Dual PWM Controller with Short Circuit Restart Function

Halogen Free

General Description

The FP5453 is a single chip composed of a 2.5V precision voltage reference regulator, totem-pole output stages, two pulse width modulation control circuits each with one error amplifier and duty comparator (DTC). Its built-in functions includes under-voltage lockout circuit (UVLO) and programmable auto-restart timer for short circuit protection (SCSAR). With above features, it offers space and low cost solutions in many applications such as the DC / DC converter.

FP5453, a high performance IC, is designed to complete a control circuit with few external components. The circuit diagram of the typical application example is shown in below.

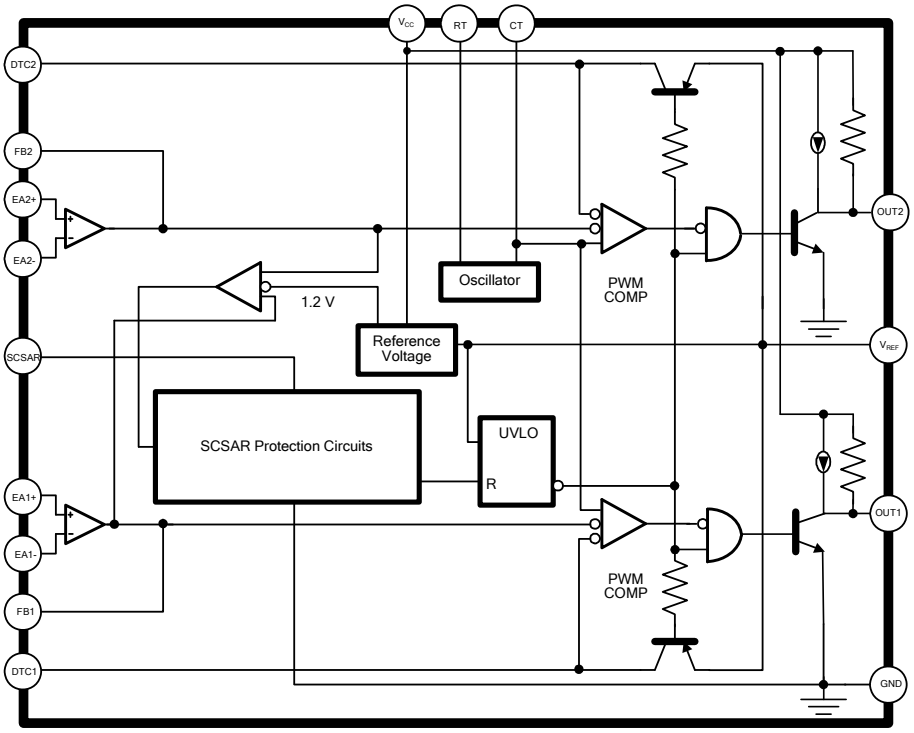
Features

- Wide Operating Voltage Range: 3.6~25V
- Feedback Reference Voltage: 2.5V
- Oscillator Frequency: Max. 1.2MHz
- Reference Voltage Precision: 2%
- Low Quiescent Supply Current Under 4mA
- Totem-pole Output Stage
- Variable Duty Control (DTC)
- Short Circuit Shutdown / Auto Re-start Function (SCSAR)
- UVLO Protection Function
- Package: SOP-16L / SOP-16L (EP) / SSOP-16L

Applications

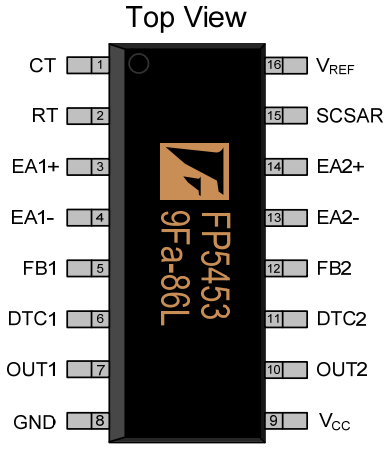
- HUB / Router
- Set Top Box
- HDD Server
- CATV

Function Block Diagram



Pin Descriptions

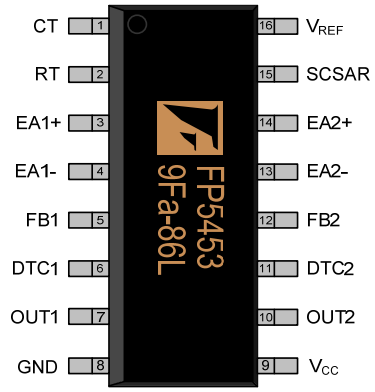
SOP-16L



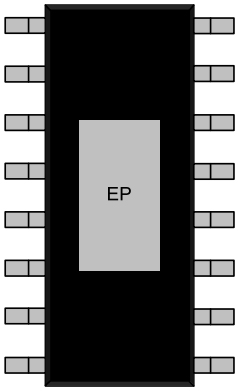
Name	No.	I / O	Description
CT	1	I	Connect a Capacitor to This Pin to Adjust Oscillator Frequency
RT	2	I	Connect a Resistor to This Pin to Adjust Oscillator Frequency
EA1+	3	I	Error Amplifier 1 Non-inverting Input
EA1-	4	I	Error Amplifier 1 Inverting Input
FB1	5	O	Error Amplifier 1 Output
DTC1	6	I	Output 1 Duty Comparator
OUT1	7	O	Totem-pole Output 1
GND	8	P	IC Ground
V_{CC}	9	P	IC Power Supply
OUT2	10	O	Totem-pole Output 2
DTC2	11	I	Output 2 Duty Comparator
FB2	12	O	Error Amplifier 2 Output
EA2-	13	I	Error Amplifier 2 Inverting Input
EA2+	14	I	Error Amplifier 2 Non-inverting Input
SCSAR	15	I	Short Circuit Protection Input
V_{REF}	16	O	2.5V Reference Voltage Output

SOP-16L (EP)

Top View



Bottom View



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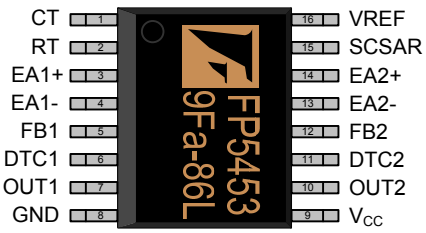
GND	8	P	IC Ground
V_{CC}	9	P	IC Power Supply
OUT2	10	O	Totem-pole Output 2
DTC2	11	I	Output 2 Duty Comparator
FB2	12	O	Error Amplifier 2 Output
EA2-	13	I	Error Amplifier 2 Inverting Input
EA2+	14	I	Error Amplifier 2 Non-inverting Input
SCSAR	15	I	Short Circuit Protection Input
V_{REF}	16	O	2.5V Reference Voltage Output
EP	17	P	Exposed PAD. Must be connected to GND

SSOP-16L

Top View



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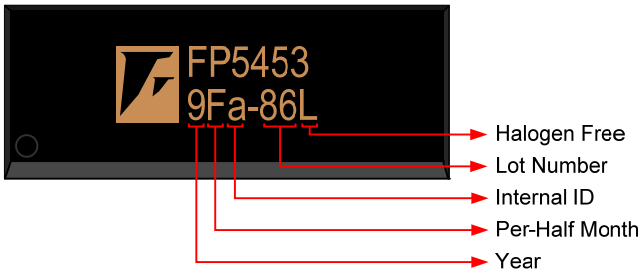
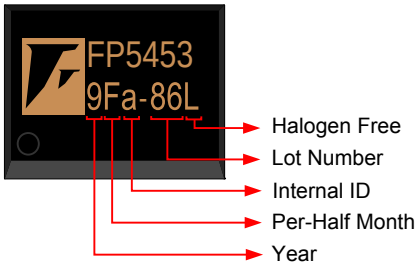
SCSAR	15	I	Short Circuit Protection Input
V_{REF}	16	O	2.5V Reference Voltage Output

Marking Information

SOP-16L & SOP-16L (EP)



SSOP-16L



Halogen Free: Halogen free product indicator

Lot Number: Wafer lot number's last two digits

For Example: 132386TB → 86

Internal ID: Internal Identification Code

Per-Half Month: Production period indicated in half month time unit

For Example: January → A (Front Half Month), B (Last Half Month)

February → C (Front Half Month), D (Last Half Month)

Year: Production year's last digit

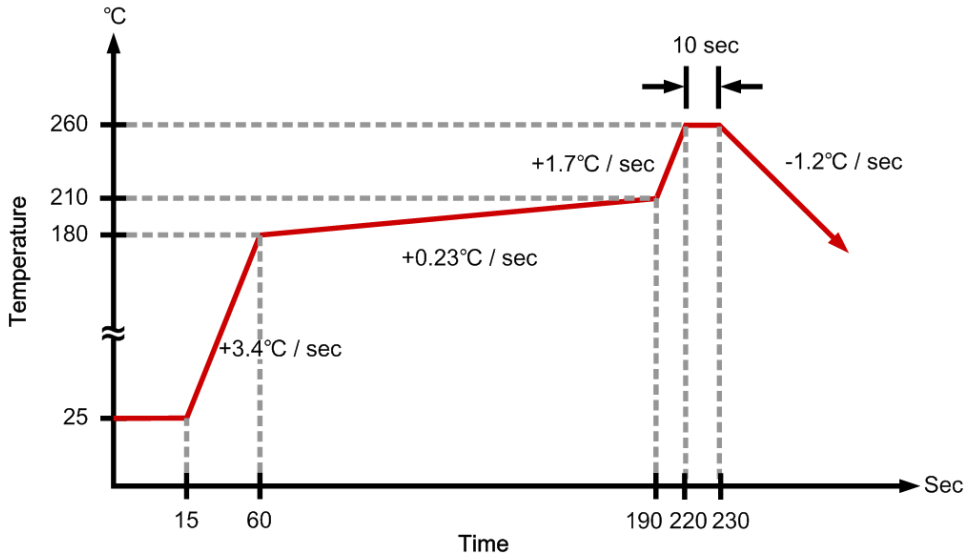
Ordering Information

Part Number	Operating Temperature	Package	MOQ	Description
FP5453DR-LF	-20°C ~ +85°C	SOP-16L	2500EA	Tape & Reel
FP5453XR-LF	-20°C ~ +85°C	SOP-16L (EP)	2500EA	Tape & Reel
FP5453RR-LF	-20°C ~ +85°C	SSOP-16L	2500EA	Tape & Reel

Absolute Maximum Ratings

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Power Supply Voltage	V_{CC}		3.6		26	V
Differential Input Voltage	V_{id}				3	V
Output Current	Io				150	mA
Maximum Junction Temperature	T_J				+150	°C
Thermal Resistance Junction to Ambient	θ_{JA}	SOP-16L			+90	°C / W
		SOP-16L (EP)			+50	°C / W
		SSOP-16L			+110	°C / W
Thermal Resistance Junction to Case	θ_{JC}	SOP-16L			+45	°C / W
		SOP-16L (EP)			+7	°C / W
		SSOP-16L			+55	°C / W
Maximum Power Dissipation	P_D	SOP-16L , T_A=25℃			830	mW
		SOP-16L (EP)			1.4	W
		SSOP-16L, T_A=25℃			570	mW
Storage Temperature Range			-65		+150	℃
Lead Temperature (soldering, 10 sec)					+260	℃

Suggested IR Re-flow Soldering Curve



Recommended Operating Conditions

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply Voltage			3.6		25	V
Operating Temperature			-20		+85	℃

DC Electrical Characteristics (V_{CC}= 6V, f=200kHz, unless otherwise noted)

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Reference section						
Output Voltage (pin 16)	V_{REF}	I_O=1mA	2.45	2.5	2.55	V
Output Voltage Change with Temperature		T_A=-20℃ to +25℃		-0.1	±1	%
		T_A=+25℃ to +85℃		-0.2	±1	%
Input Voltage Regulation	$\triangle V_{REF}$ / V_{REF}	V_{CC}=3.6V～25V		2	12.5	mV
Output Voltage Regulation	$\triangle V_{REF}$ / V_{REF}	Io = 0.1mA to 1 mA		3	8	mV
Short-circuit Output Current	I_{SHORT}	V_O=0	3	10	30	mA
Under Voltage Lockout Section						
Upper threshold voltage(V_{CC})	V_{UPPER}	$I_{O\ (REF)}$ = 0.1 mA, T_A=25℃		3.2		V
Lower threshold voltage(V_{CC})	V_{LOW}			3.0		V
Hysteresis (V_{CC})	V_{HYS}		100	200		mV
Short-circuit Protection Control Section						
SCP re-Start Voltage	V_{RS}	V_{FB1} or V_{FB2} <1.5V		0.5		V
SCP Threshold Voltage	V_{TH}	V_{FB1} or V_{FB2} <1.5V		1.0		V
SCP Re-start Charge Current	I_{RSC}	V_{FB1} or V_{FB2} <1.5V		20		μA
SCP Re-start / Hold Time ratio	T_{RS} / T_{HOLD}	V_{FB1} or V_{FB2} <1.5V		1 / 50		-
SCP Comparator 1 Threshold Voltage	$V_{COMP\ (TH)}$			1.2		V
Oscillator Section						
Frequency	f	C_T=330pF, R_T=10K		200		KH_Z
Frequency Change with Voltage	$\triangle f$ / $\triangle V$	V_{CC}=3.6V to 25V		0.2		%
Frequency Change with Temperature	$\triangle f$ / $\triangle T$	T_A=-20℃ to 25℃		-0.4	±2	%
		T_A=25℃ to 85℃		-0.2	±2	%
Duty Control Section						
Input Bias Current (DTC)	I_{BIAS}				1	μA
Input Threshold Voltage	V_{TH}	Zero Duty Cycle		2.0	2.20	V
		Maximum Duty Cycle	1.2	1.4		V

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Error Amplifier Section						
Input Offset Voltage	V_{IO}	V_{FB}=1.25V			±6	mV
Input Offset Current	I_{IO}	V_{FB}=1.25V			±100	nA
Input Bias Current	I_{BIAS}	V_{FB}=1.25V		160	500	nA
Common-mode input voltage range	V_{ICM}	V_{CC}=3.6V to 25 V	1.0		1.5	
Open-loop Voltage Amplification	A_{VO}		70	80		dB
Unity-Gain Bandwidth	BW			1.5		MH_Z
Positive Output Voltage Swing	V_{POS}		V_{REF}-0.3			V
Negative Output Voltage Swing	V_{NEG}				1	V
Output (Sink) Current (Feedback Pin)	I_{SINK}	V_{ID}= -0.1V, V_O=1.25V	2	3		mA
Output (Source) Current (Feedback Pin)	I_{SOURCE}	V_{ID}=0.1V, V_O=1.25V	-100	-140		μA
Output Section						
V_{OUT} Low Voltage	V_{OL}	I_{SINK}=20mA		0.18	0.2	V
		I_{SINK} =130mA, V_{CC}=15V		1.7	2.0	V
V_{OUT} High Voltage	V_{OH}	I_{SOURCE} =20mA	4.0	4.5		V
		I_{SOURCE} =130mA, V_{CC}=15V	12.8	13.4		V
Rise Time	t_R	T_J=25°C, C_L=1nF		50	100	nS
Fall Time	t_F	T_J=25°C, C_L=1nF		50	100	nS
PWM Comparator Section						
Input Threshold Voltage at f=10kHz (Feedback)	V_{TH}	Zero Duty Cycle		2.0	2.20	V
		Maximum Duty Cycle	1.2	1.4		V
Total Device						
Standby Supply Current	$I_{STANDBY}$	Off-state		4.0	5.5	mA
Average Supply Current	I_{AVE}	R_T=10K		4.5	6.0	mA

Typical Operating Characteristics

TRIANGLE OSCILLATOR FREQUENCY
VS
TIMING RESISTANCE

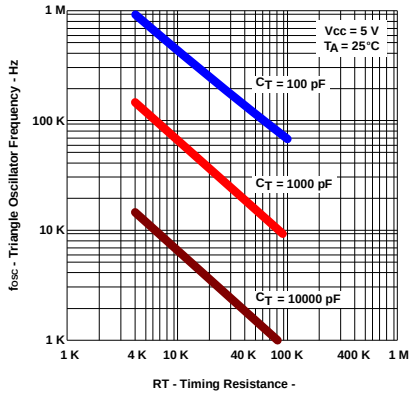


Figure 1

OSCILLATOR FREQUENCY VARIATION
VS
FREE-AIR TEMPERATURE

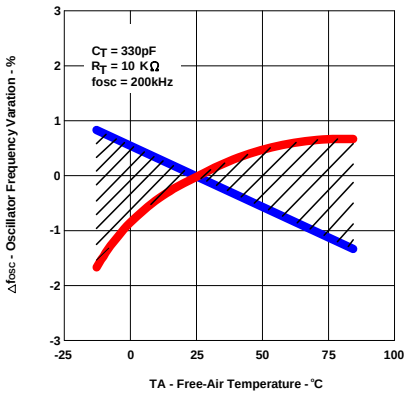


Figure 2

TRIANGLE WAVEFORM SWING VOLTAGE
VS
TIMING CAPACITANCE

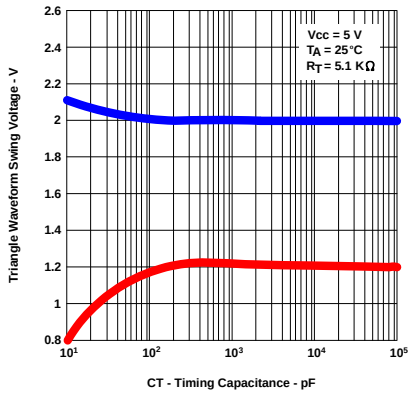


Figure 3

TRIANGLE WAVEFORM PERIOD
VS
TIMING CAPACITANCE

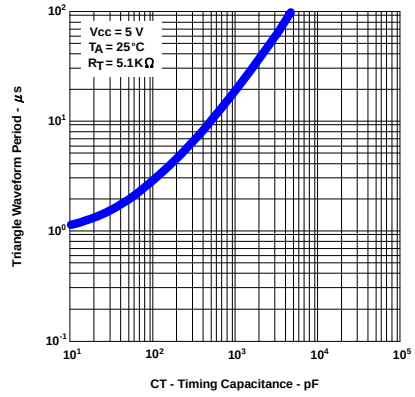


Figure 4

REFERENCE OUTPUT VOLTAGE VARIATION
VS
FREE-AIR TEMPERATURE

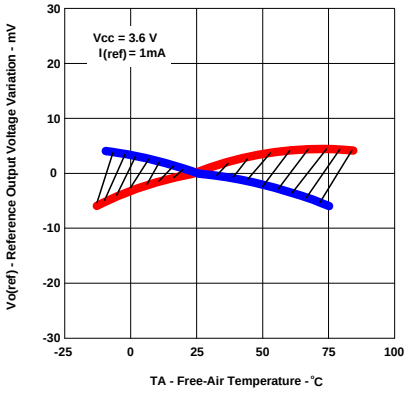


Figure 5

REFERENCE OUTPUT VOLTAGE VARIATION
VS
FREE-AIR TEMPERATURE

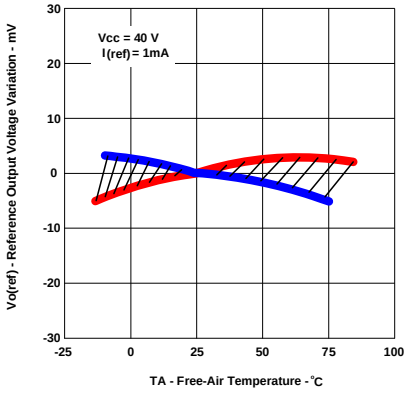


Figure 6

REFERENCE OUTPUT VOLTAGE
VS
SUPPLY VOLTAGE

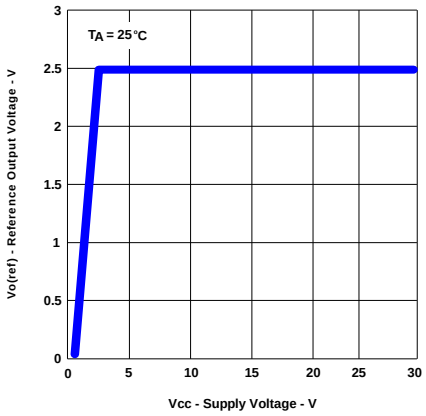


Figure 7

UNDERVOLTAGE LOCKOUT
HYSTERESIS CHARACTERISTICS

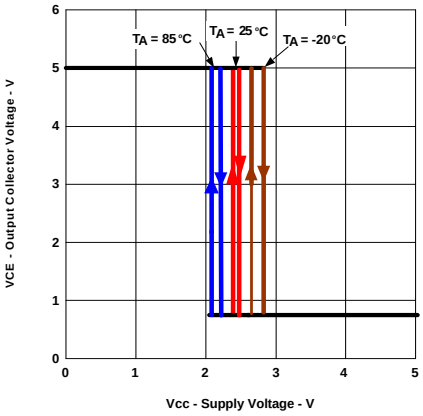


Figure 8

ERROR AMP MAXIMUM
OUTPUT VOLTAGE SWING
VS
FREQUENCY

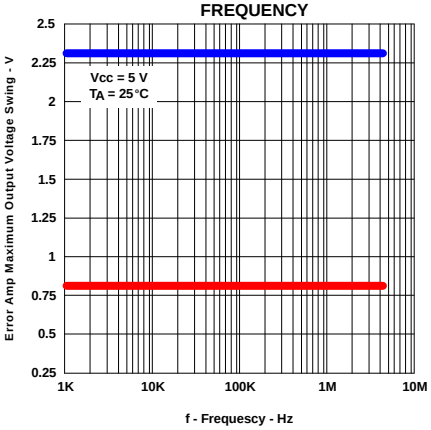


Figure 9

OUTPUT TRANSISTOR ON DUTY CYCLE
VS
DEAD - TIME INPUT VOLTAGE

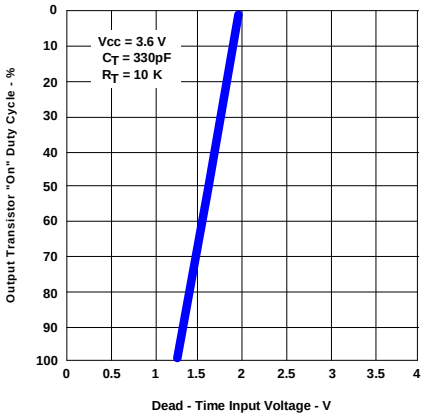


Figure 10

STANDBY CURRENT
VS
SUPPLY VOLTAGE

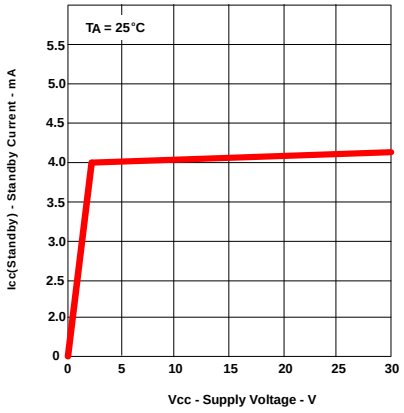


Figure 11

STANDBY CURRENT
VS
FREE - AIR TEMPERATURE

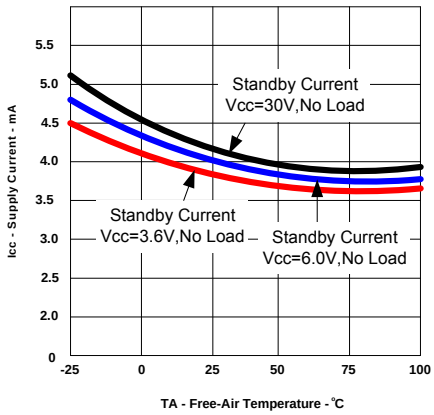


Figure 12

Timing Waveform

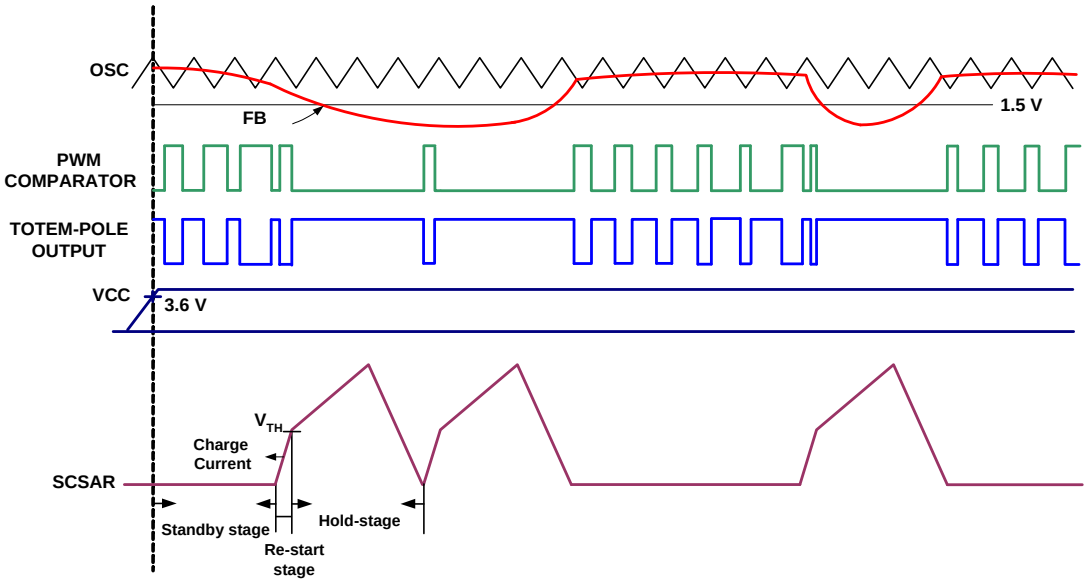


Figure 13. FP5453 Timing Diagram

Function Description

Voltage Reference

FP5453 includes an internal 2.5V reference regulator to provide its internal circuits' voltage bias. It also can be used with external resistive divider which connecting to the IC error amplifier inverting input to provide output feedback reference (see Fig 14).

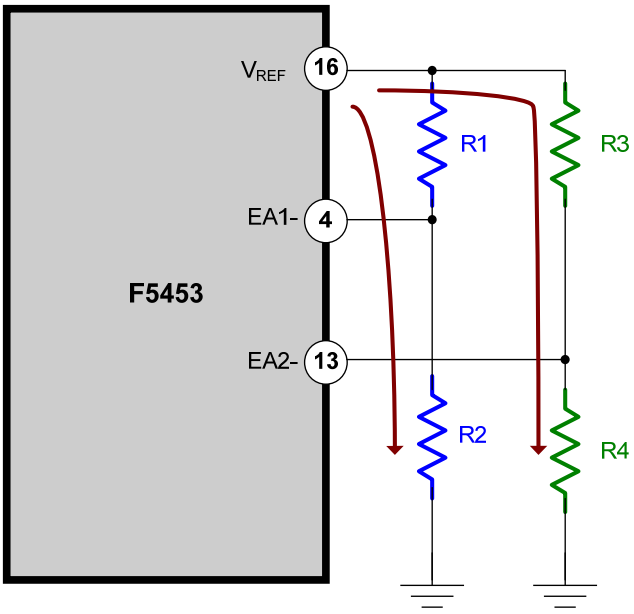


Figure 14 Reference and Error Amplifiers with Resistive Dividers

The error amplifier inverting input (EA1- or EA2-) reference voltage equations are shown as followings:

$$V_{EA1-} = V_{REF}(2.5V) \times \frac{R2}{R1+R2}$$

$$V_{EA2-} = V_{REF}(2.5V) \times \frac{R4}{R3+R4}$$

Error Amplifier

The error amplifiers of FP5453 compare the feedback voltage from the resistive dividers of DC-DC converter's output with the reference bias (see Fig 15) and generate the error signals for the PWM comparators.

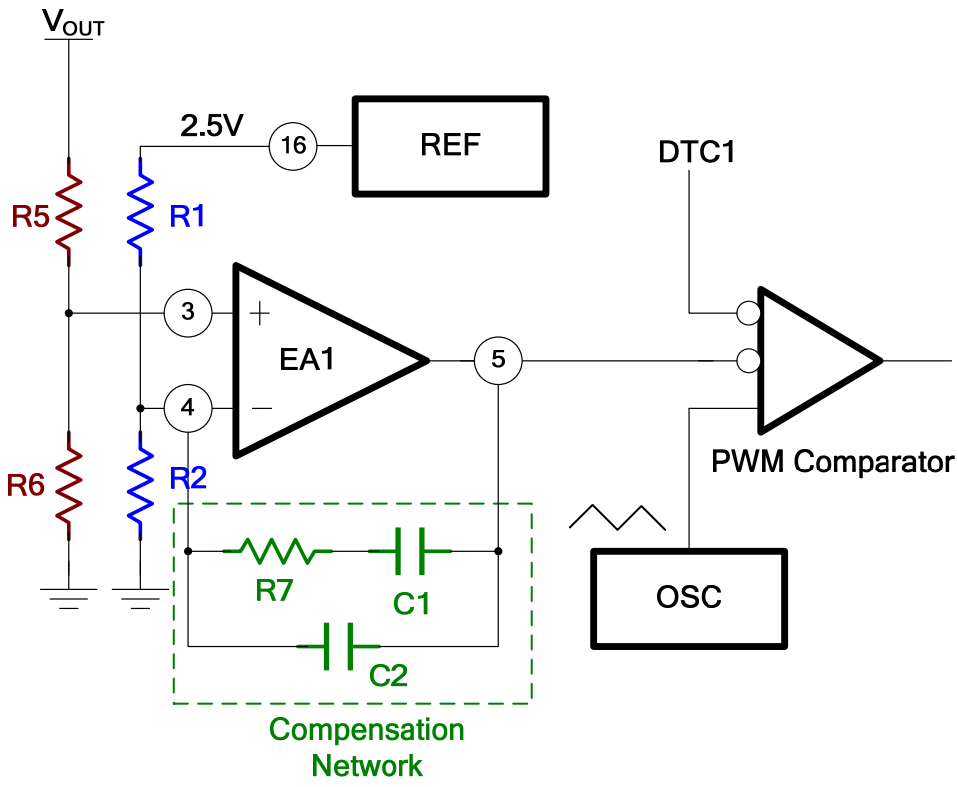


Figure 15 Error Amplifier with Feedback / Compensation Circuits

The Buck converter output voltage:

$$V_{OUT} = \left(1+\frac{R5}{R6}\right)\times\left(\frac{R2}{R1+R2}\right)\times 2.5V$$

Error Amplifier Gain:

$$Av = 1+\frac{1+sR7C1}{sRi(C1+C2)(1+sR7C2)} \quad , Ri=R1//R2$$

Error Amplifier Zero and Pole Frequency:

$$F_Z = \frac{1}{2\pi R7C1}, \qquad Fp = \frac{1}{2\pi R7C2}$$

Oscillator / PWM Comparator

The oscillator frequency can be adjusted from 20KHz to 1.2MHz by the capacitor (CT) and resistor (RT) which are connected to pin 1 and pin 2 of FP5453 respectively. A sawtooth waveform would compare with output signal of the error amplifier and duty control voltage. Figure 16 shows the relationship of oscillator, error amplifier and PWM comparator. Figure 17 shows the FP5453 pin waveforms.

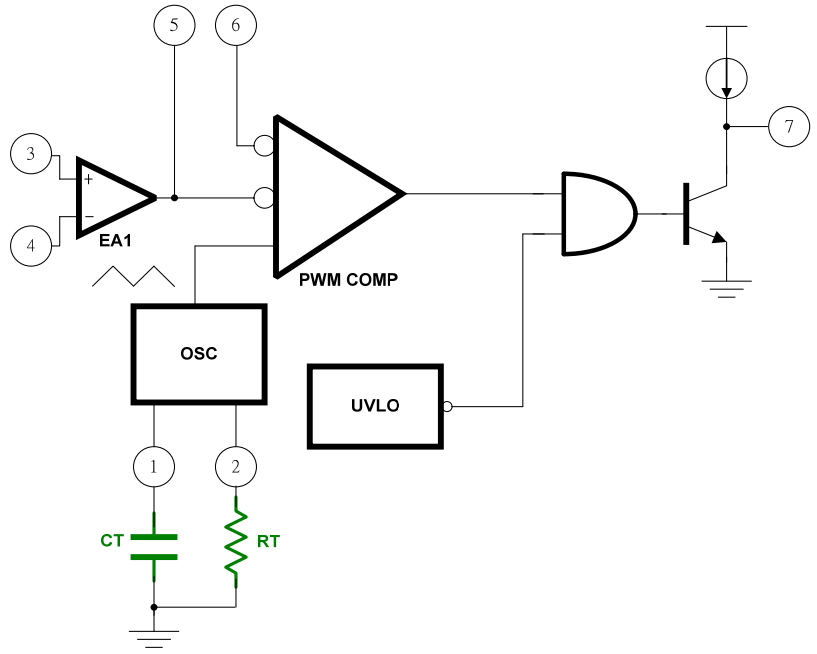


Figure 16 Oscillator / PWM Comparator with Frequency RC Circuits

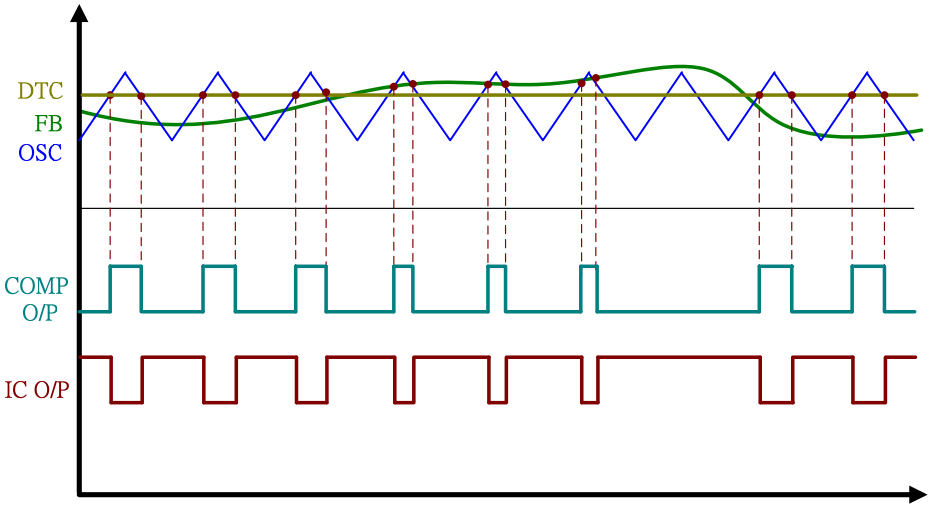


Figure 17 FP5453 Timing Waveforms

The relationship of oscillator waveform and duty voltage is shown below (see Fig 18):

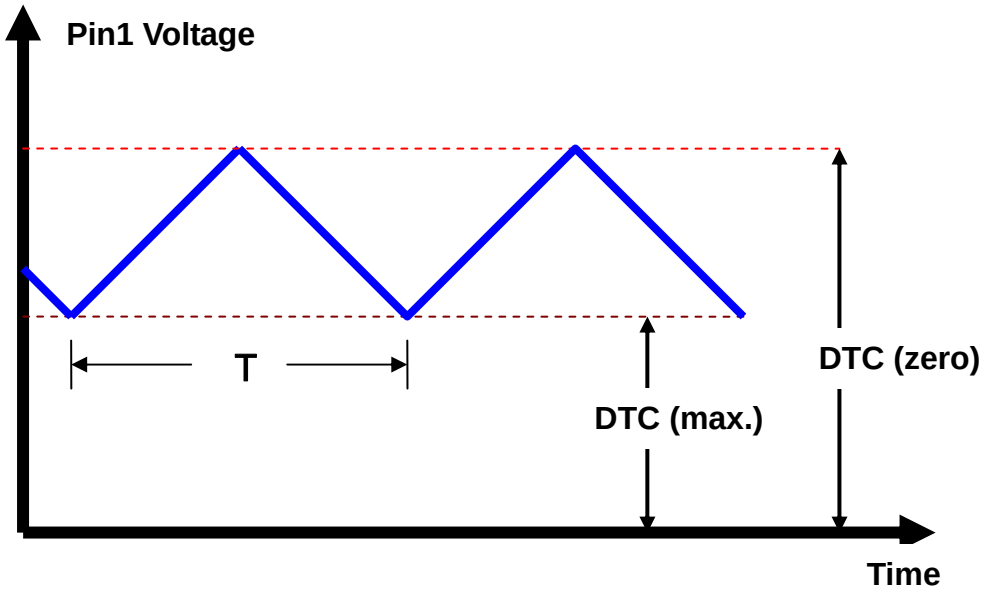


Figure 18. Oscillator Frequency with DTC Voltage

The oscillator frequency can be calculated by:

$$f = \frac{VT}{2 \times CT \times RT \times (Vzero - V\,max.)}$$

Duty Control / Soft-Start

The duty control (DTC) is a function for the PWM duty cycle limitation. If the DTC voltage is lower than DTC maximum voltage (1.35V typically), the PWM duty cycle can be as large as 100% cycle. If the DTC voltage is higher than DTC zero voltage (2.0V typically), the PWM duty cycle will always be turned-off (zero duty).

The system of DC-DC converter can use DTC function with an external RC for Power-On soft-start (see Fig 19).

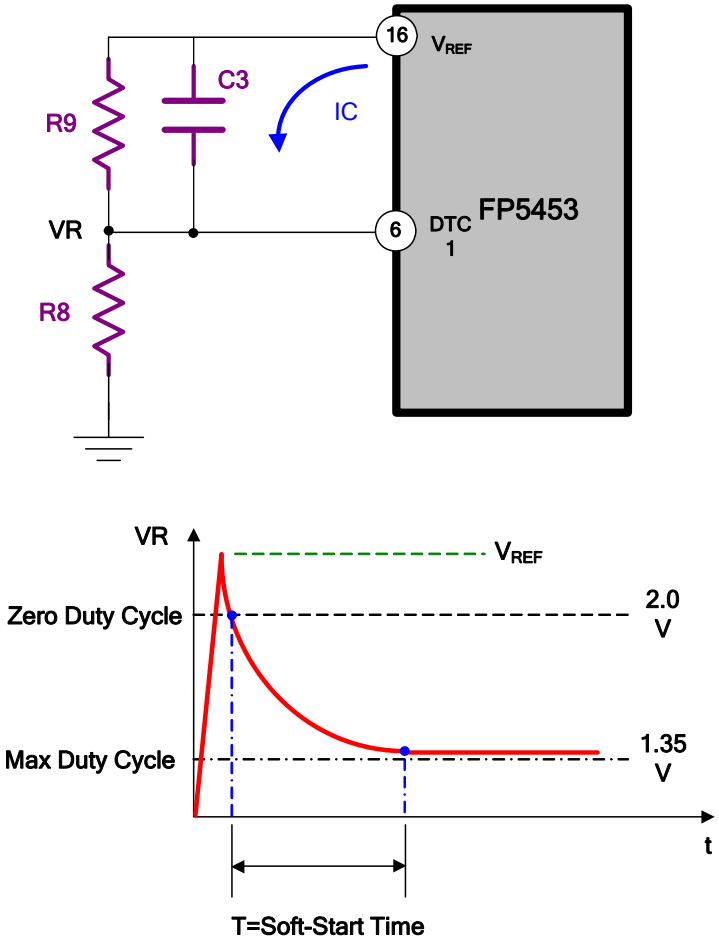


Figure 19 DTC Soft-start RC Circuit and Waveform

The soft-start time equation:

$$t = 5 \times (\frac{R9 \times R8}{R9 + R8}) \times C3$$

Short-circuit Shutdown and Auto Re-start Protection (SCSAR)

FP5453 includes short-circuit shutdown and auto re-start protection function (see Figure 20), which turns the Power MOS off to prevent damage when the converter output is over loading or short circuit.

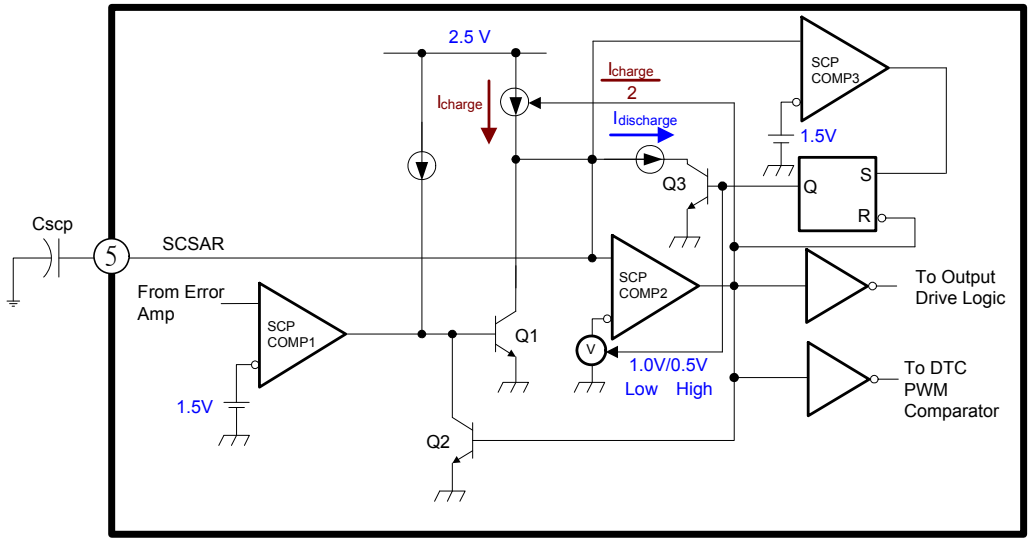


Figure 20. SCSAR Protection Circuit

In normal condition, error amplifier output voltage is higher than 1.5V, SCP comparator 1 output keeps a high state and Q1 is turn-on, so that C_{SCP} cannot be charged. When short circuit condition occurs, the error amplifier output would be pulled to lower than 1.50V, SCP comparator 1 output then changes to low state and C_{SCP} is charged by I_{CHARGE} current. The SCP function of FP5453 is no longer triggered if short circuit condition is removed before SCP comparator 2 outputs high.

When C_{SCP} is charged to 1.0V threshold voltage, SCP comparator 2 output changes to high state and Q2 is turned on to keep Q1 off in latch mode. Meanwhile, the source current of C_{SCP} would change to half of original current for the first shutdown phase, FP5453 output is turn-off and DTC pin is pulled to low.

As the C_{SCP} is charged continuous, its potential will finally to reach higher 1.5V and even higher. At this time, SCP comparator 3 would output high then make the S-R Latch output turns on Q3 to discharge C_{SCP} and change SCP comparator 2's threshold from 1.0V to 0.5V. The C_{SCP} is discharged continuously to 0.5V then SCP comparator 2 output low to release the S-R latch. Output of FP5453 is active and DTC pin is working in soft-start state or limitation of duty cycle.

C_{SCP} discharging from 1.5V to 0.5V is the second shutdown phase which finishes SCP; and FP5453 would be released from shutdown state and re-start the normal operation. Figure 21 explains relationship about SCSAR pin and the other pins of FP5453.

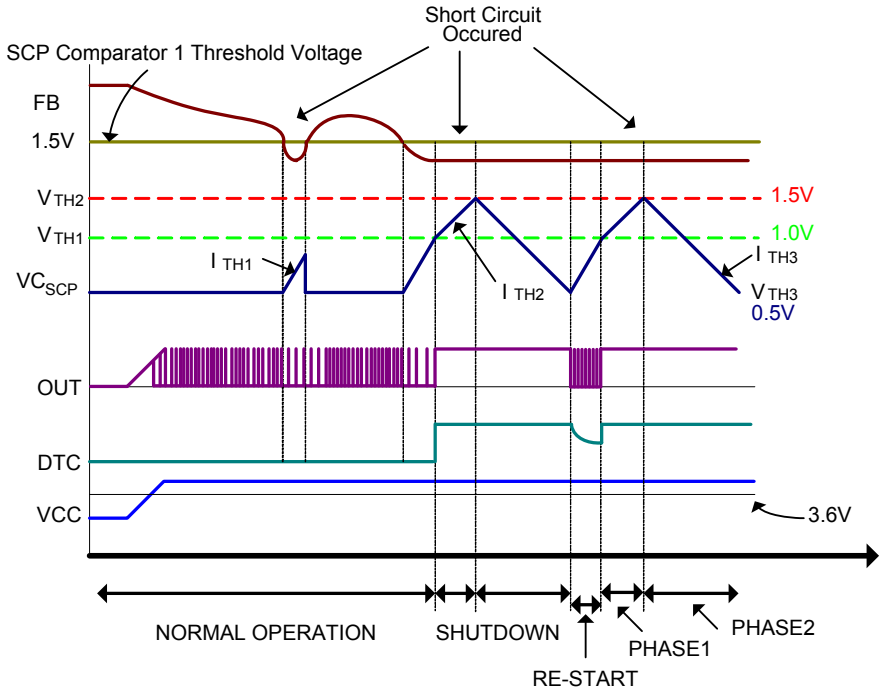


Figure 21. Shutdown and Re-start waveform

The equations are shown below for shutdown and re-start time calculation:

AUTO RE-START time equation:

$$t_{RE-START} = \frac{V_{TH1} \times C_{SCP}}{I_{TH1}}$$

SHUTDOWN time equation:

$$t_{SHUTDOWN} = t_{PHASE1} + t_{PHASE2} = \frac{(V_{TH2} - V_{TH1}) \times C_{SCP}}{I_{TH2}} + \frac{(V_{TH2} - V_{TH3}) \times C_{SCP}}{I_{TH3}}$$

Output Transistors

The output of the FP5453 is a totem-pole transistor pair which supplies source and sink current capacity for driving the external MOSFET directly. A basic drive method is shown as figure 22.

When PWM operation frequency is different, both of the required MOSFET ON and OFF time are different too.

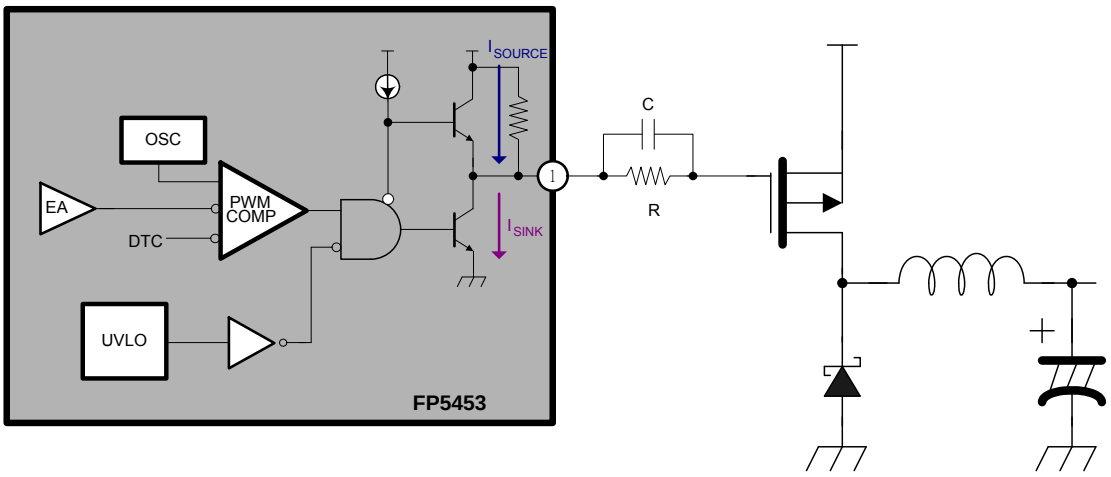


Figure 22. FP5453 MOSFET Output Driving Cricuit

Note:

It is very important to choose a suitable MOSFET for high frequency operation. The larger capacitor between gate and source of MOSFET makes more switching loss under the same supply voltage and driving current.

Application Information

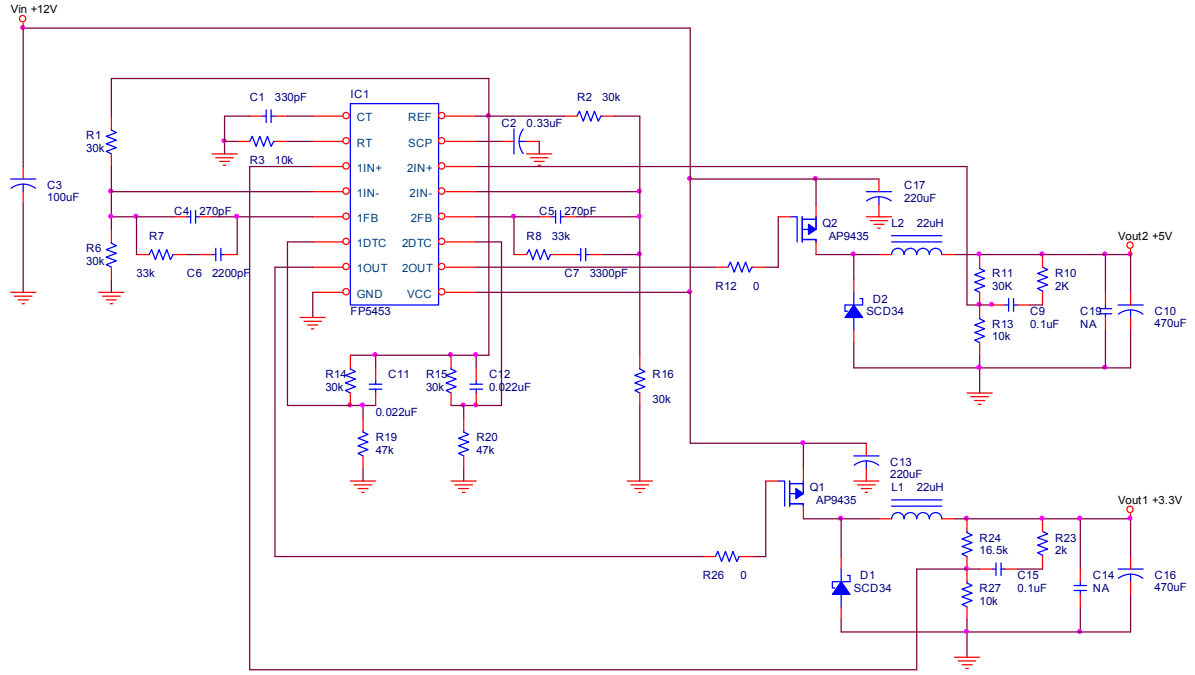


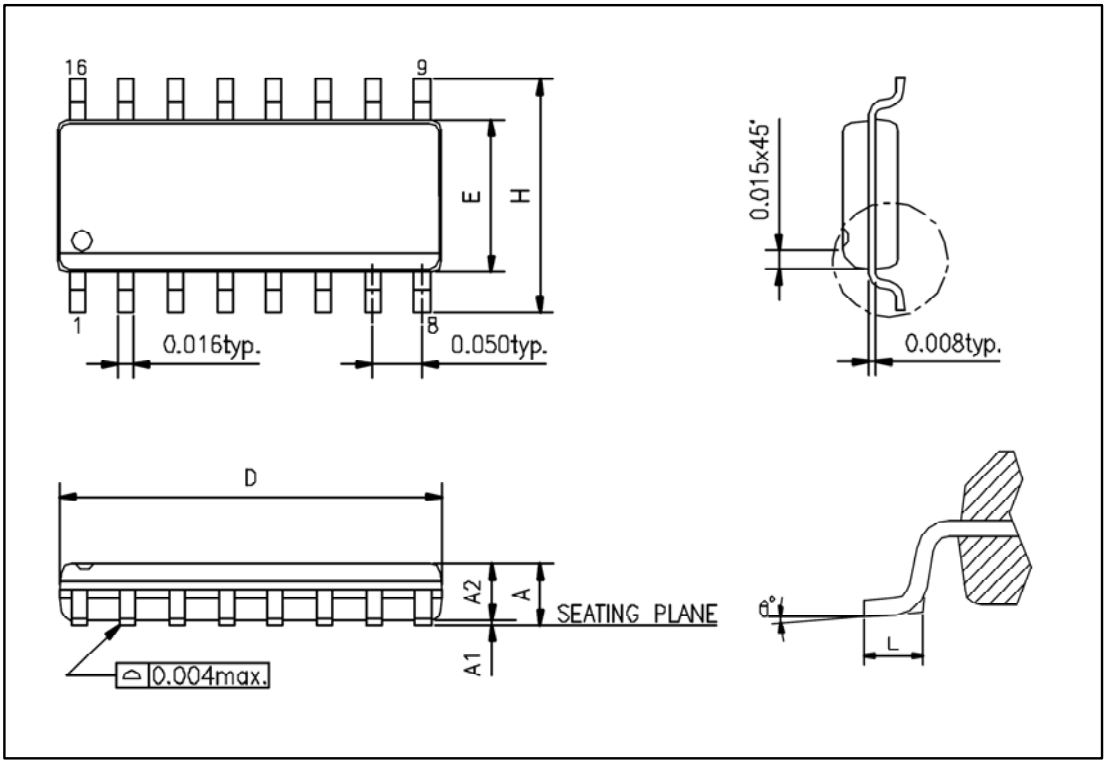
Figure 23. 2-Channel DC-DC Converter Circuit

Note:

1. The IN1- and IN2- is 1.25V a half of V_{REF} voltage because R1=R6 and R2=R16.
2. The R14-R19-C11 and R15-R20-C12 are a DTC circuits for buck regulators power-on.
3. The R11-R13 and R24-R27 are the buck regulator output voltage feedback resistances.
4. The R7-C4-C6 is the compensation circuit for error amplifier 1 of FP5453.
5. The R8-C5-C7 is the compensation circuit for error amplifier 2 of FP5453.
6. The R3-C1 is an external RC circuit for FP5453 internal oscillator.
7. The C2 is FP5453 short circuit protection delay time capacitor.

Package Outline

SOP-16L



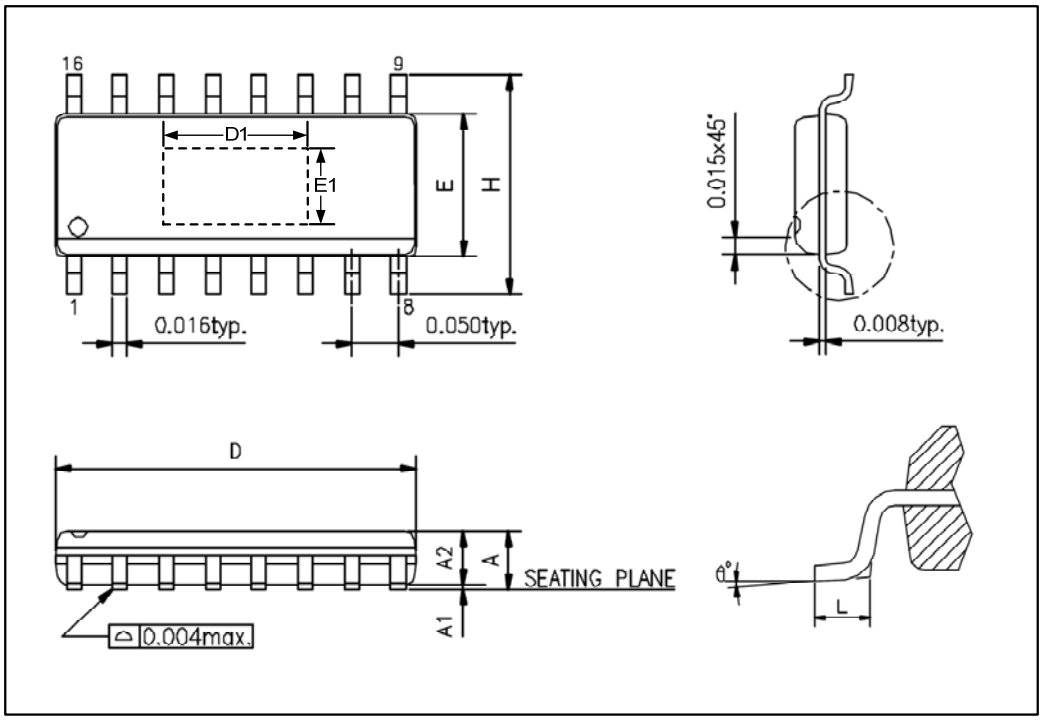
UNIT: mm

Symbols	Min. (mm)	Max. (mm)
A	1.346	1.752
A1	0.101	0.254
A2	1.244	1.651
D	9.804	10.007
E	3.810	3.987
H	5.791	6.197
L	0.406	1.270
θ°	0°	8°

Note:

1. Package dimensions are in compliance with JEDEC outline: MS-012 AC.
2. Dimension “D” does not include molding flash, protrusions or gate burrs.
3. Dimension “E” does not include inter-lead flash or protrusions.

SOP-16L (EP)



UNIT: mm

Symbols	Min. (mm)	Max. (mm)
A	1.346	1.752
A1	0.101	0.254
A2	1.244	1.651
D	9.804	10.007
E	3.810	3.987
H	5.791	6.197
L	0.406	1.270
θ°	0°	8°

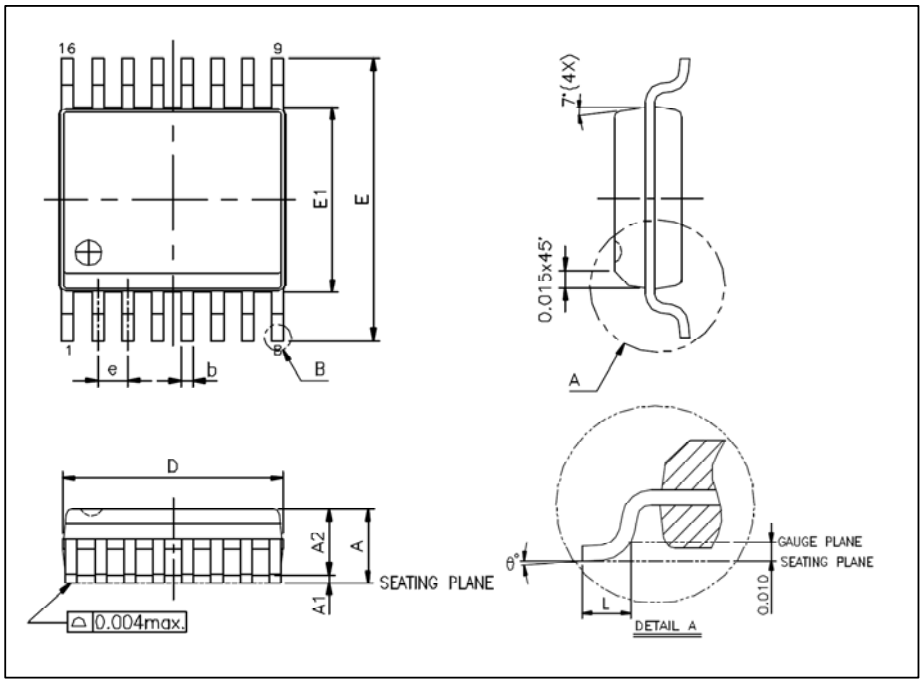
Exposed PAD Dimensions:

Symbols	Min. (mm)	Max. (mm)
E1	2.184 REF	
D1	4.114 REF	

Note:

1. Dimension ”D” does not include molding flash, protrusions or gate burrs.
2. Dimension “E” does not include inter-lead flash or protrusions.

SSOP-16L (EP)



UNIT: mm

Symbols	Min. (mm)	Max. (mm)
A	1.346	1.752
A1	0.101	0.254
A2		1.498
b	0.203	0.304
b1	0.203	0.279
c	0.177	0.254
c1	0.177	0.228
D	4.800	5.003
E1	3.810	3.987
E	5.791	6.197
L	0.406	1.270
e	0.635 BASIC	
θ°	0°	8°

Note:

1. Package dimensions are in compliance with JEDEC outline: MO-137 AB.
2. Dimension “D” does not include molding flash, protrusions or gate burrs.
3. Dimension “E” does not include inter-lead flash or protrusions