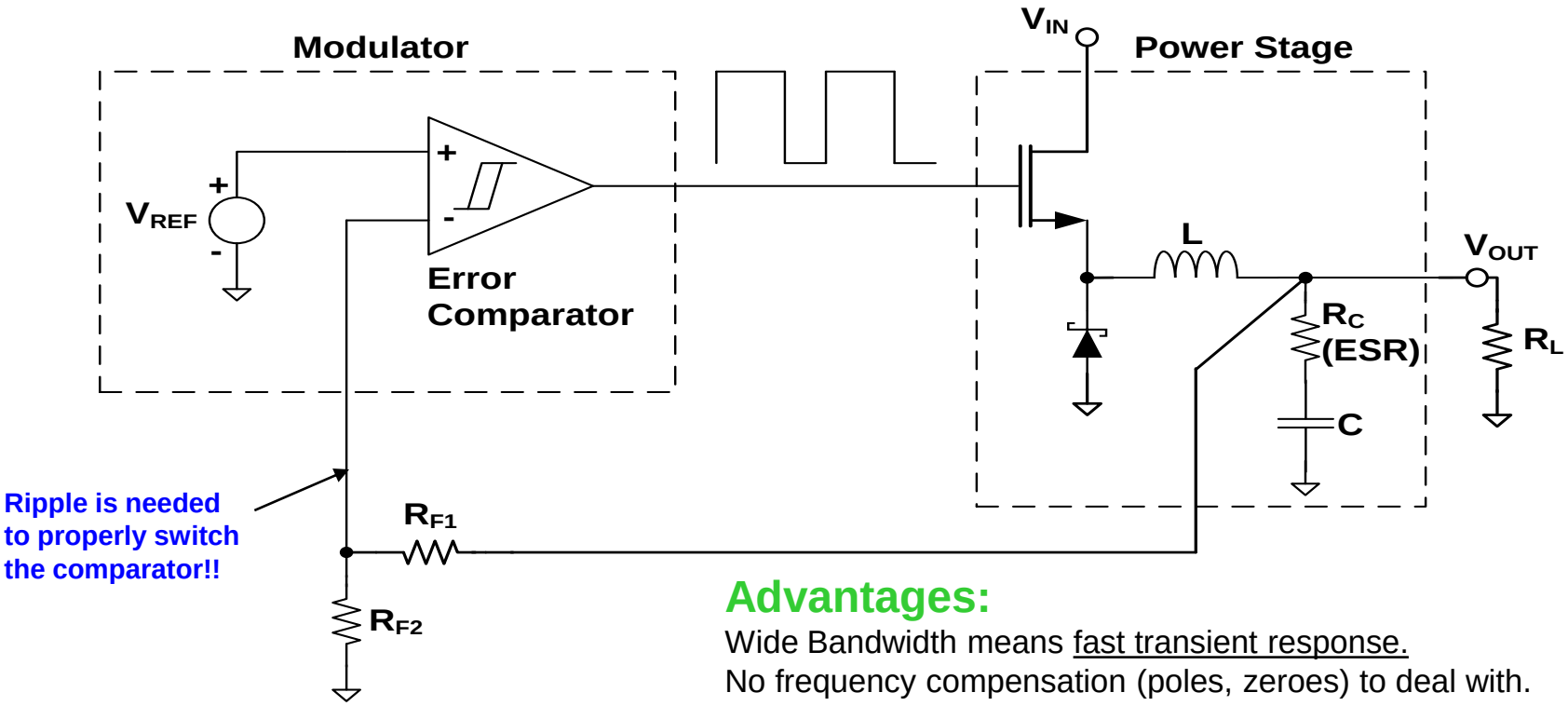
Hysteretic Mode Regulation

Наименьшее время отклика

Hysteretic Buck Regulator
Basic Architecture



Advantages:

Wide Bandwidth means fast transient response.
No frequency compensation (poles, zeroes) to deal with.
V_{IN} feedforward is inherent.

Disadvantages:

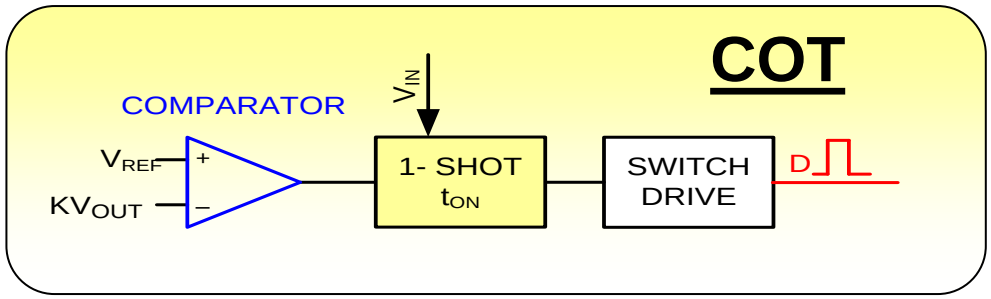
t_{ON} and t_{OFF} , and therefore the frequency, are functions of:
V_{IN}, V_{OUT}, I_L, L, ESR, ESL, $V_{HYS}*(R_{F1}+R_{F2})/R_{F2}$, and t_d

→ **Frequency is difficult to control!!**

Constant-On-Time (COT) Regulation

Не требуется компенсация ЧХ

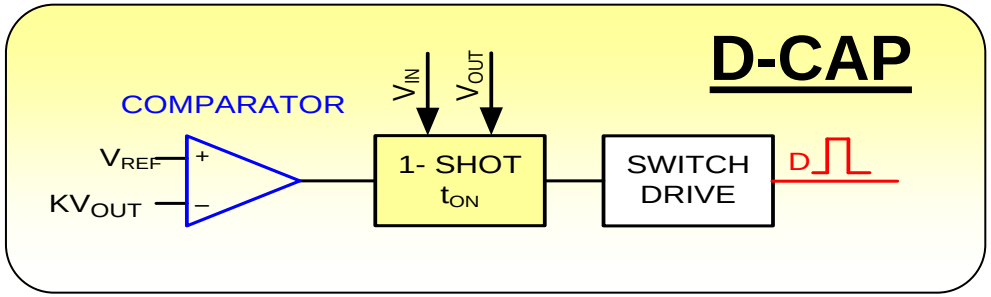
Constant On-Time – Two Methods



Commonalities:

$$t_{ON} \propto \frac{V_{OUT}}{V_{IN}}$$

- No oscillator, but (quasi) fixed tON
- Quasi-constant switching frequency
- No compensation network, no delay fastest transient response

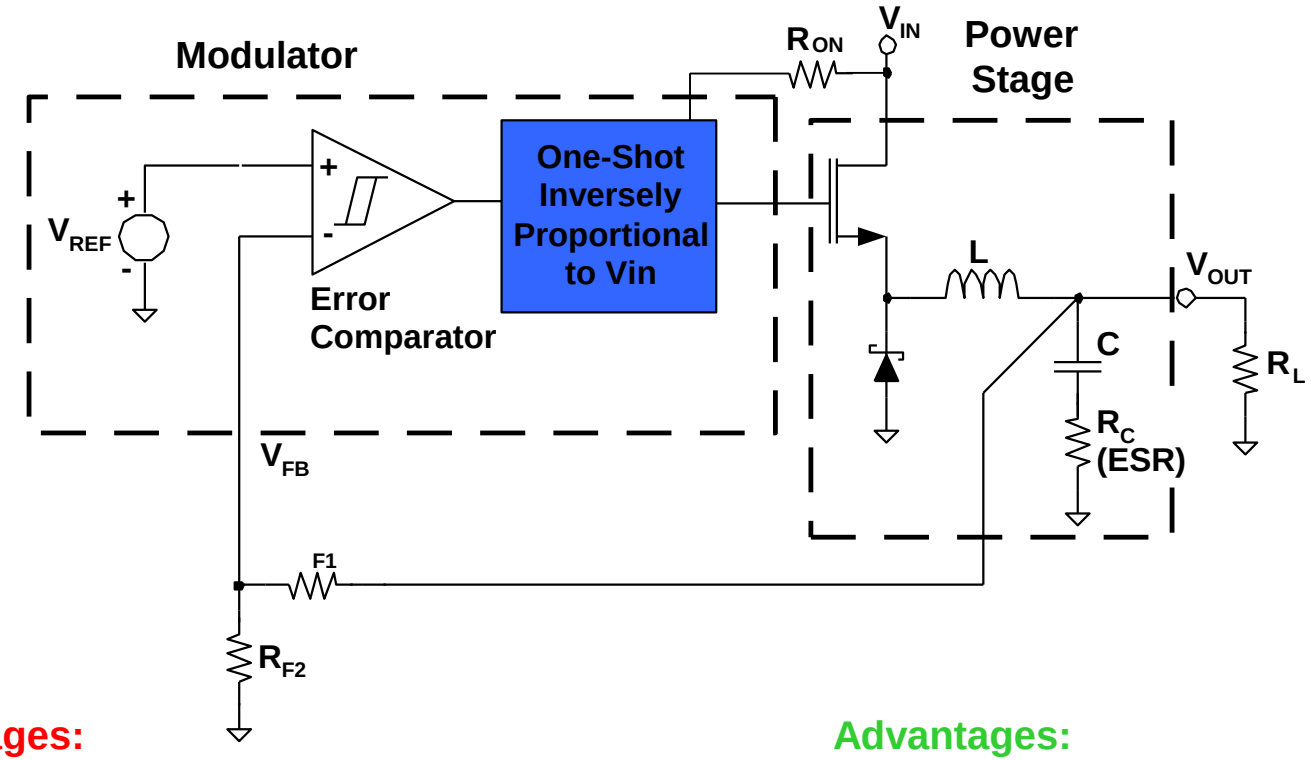


Differences:

- ON-Time also function of Vout

Constant-On-time (COT) Hysteretic Regulator

The addition of a one-shot the the basic hysteretic control



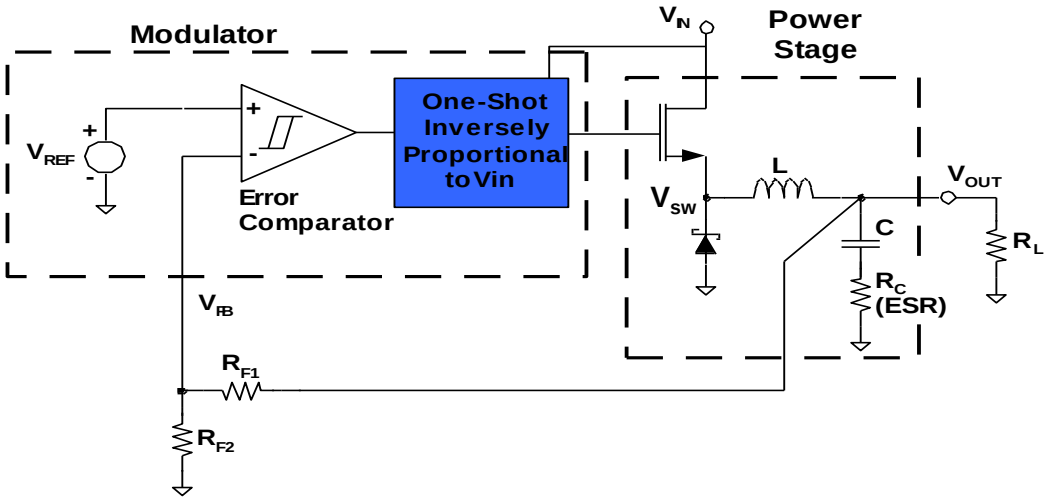
Disadvantages:

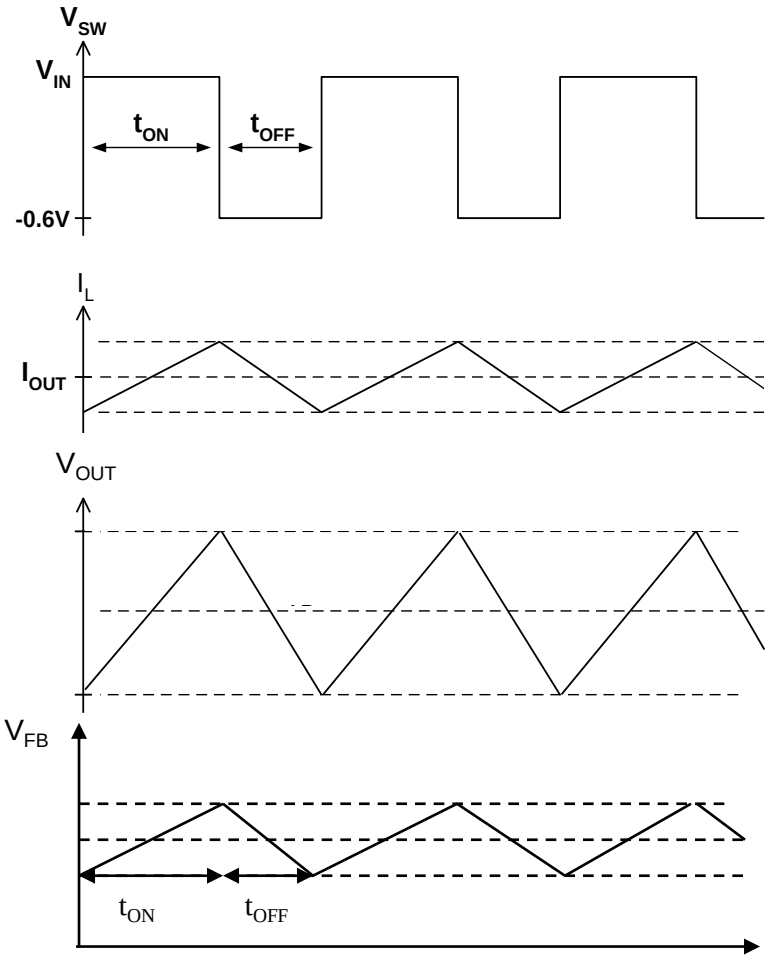
- Requires ripple at feedback comparator
- Sensitive to output noise, because it translates to feedback ripple

Advantages:

- **Constant frequency vs. V_{IN}**
- **High efficiency at light load**
- **Fast transient response for 1 cycle for fast loads**

How does COT Regulation work?





- When $V_{FB} < V_{REF}$
  - One-shot circuitry sets a t_{ON} time
  - V_{sw} is high until t_{ON} is achieved
- Once t_{ON} is achieved
  - Switch turns off
  - Cycle starts up again when $V_{FB} < V_{REF}$

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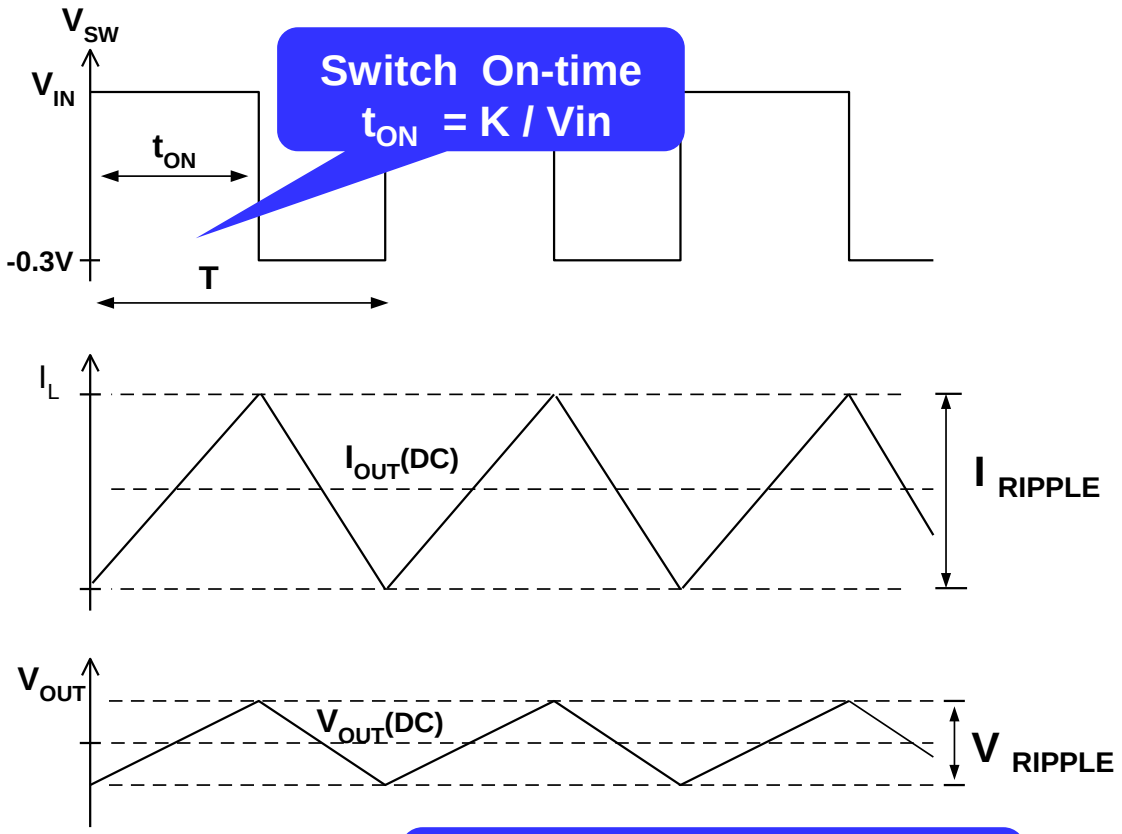
COT Regulation with V_{IN} Feedforward

Постоянная частота может быть достигнута применением прямой связи по напряжению:



Frequency is constant for constant V_{OUT}

Definition of Duty Cycle:

$$D = \frac{t_{ON}}{T} = t_{ON} \bullet f_{SW} \qquad \text{EQ1}$$

For Buck Regulator:

$$D = \frac{V_{OUT}}{V_{IN}} \qquad \text{EQ2}$$

Setting EQ1 = EQ2:

$$t_{ON} \bullet f_{SW} = \frac{V_{OUT}}{V_{IN}} \qquad \text{EQ3}$$

For COT with Feed-forward:

$$t_{ON} = \frac{K \bullet R_{ON}}{V_{IN}} \qquad \text{EQ4}$$

K is a constant = 1.3x10 $^{-10}$

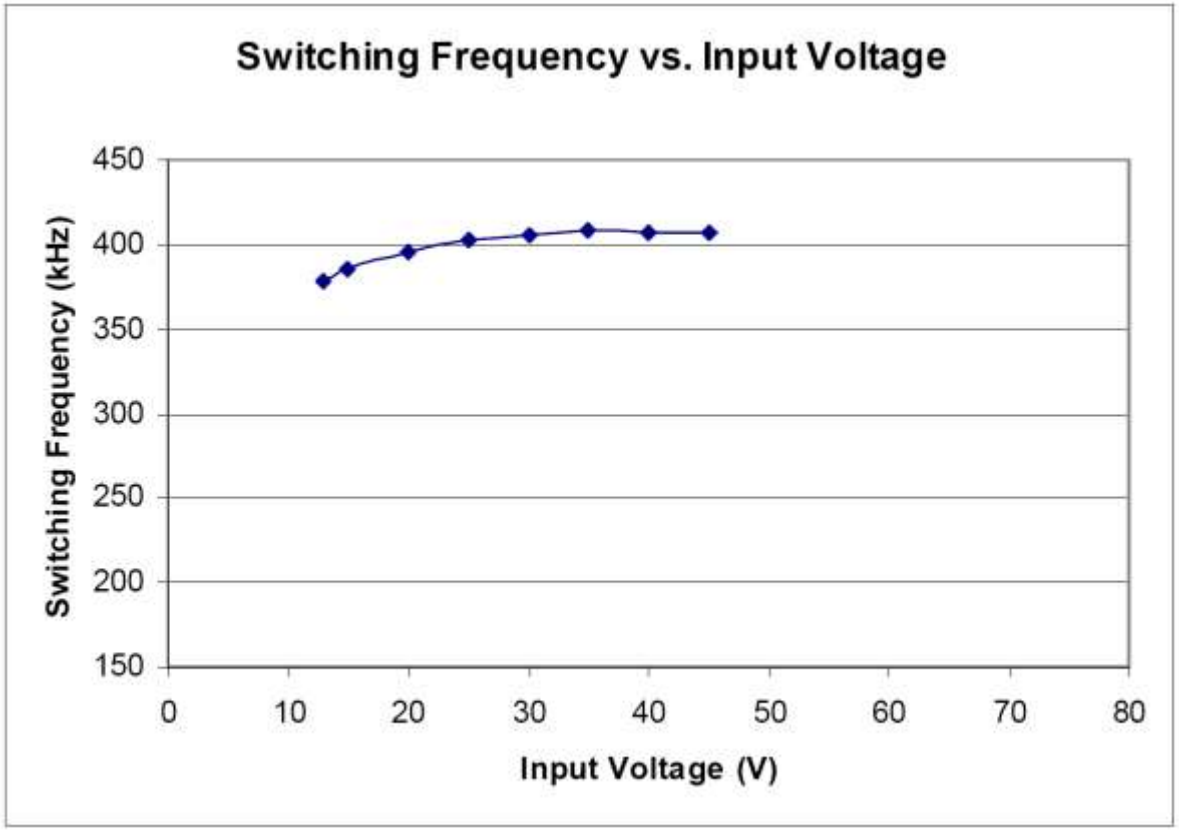
Insert EQ4 in EQ3:

$$\frac{K \bullet R_{ON}}{V_{IN}} \bullet f_{SW} = \frac{V_{OUT}}{V_{IN}}$$

Solve for f_{SW}:

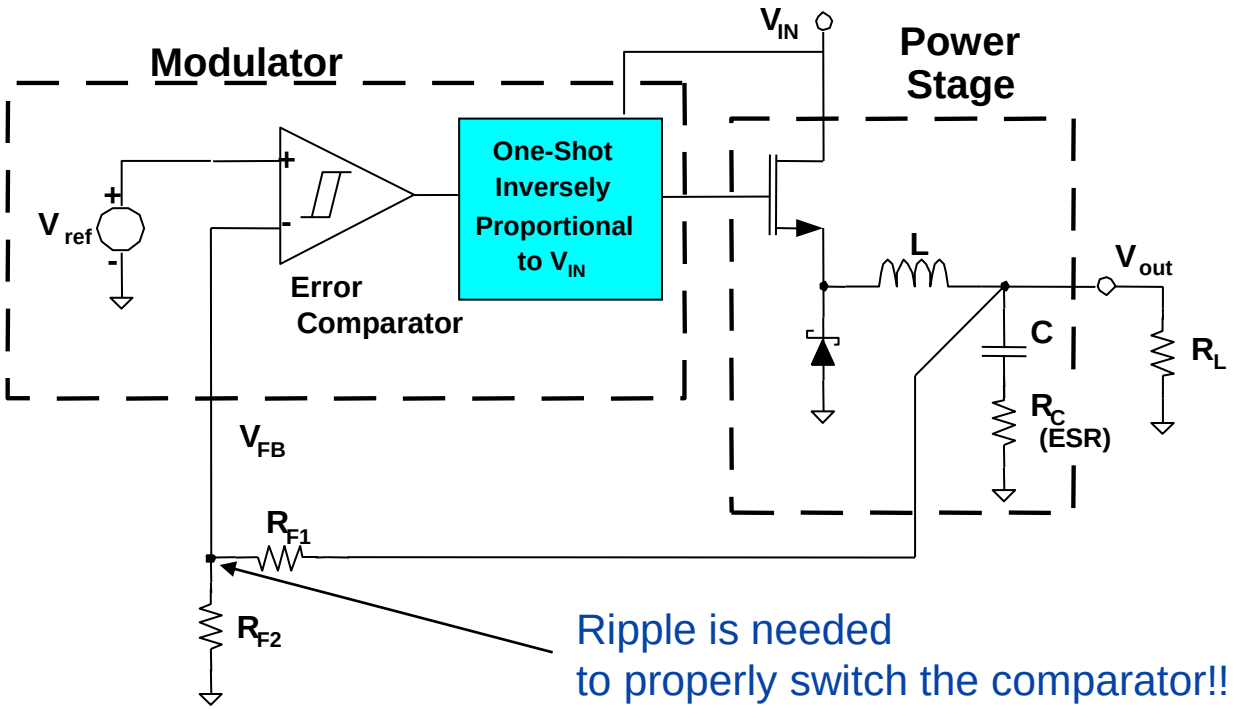
$$f_{SW} = \frac{V_{OUT}}{K \bullet R_{ON}}$$

COT Regulation with V_{IN} Feedforward



Частота относительно постоянна в широком диапазоне входных напряжений.

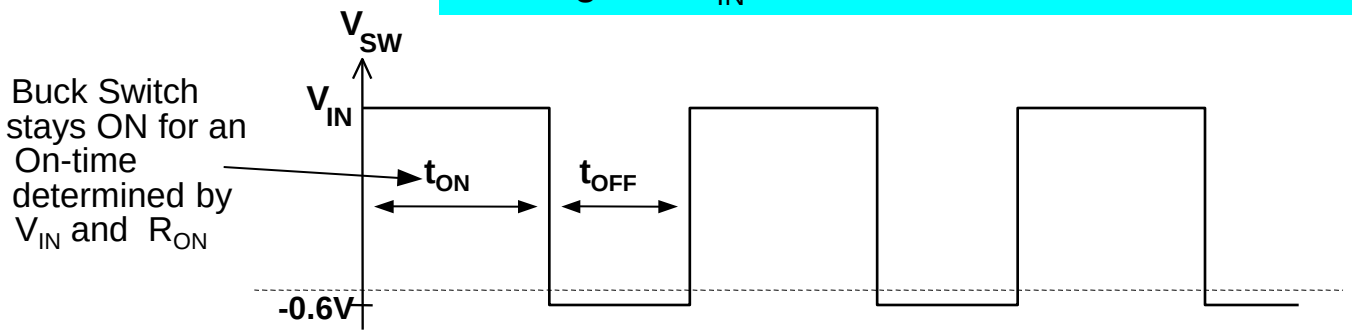
ESR необходим для достаточных пульсаций V_{OUT}



- T off regulates by comparing V_{OUT} to V_{ref}
- V_{OUT} ripple must be large enough to overcome the comparator hysteresis
- ESR of output capacitor is directly proportional to V_{OUT} ripple
- ESR must be large enough to create sufficient V_{OUT} ripple to properly switch the comparator

Hysteretic Regulator Waveforms

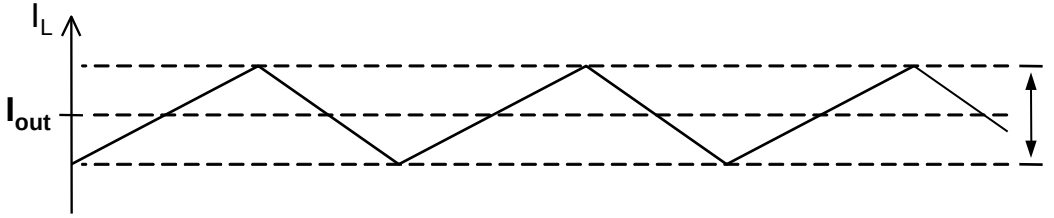
For a given V_{IN} ON-Time is constant as load current varies



Buck Switch stays ON for an On-time determined by V_{IN} and R_{ON}

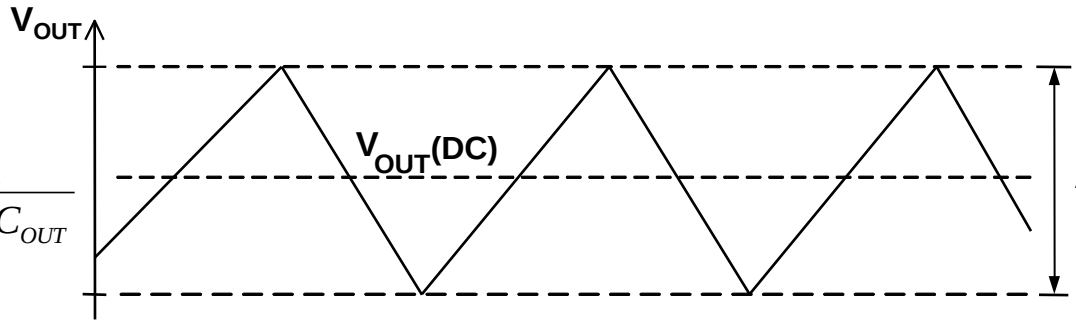
Inductor's ripple current:

$$\Delta I_L = \frac{V_{in} - V_{out}}{} \cdot t_{ON} \cdot \frac{1}{L}$$



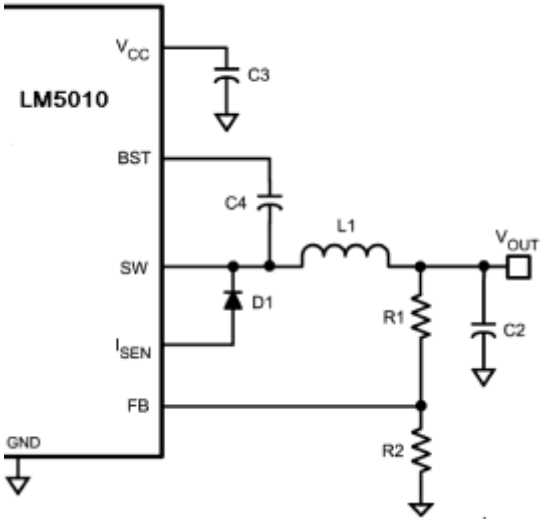
Output voltage ripple:

$$\Delta V_{OUT} = \Delta I_L \cdot ESR + \frac{\Delta I_L}{8 \cdot f_{SW} \cdot C_{OUT}}$$



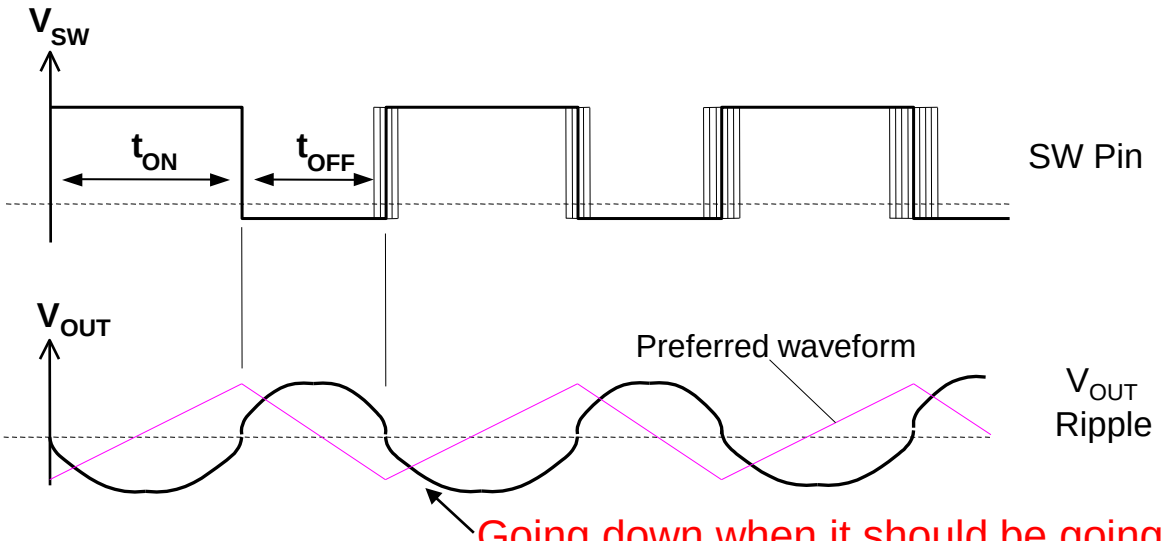
In standard COT control schemesit is recommended that a low ESR ceramic output capacitor be used in series with a resistor to provide a stable ESR

ESR необходим для уменьшения фазового сдвига между V_{OUT} и I_{sw}



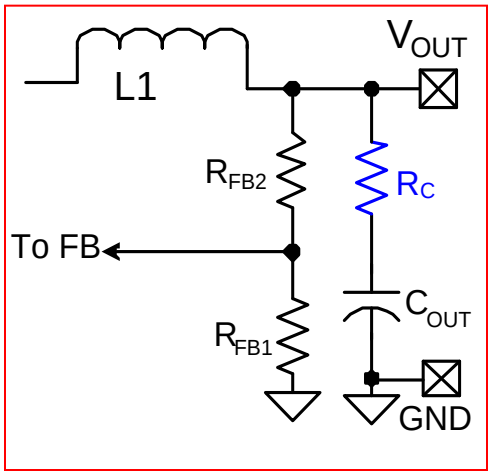
$$V_{out} = V_{ref} \cdot \frac{R1 + R2}{R2} = V_{C2} + V_{ESR}$$

- V_{C2} is phase shifted 90° from inductor current waveform
- V_{ESR} is in phase with inductor current waveform
- If V_{ESR} is small, V_{out} will be dominated by the phase shifted V_{C2} component causing V_{SW} to jitter and circuit to regulate poorly



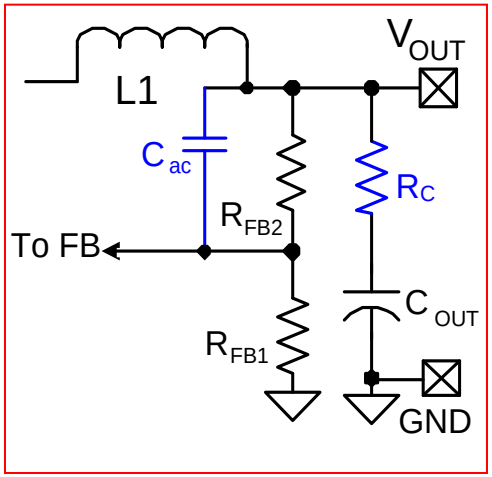
Методы добавки пульсации в ОС

Type 1
Lowest Cost
Configuration



$$R_C \geq \frac{25mV}{\Delta I_{L(\min)}} \frac{V_{OUT}}{V_{REF}}$$

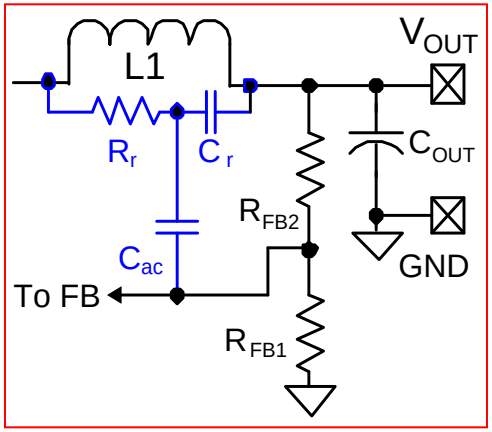
Type 2
Reduced Ripple
Configuration



$$R_C \geq \frac{25mV}{\Delta I_{L(\min)}}$$

$$C_{ac} \geq \frac{5}{f_{sw}(R_{FB1} \parallel R_{FB2})}$$

Type 3
Minimum Ripple
Configuration



$$C_r = 3300pF$$

$$C_{ac} = 100nF$$

$$R_r \leq \frac{V_{IN(\min)} - V_{OUT}}{25mV \cdot C_R} \cdot T_{ON}$$

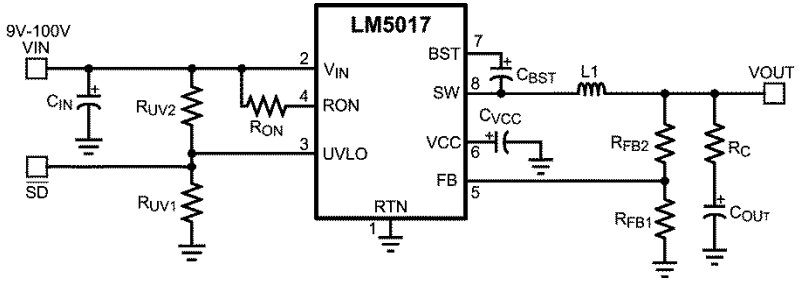
Controlling Output Ripple and Achieving ESR Independence in Constant On-Time (COT) Regulator Designs

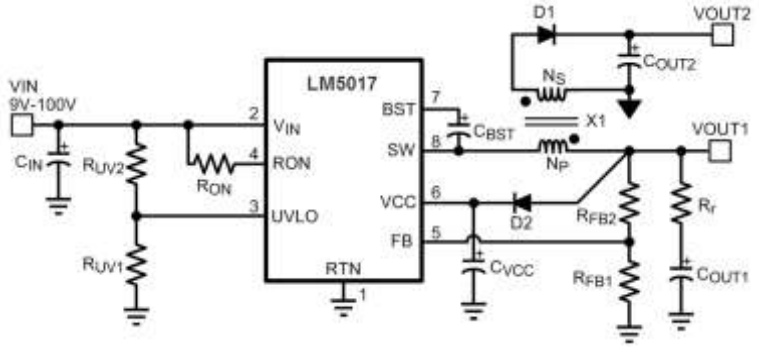
National Semiconductor
Application Note 1481
Craig Varga
September 2006

LM5017/18/19
100V Synchronous Buck Regulator Family

Key Features

- **Input voltage range: 9V to *100V***
- **Integrated HS and LS FETs**
- 600mA/300mA/100mA output current levels
- ***Isolated output when used with transformer or coupled inductor***
- Integrated Input under-voltage lock-out
- ***No Control Loop Compensation Required (COT)***
- ***Ultra-fast transient response***
- Switching frequency adjustable to 1MHz
- Output adjustable to min 1.22V
- Precision reference, ±2.5% over full temp range
- Peak current limit protection
- Thermal shutdown
- PSOP-8, LLP-8 packages
- ***Available in AEC-Q100 Grade 1 (Tjmax=125°C)***





Availability / Pricing

Order Code	Load Current [mA]	1K Web Price
LM5017	600	$1.65
LM5018	300	$1.40
LM5019	100	$1.25

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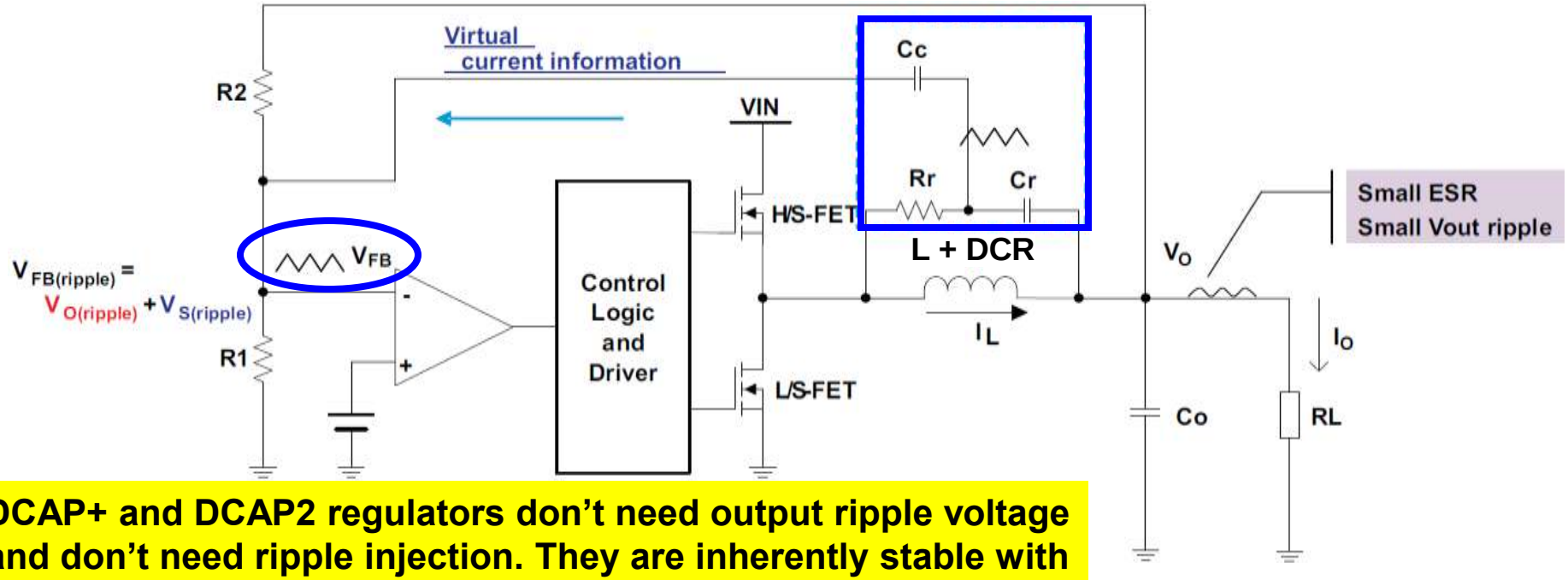
D-CAP

Не требуется компенсация ЧХ

(эквивалент COT)

D-CAP Mode - Ripple Injection Networks allows Multilayer Ceramic Capacitors (MLCC)

- D-CAP regulators need 10 … 15mV peak-to-peak voltage ripple on feedback-pin
- Ripple comes usually from output voltage ripple (caused by certain ESR of C_O)
- Output Voltage Ripple can be avoided by use of Ripple Injection Network
- App note: "D-CAP™ Mode With All-Ceramic Output Capacitor Application" SLVA453
- Ripple Injection Network generates 10 … 15mV VFB ripple w/o any ripple on VOUT: Enables use of MLCC



DCAP+ and DCAP2 regulators don't need output ripple voltage and don't need ripple injection. They are inherently stable with ceramic output capacitors (MLCC)

D-CAP Mode – Mid V_{IN} Converter Portfolio

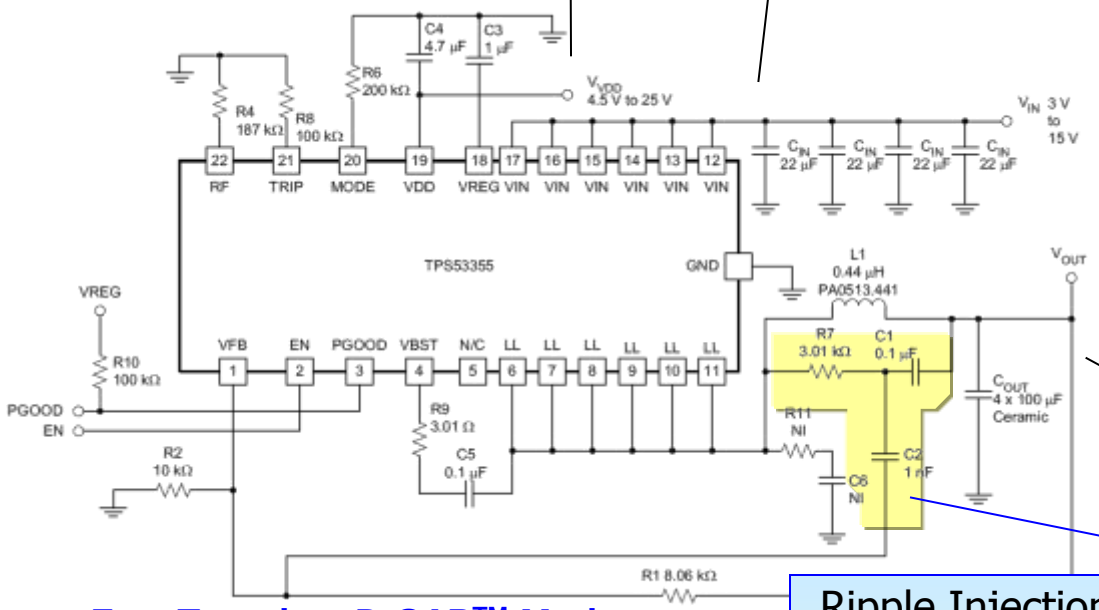
Device	IOUT	Power Path VIN (V)		Bias VIN (V)		typ RDSon (mΩ)		VOUT (V)			Package	Size
	(A)	min	max	min	max	HS	LS	min	max	Tol. (%)	Type	(mm x mm)
TPS53314	6	3	15	4.5	25	20	7.5	0.6	5.5	1	QFN40	5 x 7
TPS53318	8	3	21	4.5	21	9	5	0.6	5.5	1	QFN22	5 x 6
TPS51315	10	3	14	4.5	5.5	19	7	0.75	5.5	1.6	QFN40	5 x 7
TPS53319	12	3	21	4.5	21	9	5	0.6	5.5	1	QFN22	5 x 6
TPS53315	12	3	15	4.5	25	19	7	0.6	5.5	1	QFN40	5 x 7
TPS53353	20	3	15	4.5	25	5.5	2.2	0.6	5.5	1	QFN22	5 x 6
TPS53355	30	3	15	4.5	25	5	2	0.6	5.5	1	QFN22	5 x 6

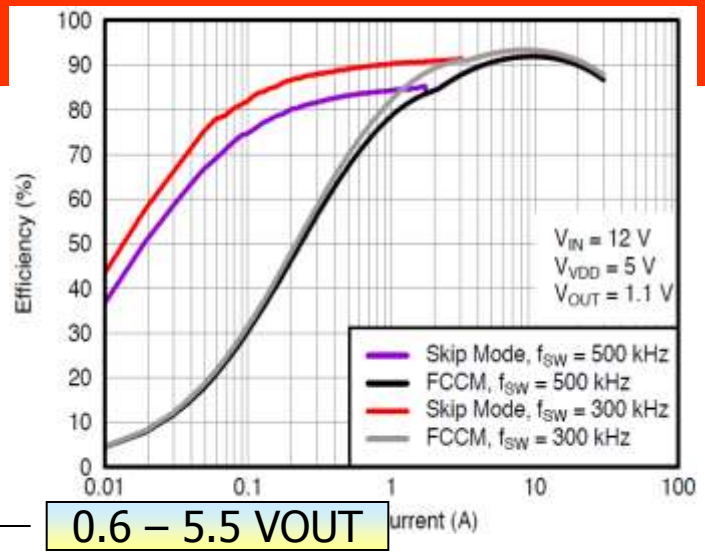
All devices with single grounded PowerPAD for reduced EMI

30A 3-15VIN D-CAP™ SR Buck Converter w/ ECO-Mode™ TPS53355

4.5 – 25V Bias Power Input

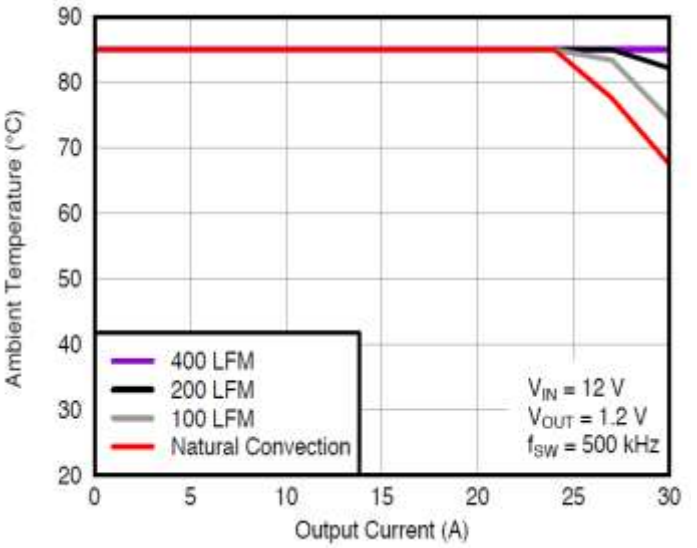
3 -15 V Power Path Input





0.6 – 5.5 VOUT

Ripple Injection Network Enables Use of MLCC Output Caps



- **Fast Transient D-CAP™ Mode**
- **No Loop Comp. Required**
- **Select. FCCM / ECO-(Skip)- Mode**
- **Pre- Bias Start- up**
- **Output OV / UV Protect. & Power Good**
- **Programmable Current Limit**
- **8 selectable switching frequ., 4 selectable SS times**
- **5V LDO Output (30mA)**

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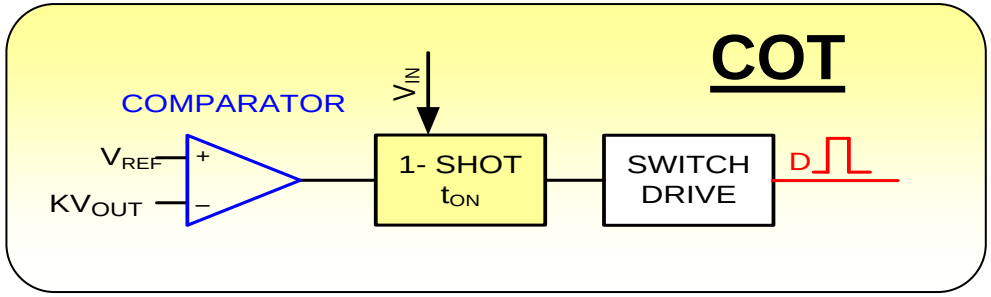
Constant-On-Time (COT) Regulation with Emulated Ripple Mode (ERM)

Малые пульсации выходного напряжения

Меньше компонентов

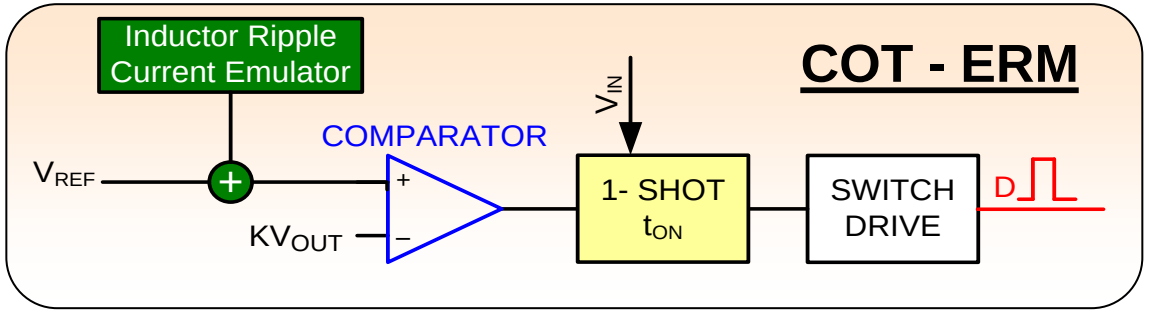
Improved Constant On-Time: COT-ERM



Commonalities:

$$t_{ON} \propto \frac{V_{OUT}}{V_{IN}}$$

- No oscillator, but (quasi) fixed tON
- Quasi-constant switching frequency
- No compensation network, no delay fastest transient response

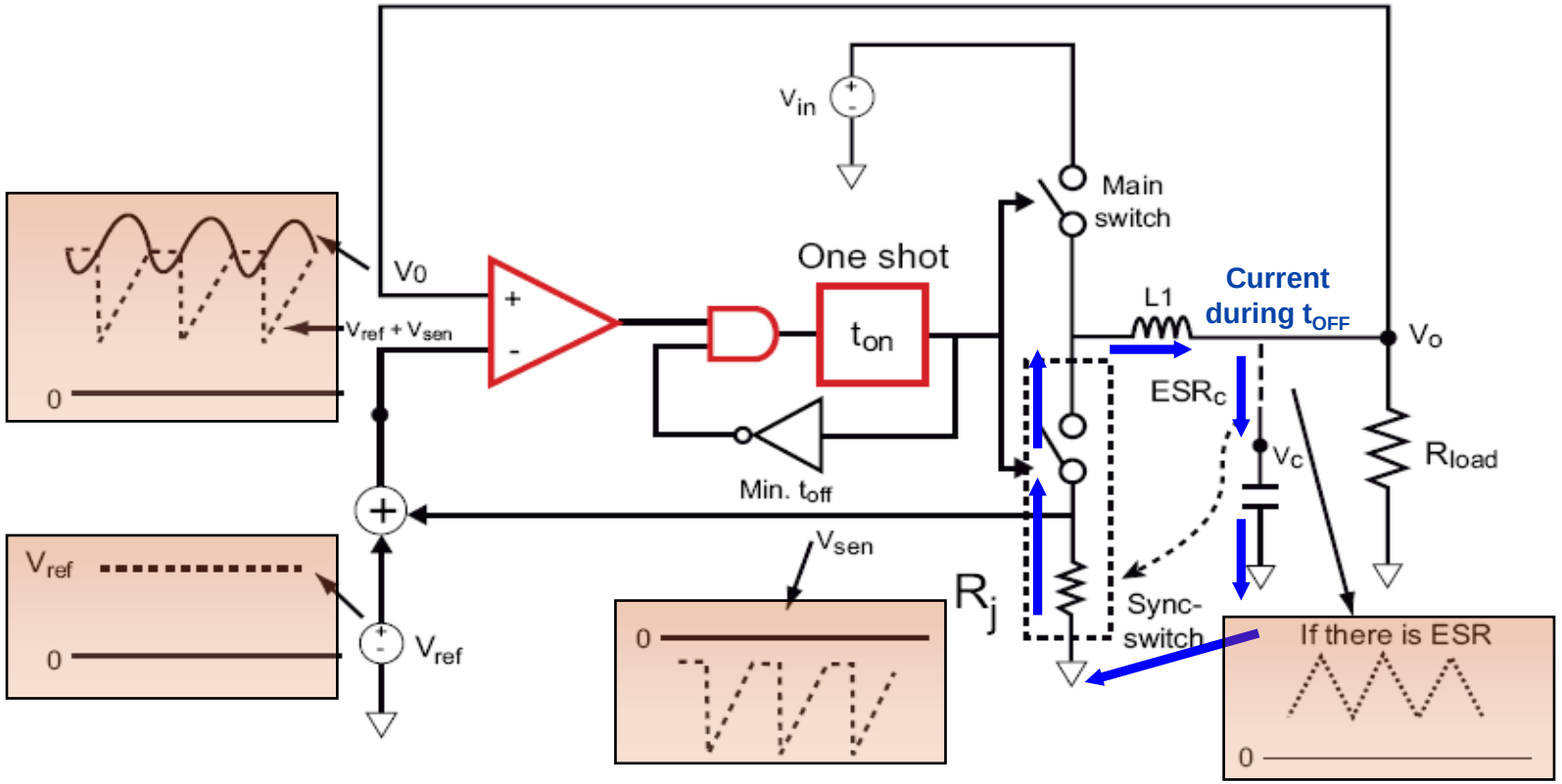


Differences:

Need for output voltage ripple:

- **COT: ~10 – 15mV ripple needed on feedback-pin**; can reduced to **0mV with ripple injection circuit**
- **COT- ERM No output ripple needed**, internally **emulated**

Как эмулируют пульсации?



- ESR current can be sensed through Rj (R_{DS_ON} of the Low Side Mosfet)
- The inverted V_{SEN} is the replication of V_{ESR} ripple during t_{OFF}
- This is added to the DC reference voltage V_{ref} before comparing to V_{OUT}
- No ESR is required on the output capacitor

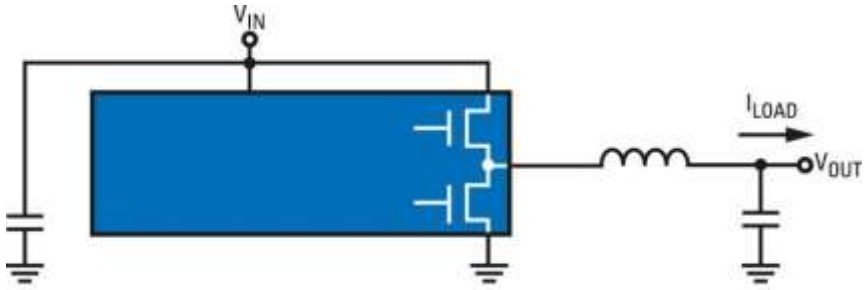
SIMPLE SWITCHER® Regulators

LM310x Family

LM310x Synchronous SIMPLE SWITCHER® Family

Key Features

- Vin Range ***4.5V to 42V*** (0.75A, 2.5A)
- ***Constant ON-Time with Emulated Ripple Mode***
- Fast transient response
- No external compensation required
- Adjustable Output Voltage (***0.8V***-25V)
- 1.5% Initial Accuracy at 25°C
- ***Precision Enable***
- Adjustable Frequency (50kHz-1MHz)
- Adjustable Soft-Start
- Stable with Ceramic Capacitors
- Packages
  - eTSSOP-16 (0.75A)
  - eTSSOP-20 (1.5A, 2.5A)
  - micro SMD (1A)



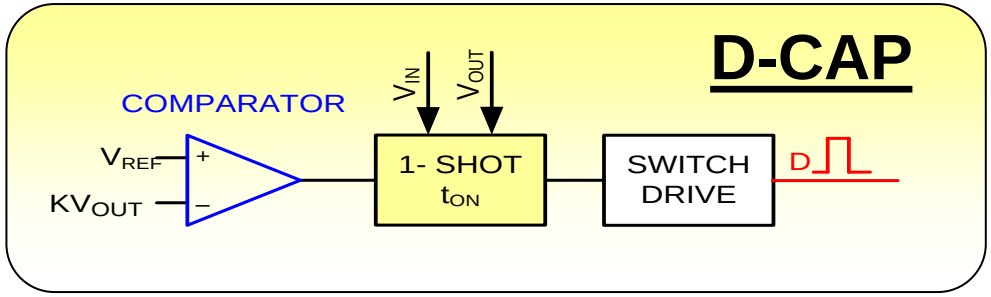
Availability / Pricing

Order Code	Load Current [A]	Vin [V]	1K Web Price
LM3103	0.75	42	$1.80
LM3100	1.5	36	$2.35
LM3102	2.5	42	$2.59

D-CAP2

Малые пульсации выходного напряжения (эквивалент COT-ERM)

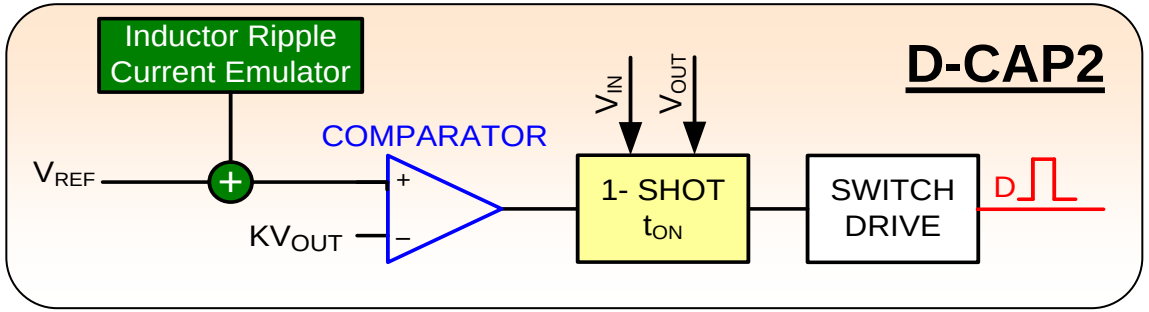
Improved Constant On-Time: D-CAP2



Commonalities:

$$t_{ON} \propto \frac{V_{OUT}}{V_{IN}}$$

- No oscillator, but (quasi) fixed tON
- Quasi-constant switching frequency
- No compensation network, no delay fastest transient response



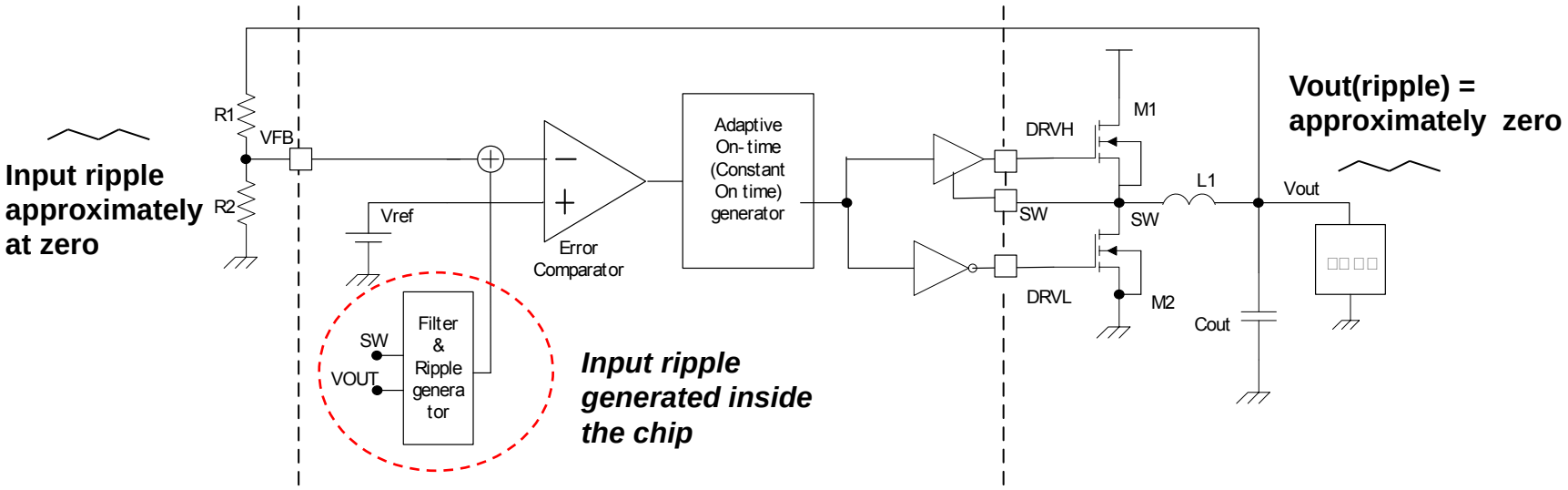
Differences:

Need for output voltage ripple:

– **D-CAP: ~10 – 15mV ripple needed on feedback-pin**; can reduced to **0mV with ripple injection circuit**

– **D-CAP2**: **No output ripple needed**, internally **emulated**

D-CAP2 mode feature



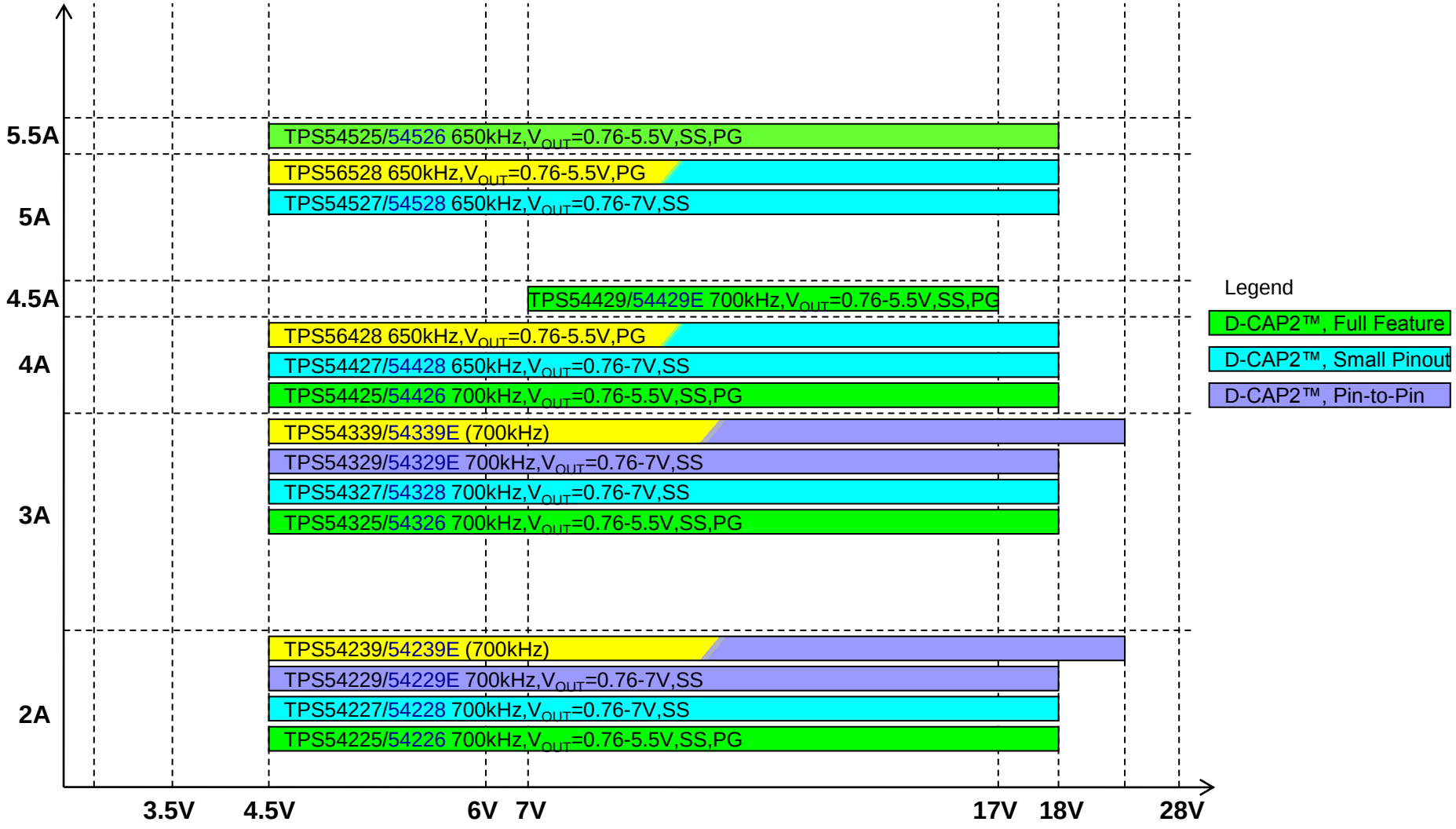
(1) TI D-CAP2 mode topology is next generation DCAP mode which integrates a switching injection circuit to allow use of ceramic output capacitors.

(2) DCAP2 mode is stable even if the Vout ripple voltage is zero. This allows the use of ceramic output capacitors.

(3) DCAP2 mode has identical operation as DCAP mode.

(4) Input feedback voltage (Vfb) to error comparator directly without an error amplifier

D-CAP2 Converters Portfolio



Mid VIN SR Buck D-CAP2 Converters TPS54x27 / x28 (aka Kirishima)

ОСОБЕННОСТИ

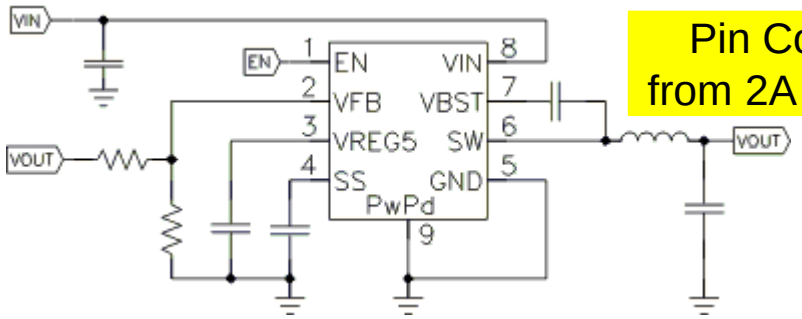
- Fast Adaptive On-Time (D-CAP2) Control Architecture
- Very Low Resistance MOSFETs
- Fixed 700kHz Switching Frequency
- Adjustable Soft-Start Time
- Auto-Skipping Eco-mode: TPS54x28

ПРЕИМУЩЕСТВА

- High Performance with 2 x 22uF Ceramic COUT
  - Faster than 20us transient response time
  - Less 10mVp-p output voltage ripple
  - No compensation components needed
- 90% Efficiency; Optimized for Low Vout
- 1,5 uHn Small Inductor
- Reduces Inrush Currents During Startup

ПРИМЕНЕНИЯ

- Digital TV
- Industrial
- Networking Home Terminal
- Digital Set Top Box



Pin Compatibility from 2A to 5A (SO-8)

	TPS54227	2	–	4.5-18	700k	0.76-7	DDA
Eco-mode	TPS54228	2	–	4.5-18	700k	0.76-7	D,DDA,DRC

Texas Instruments

Advanced COT Control Methods

Быстрые

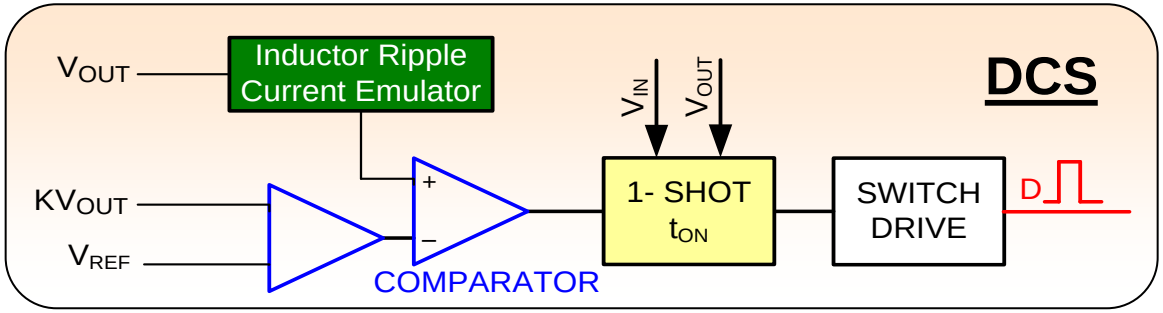
Малые пульсации выходного напряжения

Constant On-Time Control Modes

Commonalities:

- No oscillator, but (quasi) fixed tON
- Quasi-constant switching frequency
- No compensation network, no delay
- Fastest transient response

$$t_{ON} \propto \frac{V_{OUT}}{V_{IN}}$$

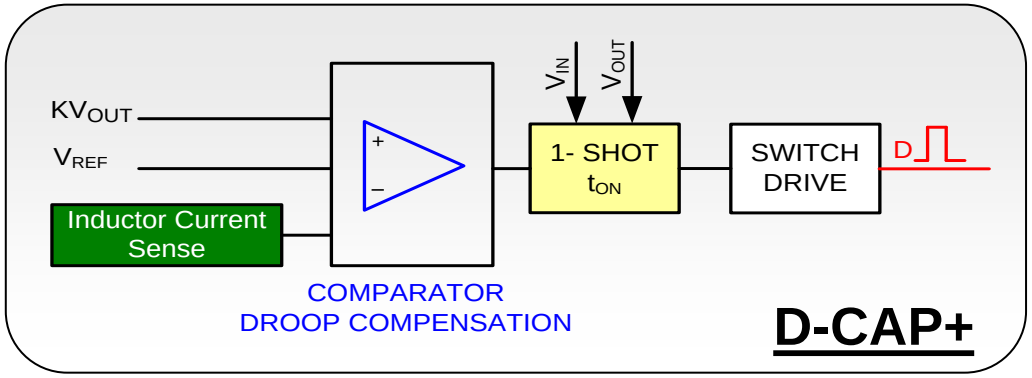


Direct Control with Seamless Transition to Power Save Mode

Differences:

Need for output voltage ripple:

- **DCS: No output ripple needed**, inductor-/ switch-**current ripple used**; is basically combination of D-CAP and VM
- **D-CAP+: No output ripple needed**, inductor-/ switch-**current ripple used**; is basically combination of D-CAP and CM



Advanced COT DCS

Direct Control with Seamless Transition to Power Save Mode

Преимущества COT DCS архитектуры

- 100% Duty-Cycle Mode
- Быстрый отклик
- Отличная стабилизация по нагрузке
- Высокий КПД во всех режимах
- Мягкая работа в пограничном режиме номинал/XX
- Фиксированная частота в стабильном режиме
- Отсутствие компенсации ЧХ
- Малый размер компонентов

TPS6213x/4x/5x COT DCS

3...17V V_{IN}, 1-3A, 3MHz Step-Down Converters in 3x3mm QFN

Features

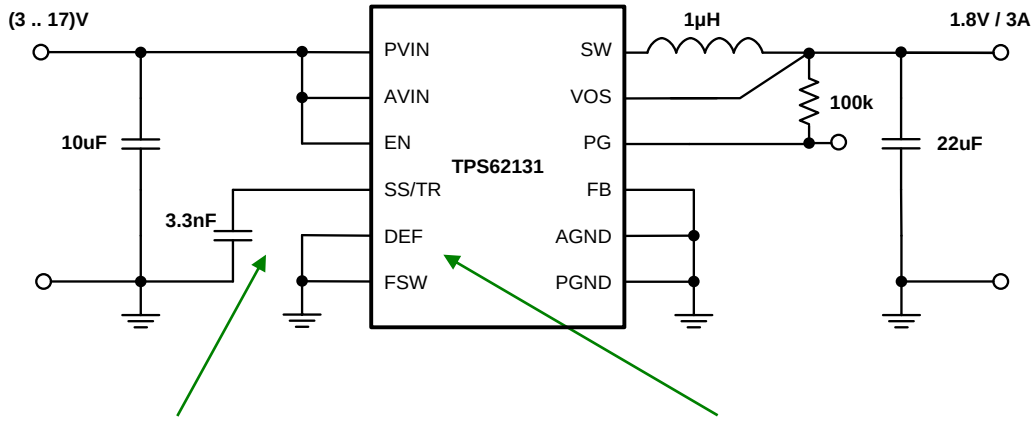
- High Efficiency Step Down Converter with DCS-Control™
- VIN range from 3 to 17V
- Adjustable VOUT from 0.9 to 6.0V
- Fixed VOUT options: 1.8V, 3.3V, 5.0V
- Output current up to: 3A (TPS62130)
  2A (TPS62140)
  1A (TPS62150)
- Seamless transition to Power Save Mode
- Pin-selectable switching frequency (full, half)
- 100% Duty Cycle Mode
- Programmable Soft Start and Tracking
- Quiescent current of 17uA (typ.)
- Power Good

Benefits

- High VIN converter with small solution size
- 12V → 3.3V / 3A utilizing a 1uH inductor
- DCS-ControlTM regulation is fast and accurate
- Low quiescent current and selectable switching frequency for high efficiency
- VFB control allows for constant current source applications

Applications

- Solid State Disk Drives
- Embedded and mobile Computing
- Industrial applications



Cstart	Adjustable Startup
TR	FB Voltage Control

DEF	Pin Selectable Output Voltage
FSW	Pin Selectable Switching Frequency

DCS-Control™ Devices

TPS62230
(Vin=6V with 500mA)

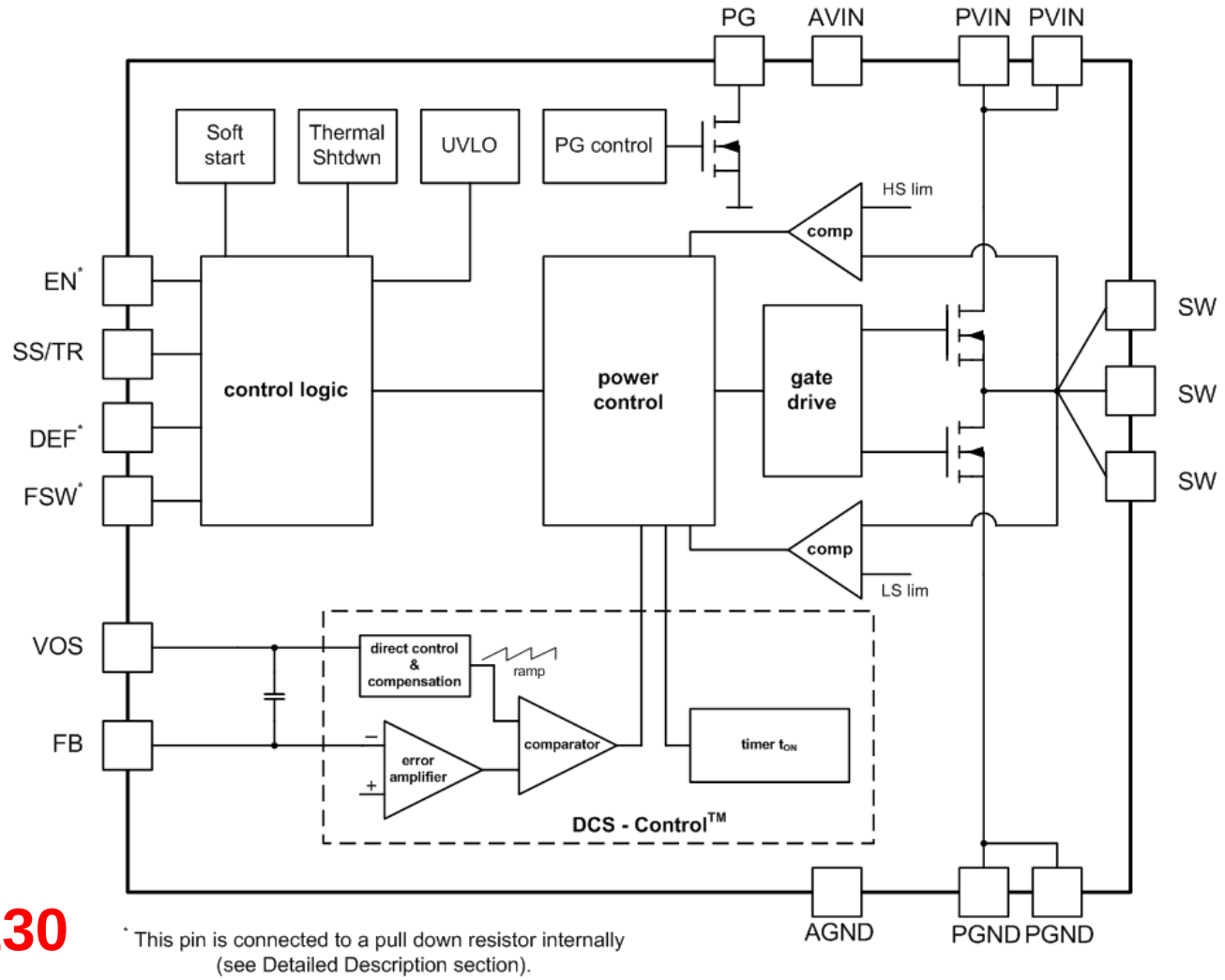
TPS62130/40/50
(Vin= 17V with 3A/2A/1A)

TPS62160/70
(Vin=17V with1A/0.5A)

TPS62080
(Vin=6V with 1.2A)

TPS62090
(Vin=6V with 3A)

TPS62125 (2Q12)



TPS62130

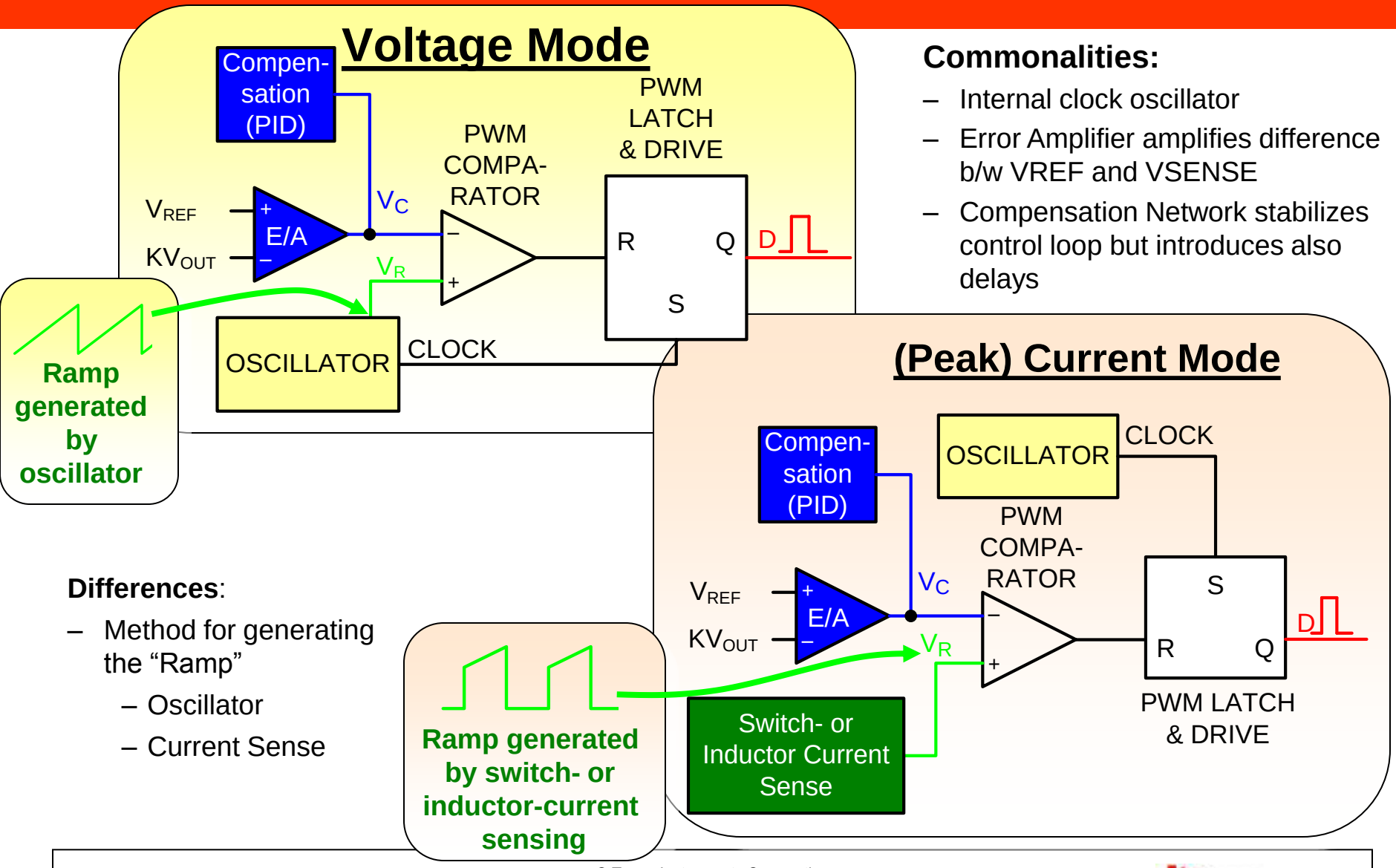
* This pin is connected to a pull down resistor internally (see Detailed Description section).

Constant Frequency

Традиционны

Оптимальны для подавления помех

Constant Frequency Control Modes



Commonalities:

- Internal clock oscillator
- Error Amplifier amplifies difference b/w VREF and VSENSE
- Compensation Network stabilizes control loop but introduces also delays

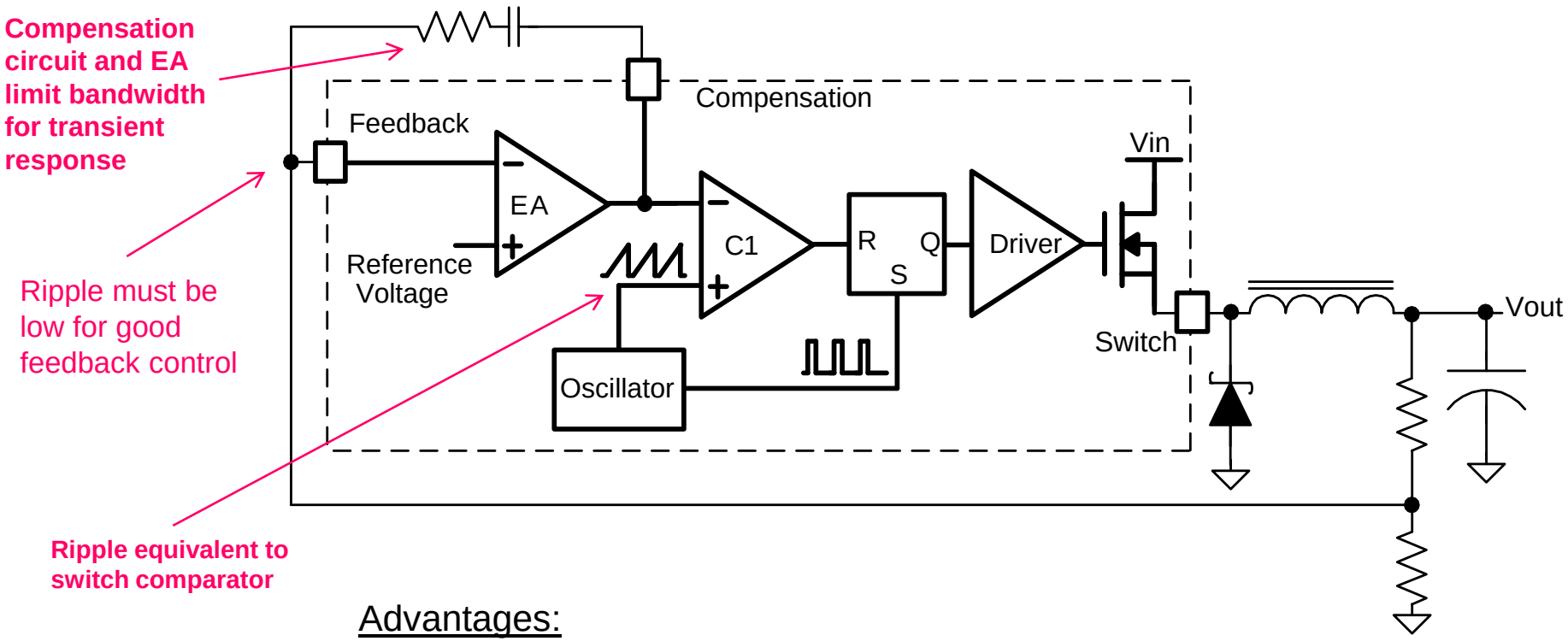
Differences:

- Method for generating the “Ramp”
  - Oscillator
  - Current Sense

Voltage Mode

Простые синхронизируемые

Basic Voltage Mode PWM DC-DC Converter



Advantages:

Fixed frequency, low ripple (necessary)

Disadvantages:

Fixed frequency, limited bandwidth → slower transient response vs. COT

SIMPLE SWITCHER® Regulators

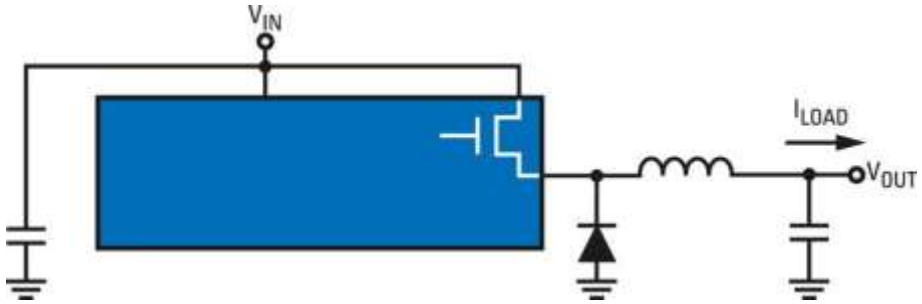
LM2267x Family

Ease of Use Regulators

LM2267x SIMPLE SWITCHER® Family

Key Features

- Vin Range ***4.5V*** to ***42V***
- Current Outputs: 0.5A, 1.0A, 2.0A, 3.0A, 5.0A
- Internally compensated ***V_{in} feed forward voltage mode control***
- Output Voltages options:
  - Adjustable range (1.285V-30V)
  - Fixed: 5.0V
- ***1.5% Initial Accuracy at 25°C***
- 2.0% V_{OUT} Accuracy over Line, and Full Temperature (Tj=-40°C to +125°C)
- ***Precision Enable***
- Optional fixed Operating Frequency: 500kHz
- ***Adjustable Frequency (200kHz-1MHz)***
- ***Frequency Sync (500kHz – 1MHz)***
- Adjustable Current Limit
- External Soft-Start
- Stable with Ceramic Capacitors
- ***Available in AEC-Q100 Grade 1 (Tjmax=125°C)***
- Packages: TO-263-7 THIN, PSOP-8



Availability / Pricing

Order Code	Iout (A)	Adj Cur Limit	Soft Start	Enable	Fsync / Fadj	1k Web Price
LM22674	0.5					$1.32
LM22671	0.5		✓	✓	✓	$1.38
LM22675	1.0			✓		$1.68
LM22672	1.0		✓	✓	✓	$1.78
LM22680	2.0		✓	✓	✓	$1.85
LM22670	3.0			✓	✓	$1.98
LM22673	3.0	✓	✓			$1.98
LM22676	3.0			✓		$1.92
LM22677	5.0			✓	✓	$3.38
LM22678	5.0			✓		$3.25
LM22679	5.0	✓	✓			$3.38

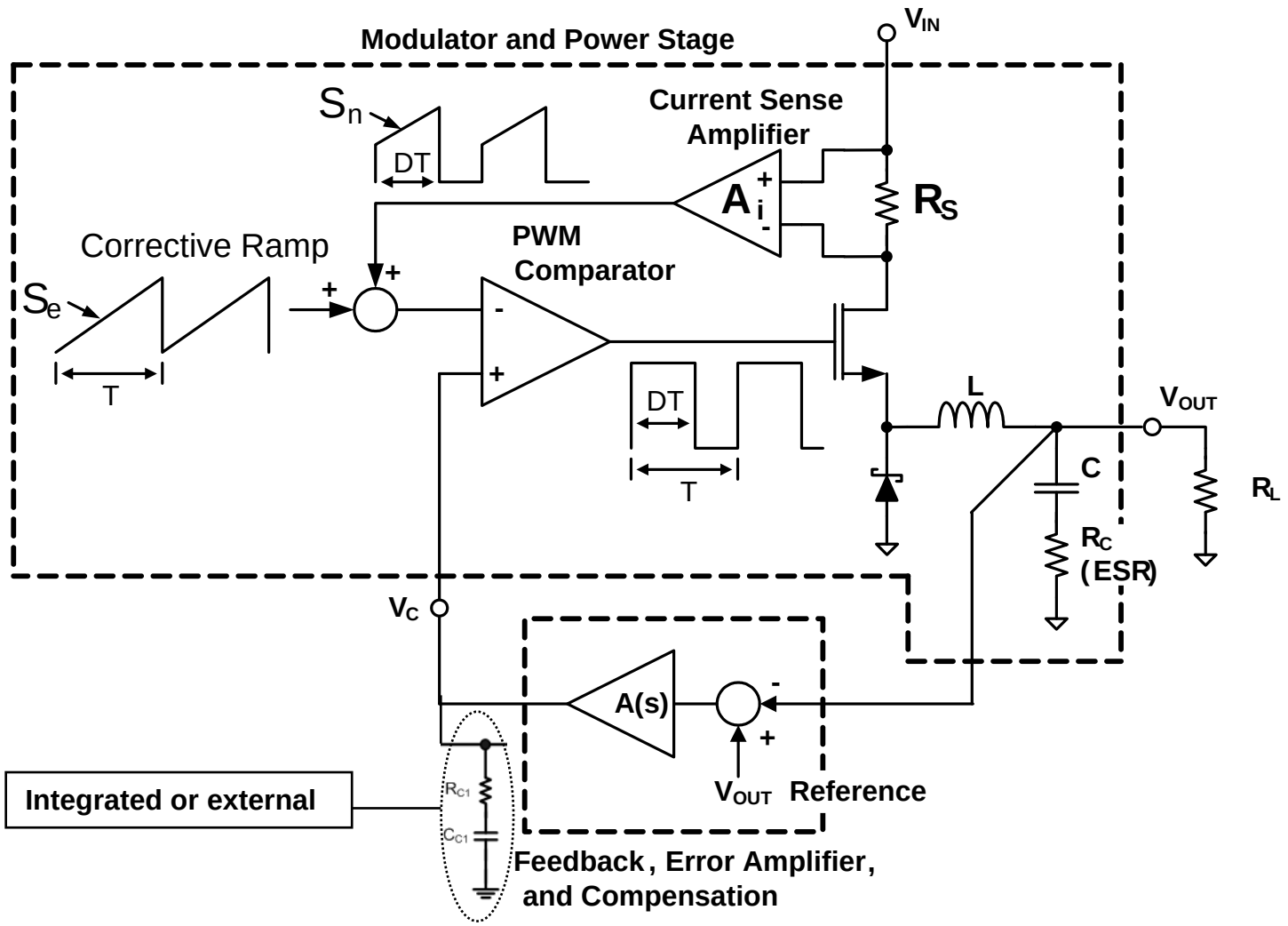
Current Mode Regulation

Синхронизируемые

Простые в компенсации

Простые в объединении по току

Current-Mode Buck-Regulator Architecture

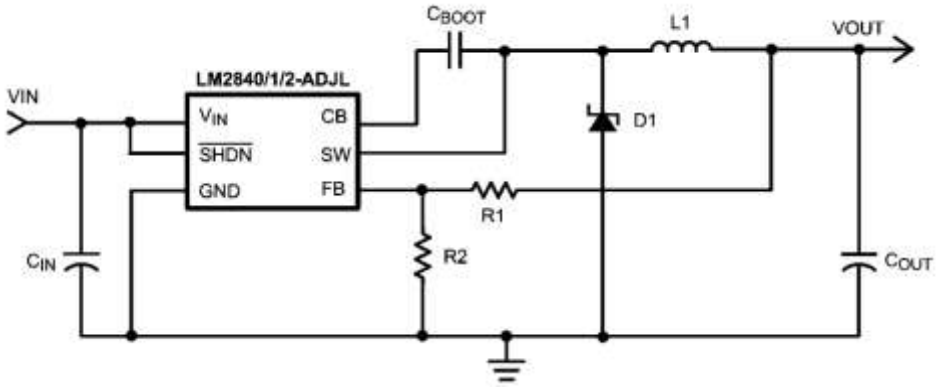


Peak-CMC architecture is used in most of Boost regulators and some Buck like LM28xx

LM2840/41/42
Tiny SOT-23 100-600mA Regulator

Key Features

- Wide Vin range of ***4.5V to 42V***
- ***100mA / 300mA / 600mA*** Output Current
- Internally compensated ***current mode*** control
- Fixed Operating Frequencies: 500kHz / 1.2MHz
- Adjustable output voltage down to 0.75V ±2%
- ***Precision Enable***
- Thermal shutdown
- Stable with Ceramic Capacitors
- Package: ***SOT-23***
- ***Available in AEC-Q100 Grade 1 (Tjmax=125℃)***



Availability / Pricing

Order Code	Load Current [mA]	1K Web Price
LM2840	100	$1.17
LM2841	300	$1.29
LM2842	600	$1.44

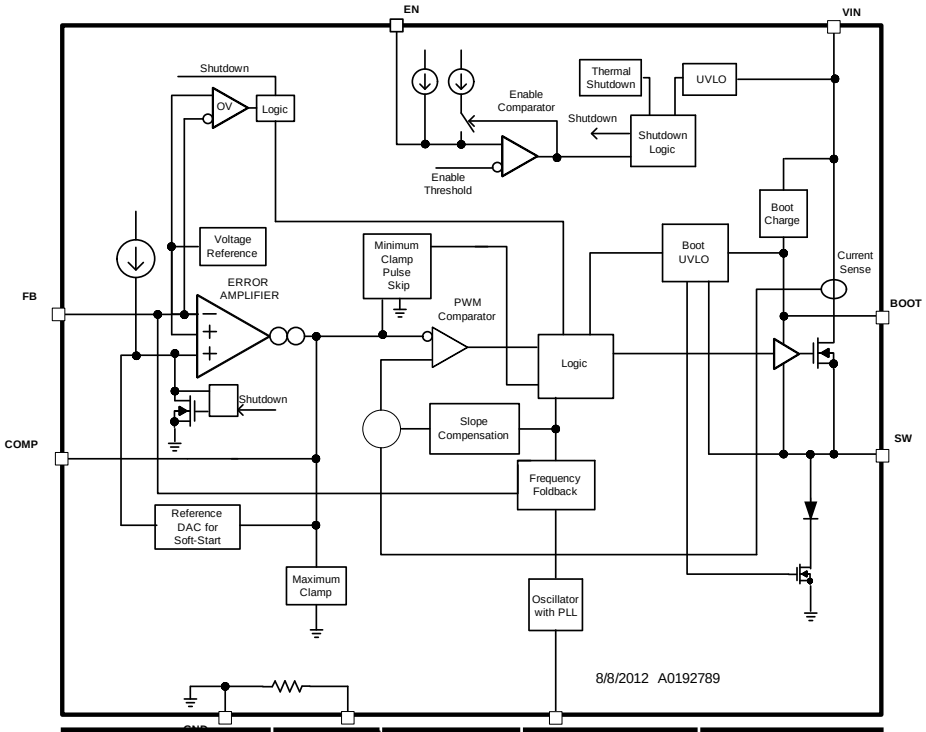
TPS54360/ TPS54560
60V 3.5A DC-DC Regulator with EcoMode

ОСОБЕННОСТИ

- Integrated 92mΩ High Side MOSFET
- Current Mode PWM with Light Load Eco-Mode™
- 146uA No-Load Iq, 1uA Shutdown Iq
- 100 kHz to 2.5 MHz Switching Frequency
- Synchronizes to External Clock
- 1% Accurate Feedback Voltage Reference
- -40 °C to +150 °C Operating Temperature

ПРИМЕНЕНИЯ

- 24/36/48V Industrial Power Systems
- PLC, E-Meter, Security, Automation
- Automotive



Pin to pin compatibility across the family

HSOIC 8

SON10 4mmx4mm

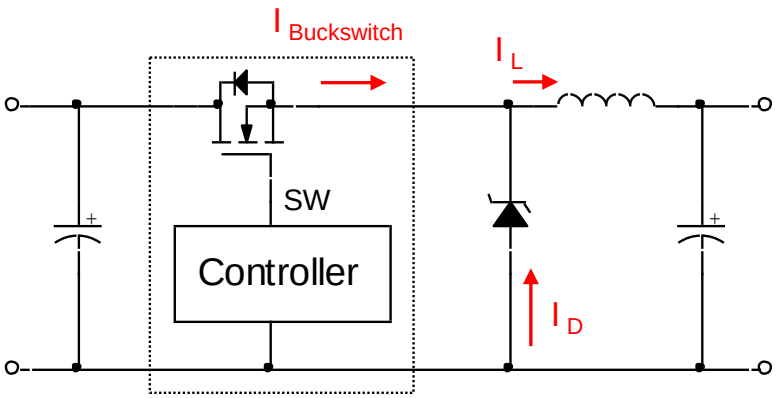
Part Number	Iout (A)	Vin (V)	Package	Release
TPS54360	**3.5**	4.5 - **60**	HSOIC8	Now
TPS54340	**3.5**	4.5 - **42**	HSOIC8	Now
TPS54560	**5.0**	4.5 - **60**	HSOIC8	1Q13
TPS54540	**5.0**	4.5 - **42**	HSOIC8	1Q13

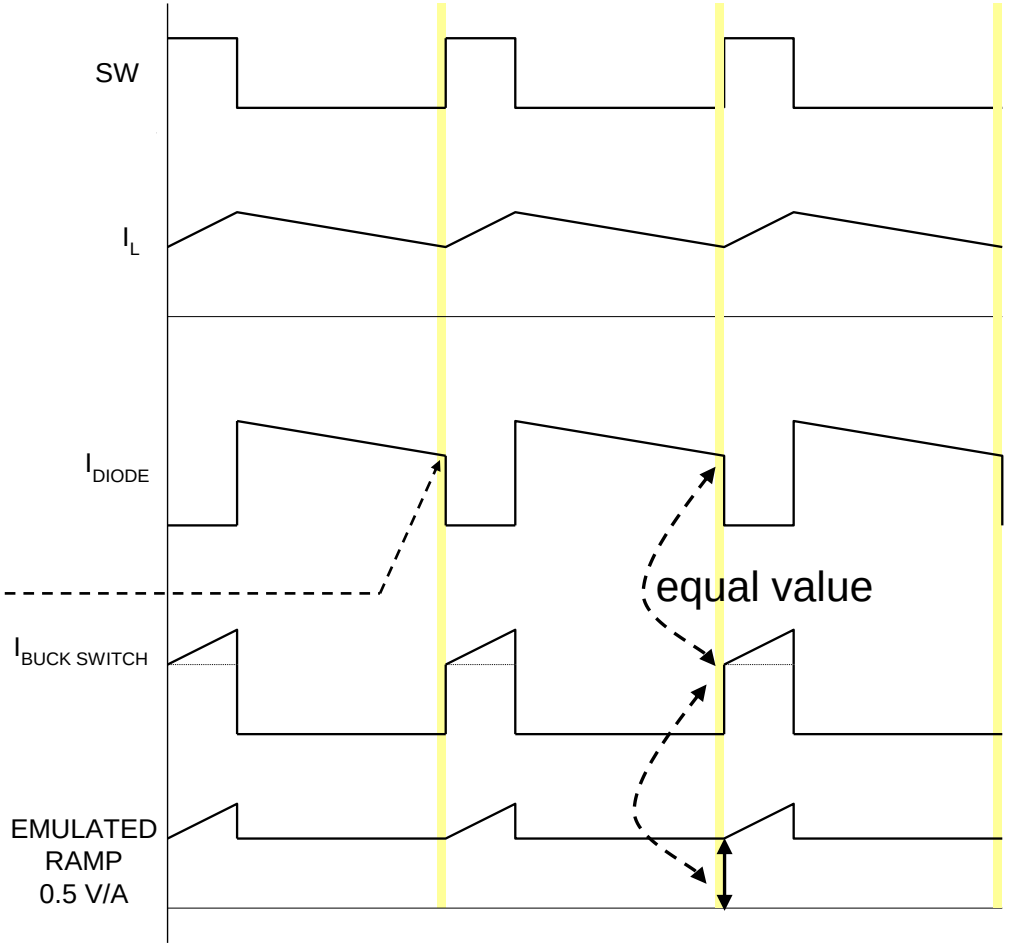
Emulated Current Mode
ECM Regulation

Большие соотношения Vin / Vout

Устойчивость к помехам

Emulated Current Mode Waveforms





Sample and Hold of Diode (Inductor) Current

Due to the high input to output voltage ratios ON-times get too short to derive the regulation signal out of it.

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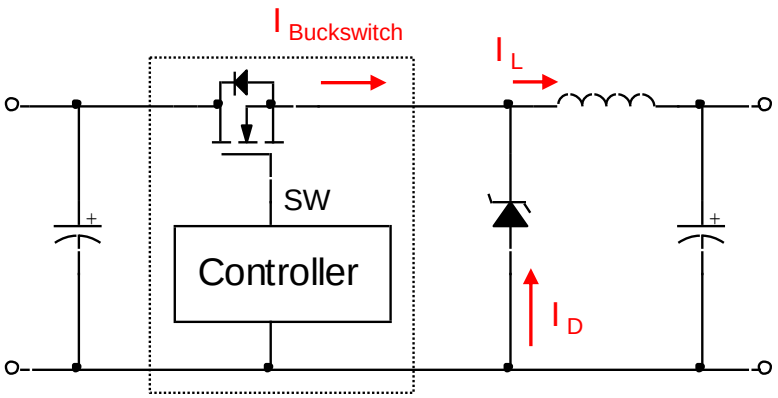
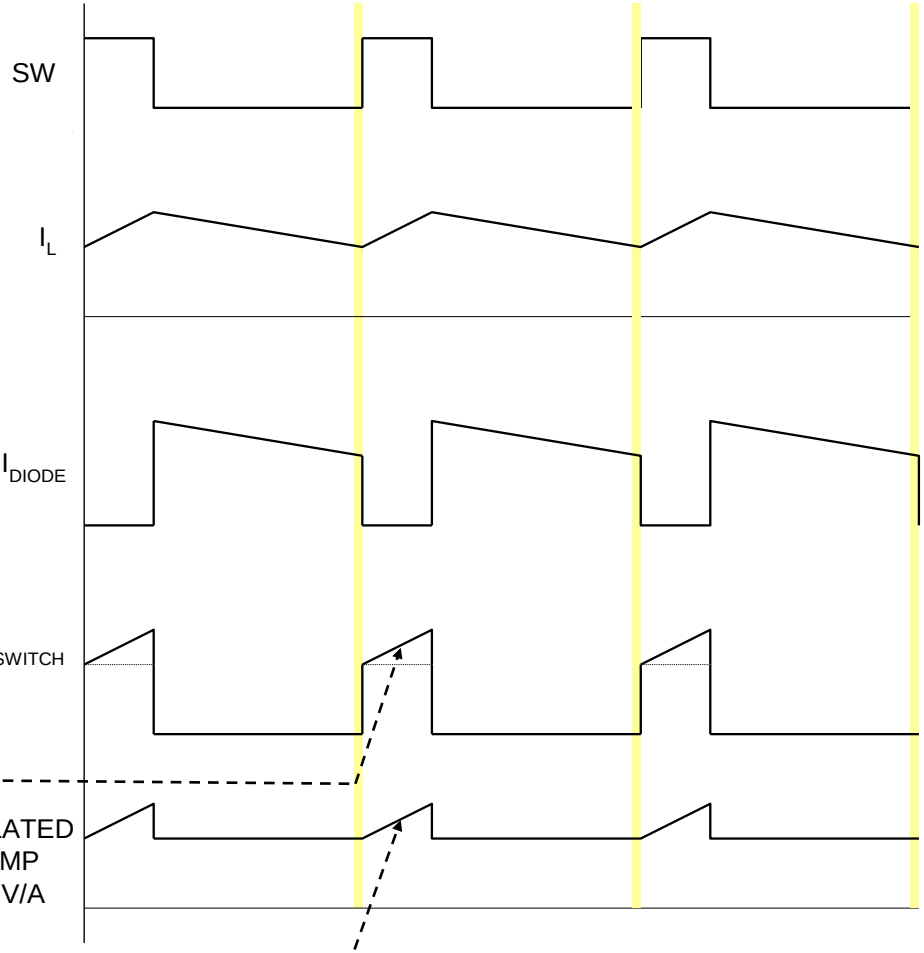
Emulated Current Mode Waveforms



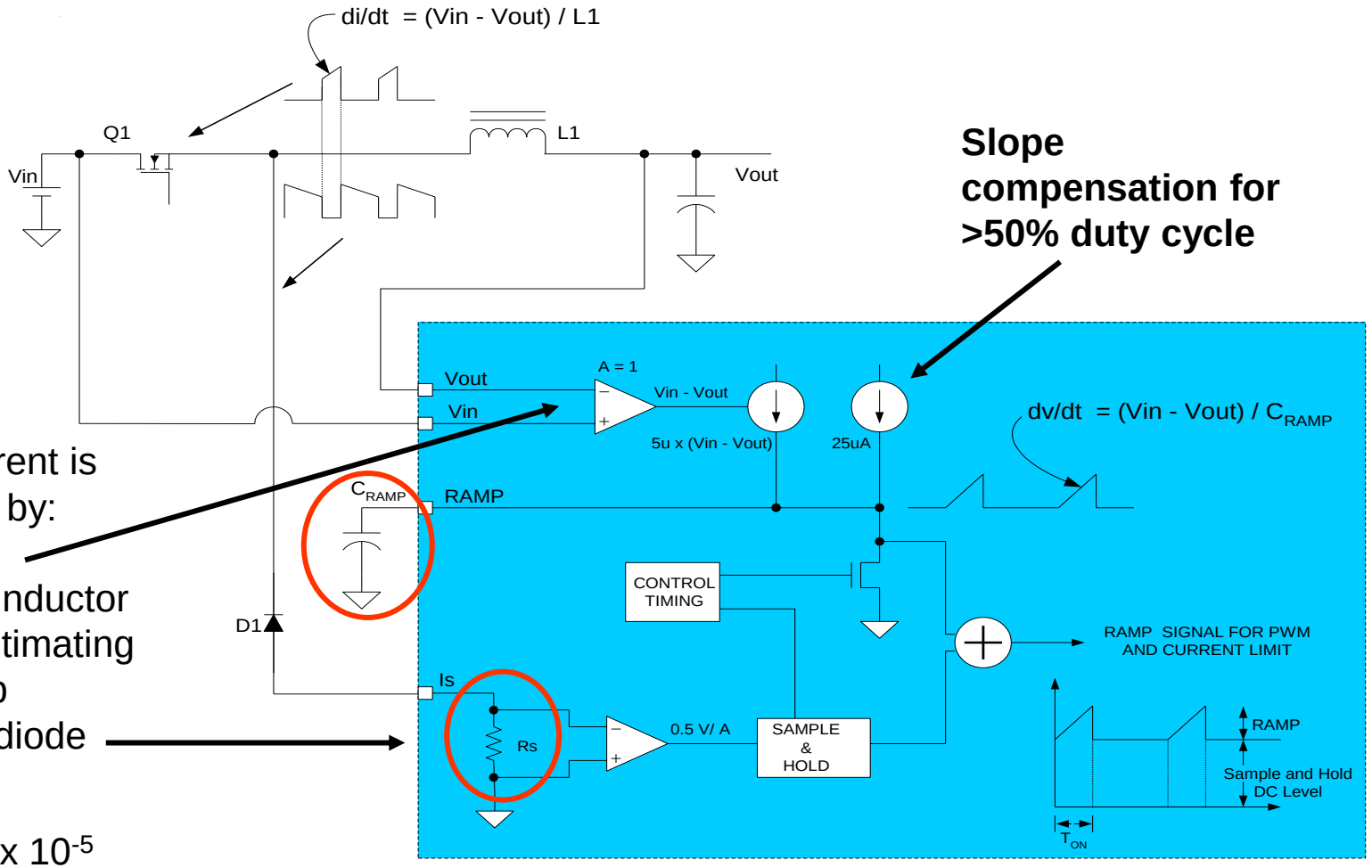
To emulate the ramping portion of the buck switch signal dI/dt needs to be detected.
di/dt = (Vin – Vout) / L



Slope of Inductor Current
dI/dt=(Vin-Vout)/L

Emulated
Inductor Current

Emulated-Current-Mode (ECM)

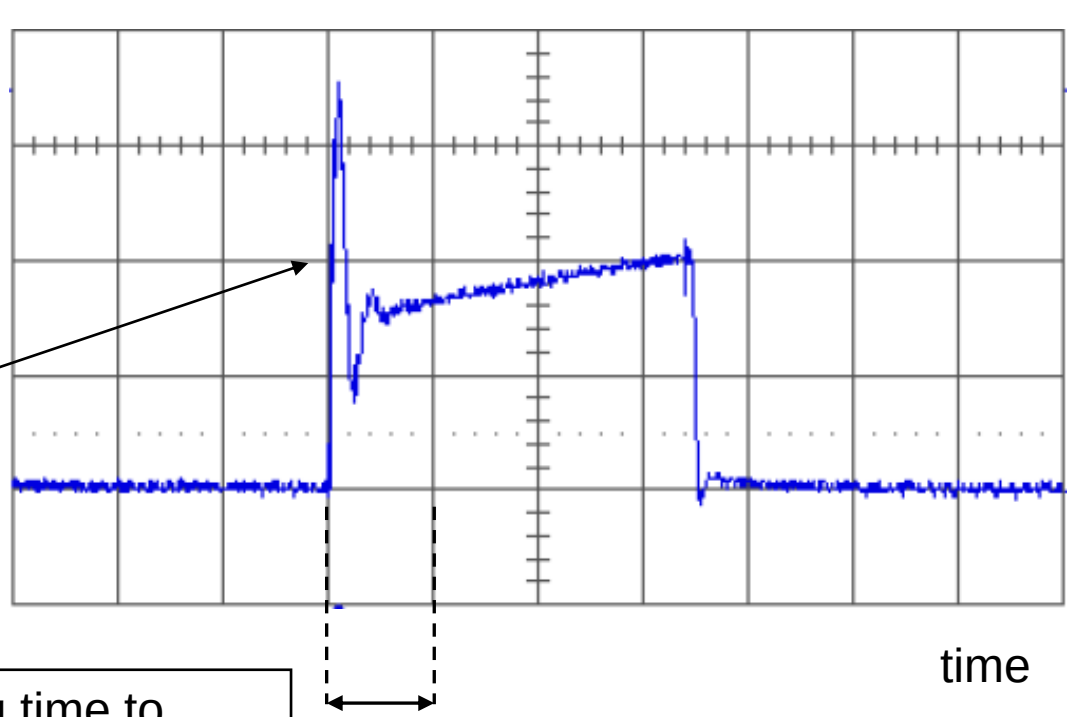


Inductor current is EMULATED by:

- Measuring inductor voltage & estimating current ramp
- Measuring diode current

$C_{RAMP} = L \times 10^{-5}$

Problem in normal Current Mode not a Problem in ECM !

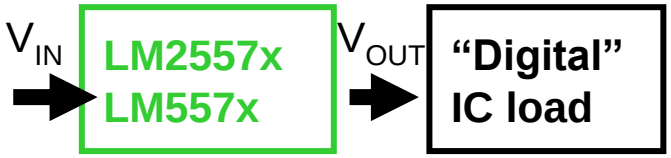


- Mosfet turns ON
- Leading edge spike, from reverse recovery current of diode

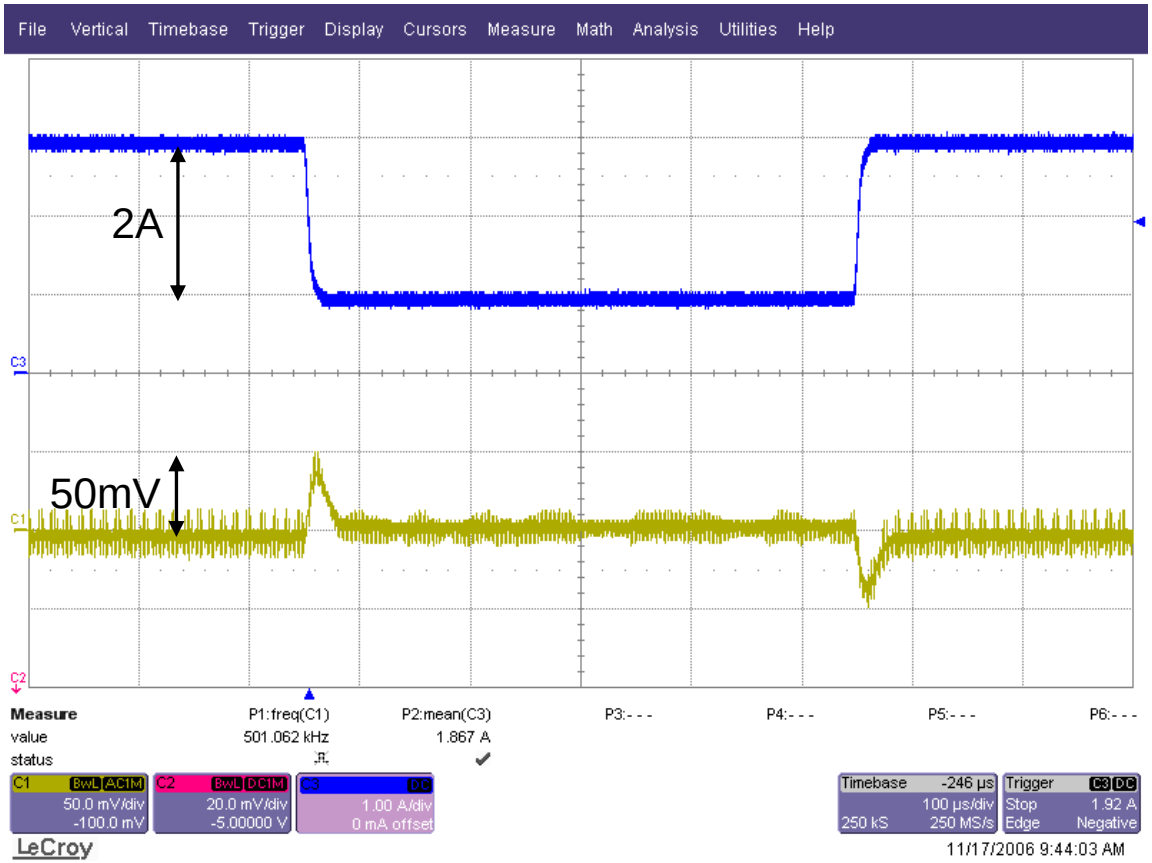
- Blanking time to avoid overdriving the PWM comparator

While current mode control provides better line (input voltage) regulation and better transient response, it is more susceptible to noise.

Benefits of ECM vs.Voltage Mode: LM5576 Transient Response



- V_{IN}=24V
- V_{OUT} = 5V
- < 50mV output transient
- 1 to 3 Amp transient



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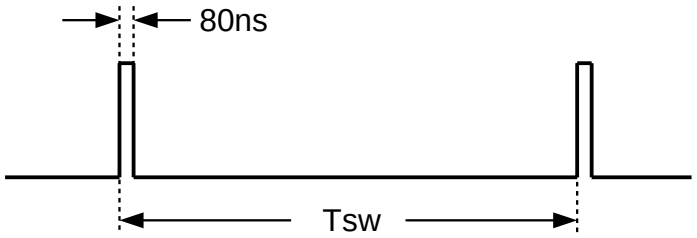
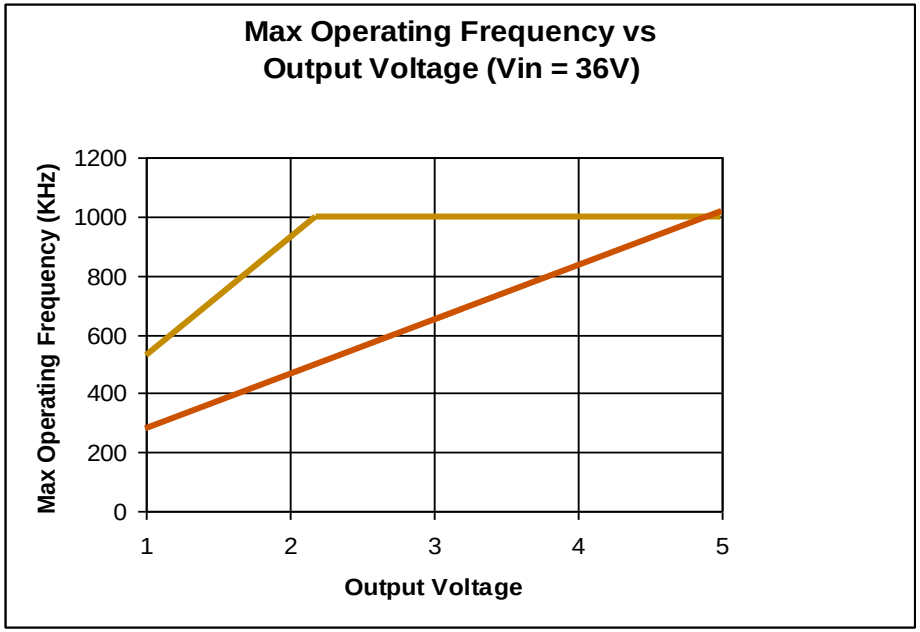
Output Voltage vs. Operating Frequency

- The maximum operating frequency is a function of minimum ON-time & the input and output voltage.
- $f_{sw(max)} = (V_{OUT}+V_{diode}) / (t_{ON(MIN)} * V_{IN(max)})$

Min ON-Time





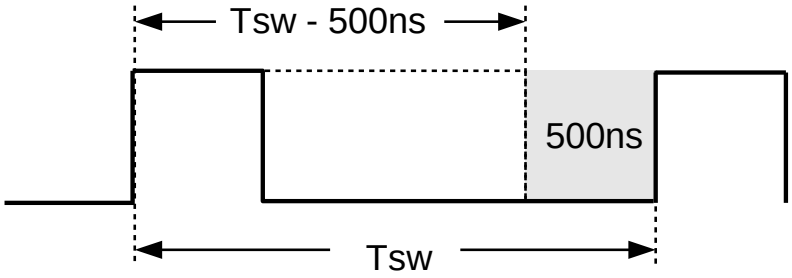
— Min ON time 80ns

— Competitor 2.8MHz switcher, Min ON time 150ns

Texas Instruments

Minimum Input Voltage vs. Operating Frequency

- Forced OFF-Time of 500ns
- To allow time for the sample & hold of the diode current
- The maximum duty cycle is limited for high frequency applications
- The minimum input voltage drop may be limited



$$V_{IN(min)} = (V_{OUT} + V_{diode}) / (1 - f_{sw)} * 500ns)$$

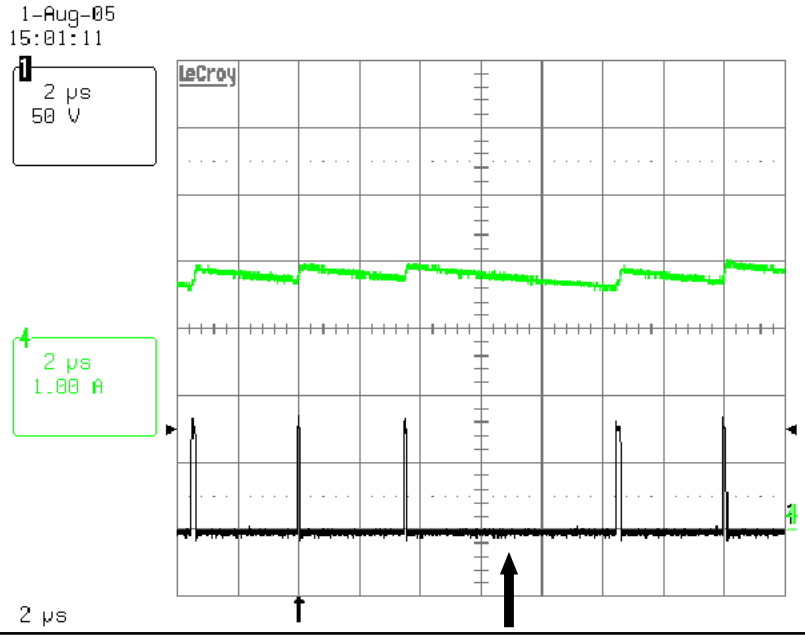
Example1: V_{OUT}=5V, f_{SW}=500kHz, →$V_{IN(min)}$=7V
Example2: V_{OUT}=5V, f_{SW}=800kHz, →$V_{IN(min)}$=9V

Надежная защита по току

- **An additional benefit of ECM is “look-ahead current limiting” since the inductor current is measured prior to the buck switch on-time.**

During high input voltage, extreme short-circuit conditions the buck switch will skip cycles if the inductor current does not decay below the current limit threshold.

Skipping cycles prevents the possibility of runaway inductor current.



Vin = 75V
Output Load = Short Circuit

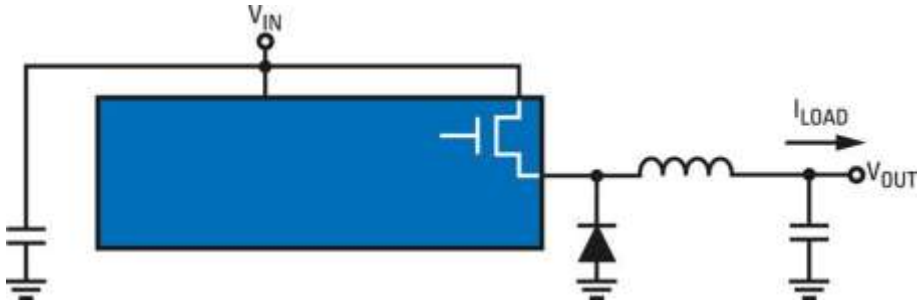
SIMPLE SWITCHER®

LM(2)557x Family

LM2557x / LM557x
SIMPLE SWITCHER® Family

Key Features

- Vin Range ***6V*** to ***42V / 75V***
- Current Outputs: ***0.5A***, ***1.5A***, ***3.0A***
- Internally compensated ***Emulated current mode*** control for huge V_{IN} to V_{OUT} ratio
- Adjustable Output Voltages down to 1.225V
- ***1.5% V_{OUT} Accuracy over full Temperature (Tj=-40°C to +125°C)***
- Enable pin
- ***Adjustable Frequency (50kHz-1MHz / 500KHz)***
- ***Frequency Sync (External or Master/Slave)***
- Adjustable Soft-Start
- Stable with Ceramic Capacitors
- ***Available in AEC-Q100 Grade 1 (Tjmax=125°C) and Grade 0 (Tjmax=150°C)***
- Packages:
  - TSSOP-16, TSSOP-16-EP, TSSOP-20-EP
  - ***Bare Die version available***



Availability / Pricing

Order Code	Load Current [A]	Vin [V]	1K Web Price
LM25574	0.5	42	$1.48
LM5574	0.5	75	$1.75
LM25575	1.5	42	$1.76
LM5575	1.5	75	$2.20
LM25576	3	42	$2.40
LM5576	3	75	$3.05

Заключение:

что для чего использовать?

Заключение: что для чего использовать?

Voltage Mode

- Использовать, если необходима синхронизация или фиксированная частота.
- Для большой скважности предпочительней, чем традиционный токовый режим.
- Максимальная простота реализации на м/к.
- LM2267x, LM21215, LM285x, TPS40007, TPS5430, TPS54610, TPS54310

Voltage Mode (with Voltage Feed Forward)

- Если необходим актуально широкий диапазон рабочих напряжений.
- Автомобильная техника.
- TPS40170, TPS4005x, TPS56221, TPS40400

Current Mode

- Если необходима синхронизация или фиксированная частота.
- Надежная защита, объединение по току. Промавтоматика.
- TPS54620, TPS54160, LM21305, TPS54618, TPS54331

Emulated Current Mode

- Высокая устойчивость к помехам и переходным процессам в нагрузке.
- Высокая частота и скважность. Телеком UPS.
- LM557x, LM2557x, LM5005, LM5117, LM5116

Заключение: что для чего использовать?

Hysteretic

- Минимальная цена. Максимальная скорость реакции. Если частота не критична.
- LM3485, LM3475

DCAP (Constant On Time)

- Лучшее соотношение качество/ цена. Малое количество компонентов.
- Оптимизирован под недорогие компоненты (medium ESR Cout).
- Adaptive COT: TPS51124, TPS51216, TPS53355, TPS53219
- COT: LM2500x, LM5006, LM5007/8/9, LM3100

DCAP2 (Adaptive Constant On Time with Emulated Ripple Mode)

- Высокая устойчивость к помехам, переходным процессам в нагрузке, компоновке и разводке.
- Оптимизирован под керамические конденсаторы небольшой емкости.
- TPS54327/8, TPS54527/8, TPS53114, TPS5312x

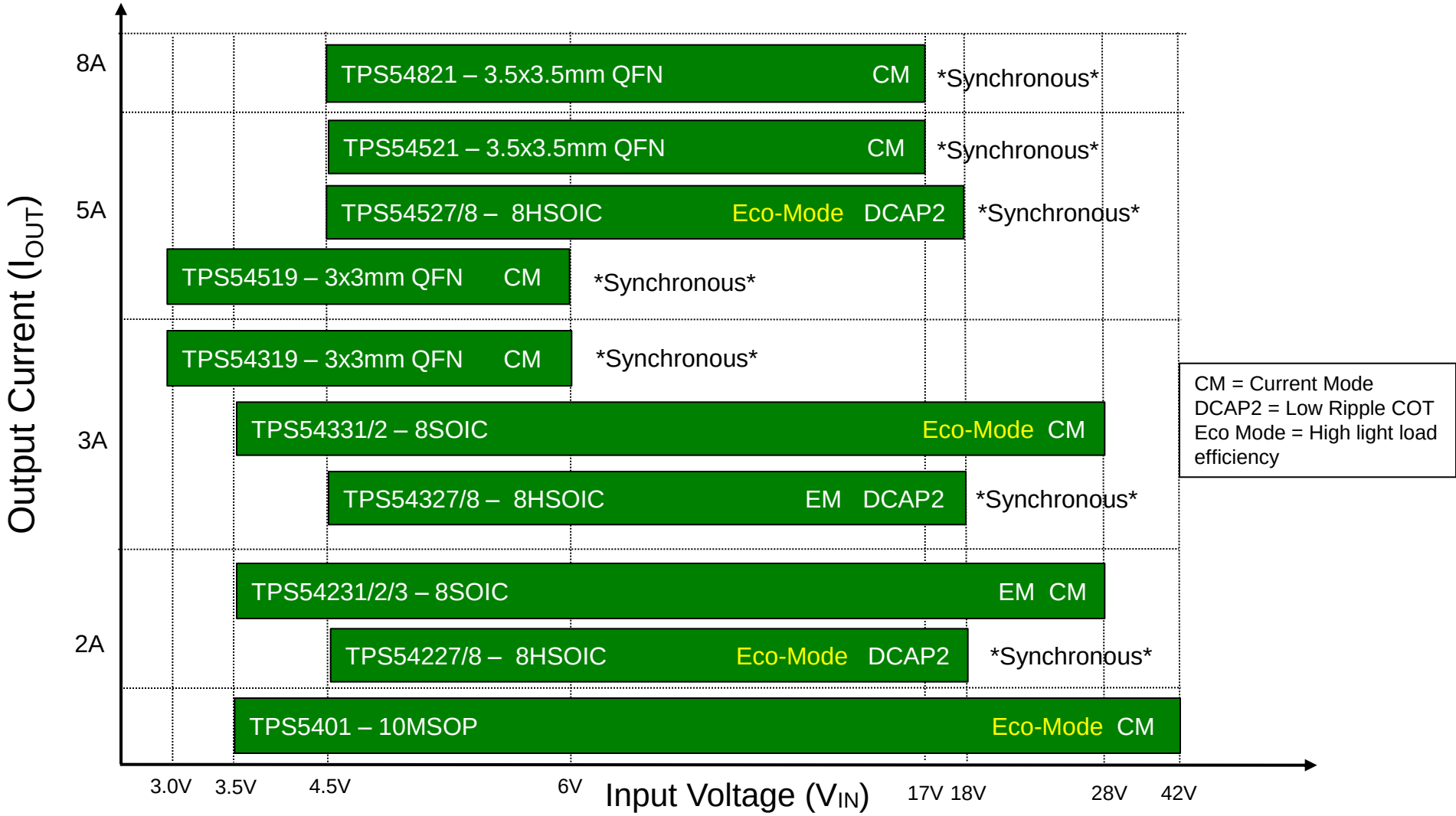
DCS (Direct Control w/ Seamless transition to Power Save Mode)

- Высокий КПД и динамические параметры.
- Портативные устройства.
- TPS62230, TPS62120/30/40/50

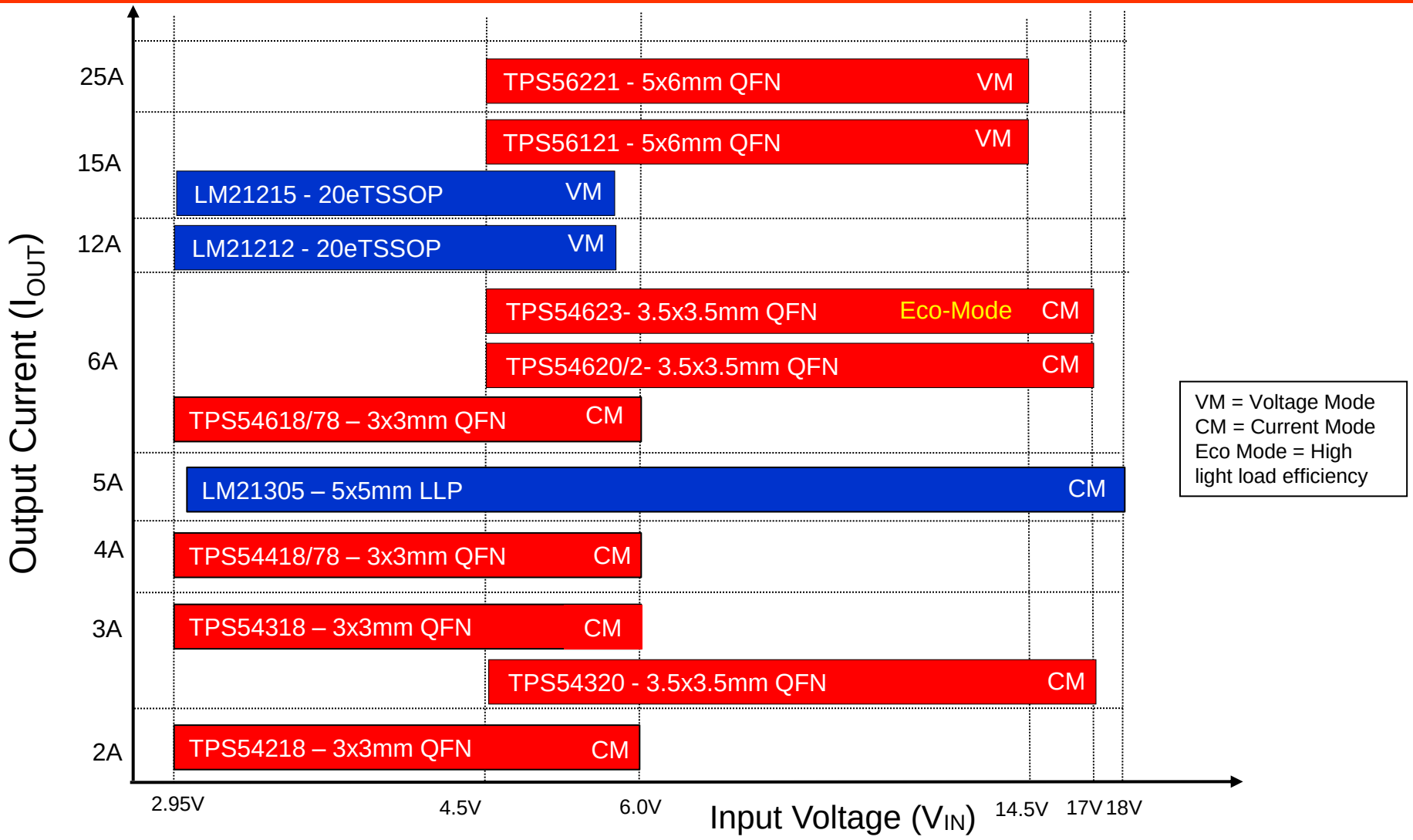
Приложение:

Выбор наиболее популярных компонентов по методам управления

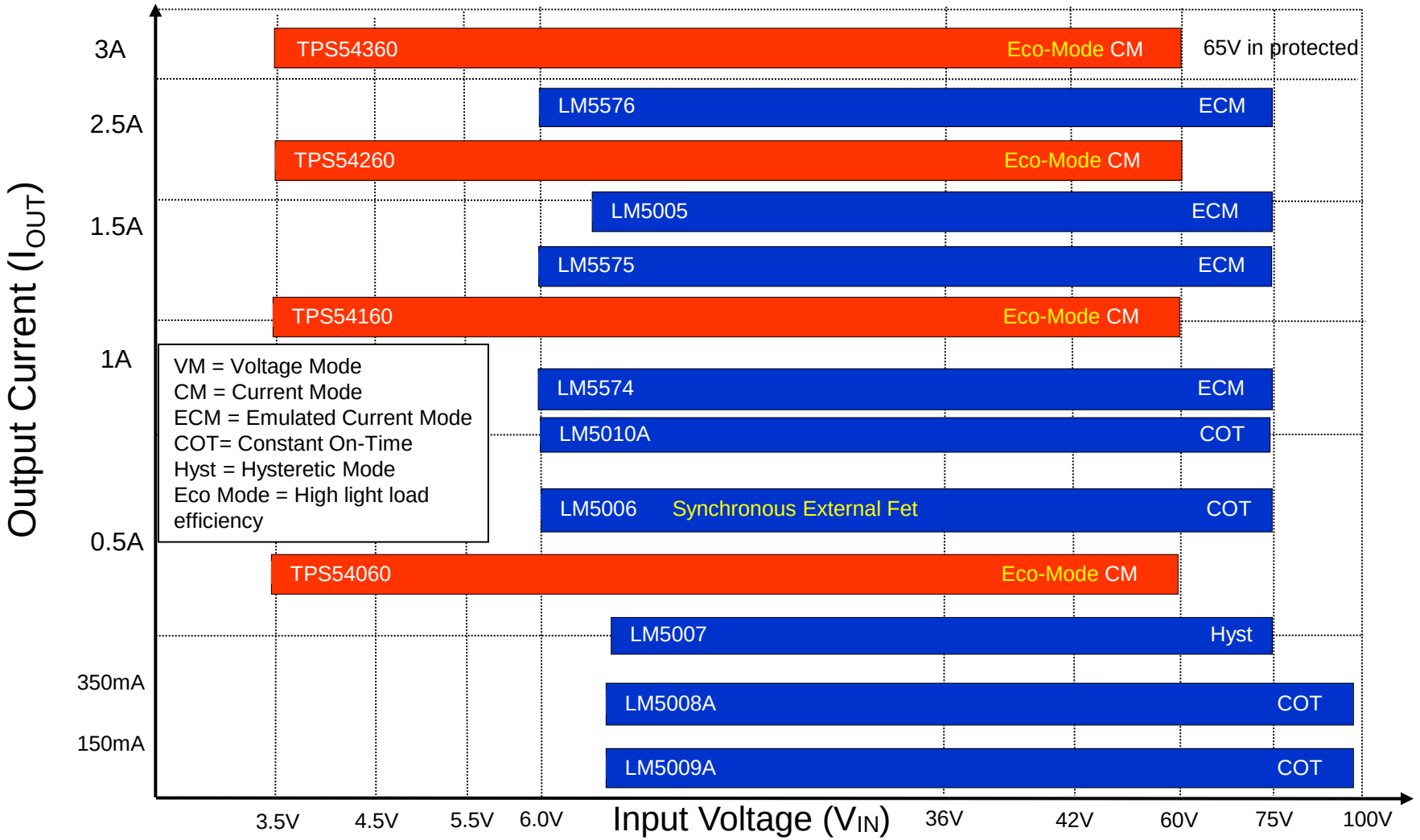
Low Cost Step-Down DC/DC Converters



Synchronous DC/DC Converters (Vin<18V)
(Low/Mid Vin) for DSP / FPGA Power



Industrial DC/DC Converters (Wide Vin)
Non-Synchronous Step-Down Converters > 42V Input



75V in max версии LM5XXX полностью совместимы с 42V версиями LM25XXX.

Спасибо за внимание !