DUAL PWM CONTROL IC WITH SHORT CIRCUIT RESTART FUNCTION

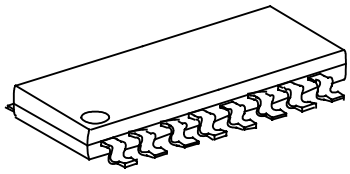
GENERAL DESCRIPTION

The **FP5453**, a 1-chip composed of totem-pole output stage pulse-width-modulation control circuits with two error amplifiers and dead-time comparators (DTC), the **FP5453** contains a **2.5V** precision voltage reference regulator, under-voltage lockout circuit (UVLO), programmable auto-restart timer for short circuit protection (SCSAR), applied to offer space and low cost in many applications such as the DC/DC converter.

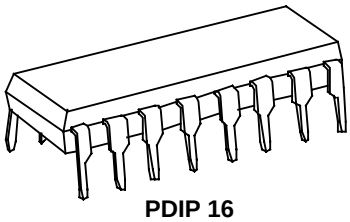
Using few external components, **FP5453**, a high performance integrated IC, is designed for a control circuit. The circuit diagram of the typical application example is as below.

FEATURES

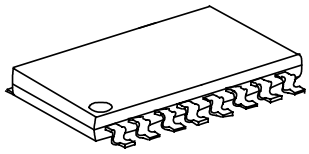
- Fixed Reference Voltage: 2.5V
- Reference Voltage Precision: 2%
- Totem-pole output stage
- Low quiescent supply current under 4mA
- Wide operating voltage range: 3.6~30V
- Variable dead-time control (DTC)
- UVLO protection function
- Short circuit shutdown/auto re-start function (SCSAR)
- Oscillator Frequency: Max. 1.2MHz
- Package: SOP16/PDIP16/SSOP16



SOP16



PDIP 16

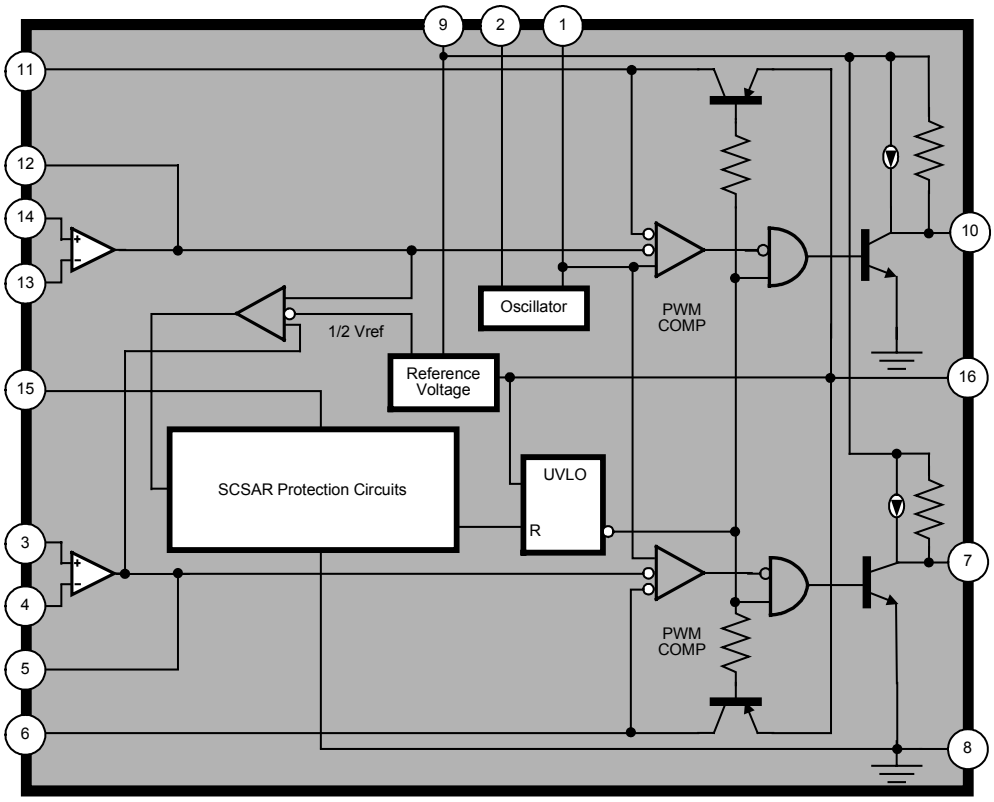


SSOP 16

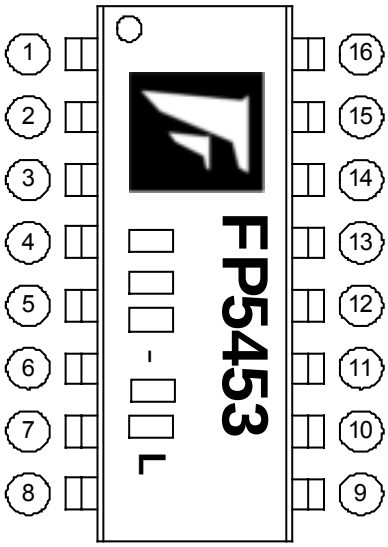
TYPICAL APPLICATION

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

FUNCTIONAL BLOCK DIAGRAM



MARK VIEW



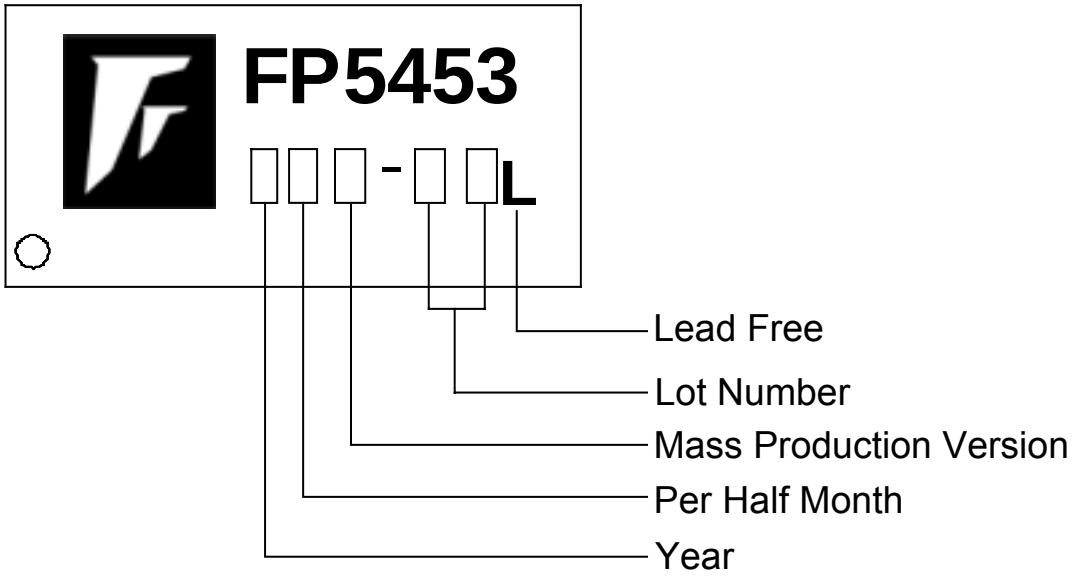
PIN DESCRIPTION

NAME	NO.	STATUS	DESCRIPTION
CT	1	I	Connect a Capacitor for Oscillator
RT	2	I	Connect a Resistor for Oscillator
EA1+	3	I	Error Amplifier 1 Non-inverting Input
EA1-	4	I	Error Amplifier 1 Inverting Input
FB1	5	O	Error Amplifier 1 Feedback Output
DTC1	6	I	Output 1 Dead-Time Comparator
OUT1	7	O	Totem-pole Output 1
GND	8	P	IC Ground
VCC	9	P	IC Power Supply
OUT2	10	O	Totem-pole Output 2
DTC2	11	I	Output 2 Dead-Time Comparator
FB2	12	O	Error Amplifier 2 Feedback 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
VREF	16	O	2.5V Reference Voltage Output

ORDER INFORMATION

Part Number	Operating Temperature	Package	Description
FP5453P-LF	-20°C ~ +85°C	PDIP16	Tube
FP5453D-LF	-20°C ~ +85°C	SOP16	Tube
FP5453DR-LF	-20°C ~ +85°C	SOP16	Tape & Reel
FP5453R-LF	-20°C ~ +85°C	SSOP16	Tube
FP5453RR-LF	-20°C ~ +85°C	SSOP16	Tape & Reel

IC DATE CODE DISTINGUISH



FOR EXAMPLE:

January A (Front Half Month), B (Last Half Month)
February C, D
March E, F ----------And so on

Lot Number is the last two numbers

For Example:

A3311C62
Lot Number

ABSOLUTE MAXIMUM RATINGS

Supply Voltage (Vcc) ---------- +30V

Differential Input Voltage (V_{id}) ---------- +3V

Output Current (Io) ---------- +150mA

Maximum Junction Temperature (T_j) ---------- +150°C

Thermal Resistance Junction to Ambient

PDIP16 package ---------- 125°C /W

SOP16 package ---------- 150°C /W

SSOP16 package ---------- 220°C /W

Power Dissipation

DIP16 package

Ta=25℃ ---------- 1000mW

Ta=70℃ ---------- 640mW

SOP16 package

Ta=25℃ ---------- 830mW

Ta=70℃ ---------- 530mW

SSOP16 package

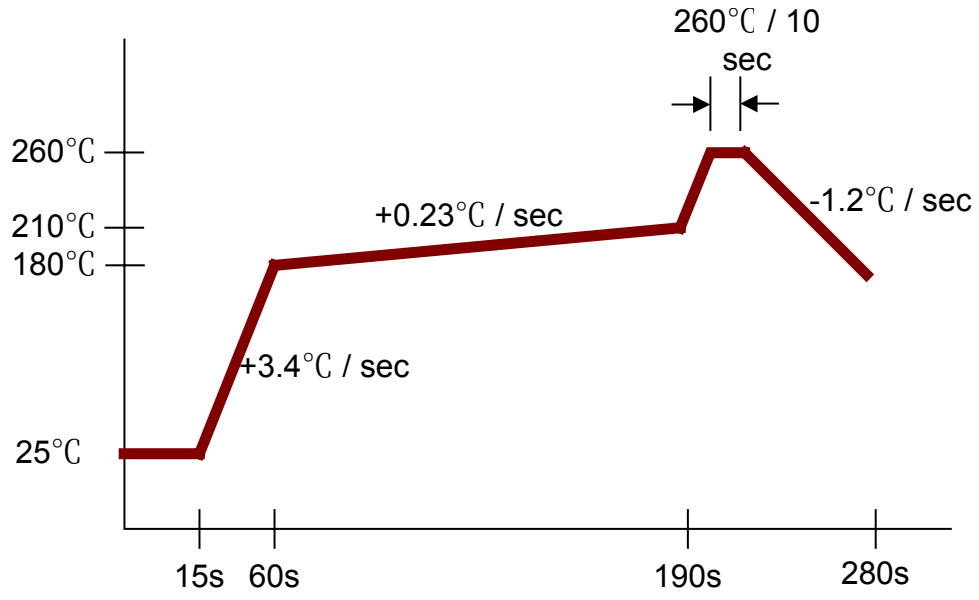
Ta=25℃ ---------- 570mW

Ta=70℃ ---------- 360mW

Operating Temperature Range ---------- -20°C 85°C

Storage Temperature Range ---------- -65°C 150°C

Lead Temperature (soldering, 10 sec) ---------- +260°C



IR Re-flow Soldering Curve

DC ELECTRICAL CHARACTERISTICS

Electrical characteristics over recommended operating free-air temperature range, V_{CC}=6V, f=200kHz (unless otherwise noted)

Reference section

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output voltage (pin 16)	V_{REF}	I_O=1mA	2.45	2.5	2.55	V
Output voltage change with Temperature		T_A=-20°C to 25°C		-0.1	±1	%
		T_A=25°C to 85°C		-0.2	±1	
Input voltage regulation	$\triangle V_{REF}/V_{REF}$	Vcc=3.6V 30V		2	12.5	mV
Output voltage regulation	$\triangle V_{REF}/V_{REF}$	Io = 0.1mA to 5 mA		3	8	mV
Short-circuit output current	I_{SHORT}	V_O=0	3	10	30	mA

Under voltage lockout section

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Upper threshold voltage(Vcc)	V_{UPPER}	$I_{O(REF)}$ = 0.1 mA, T_A=25°C		3.2		V
Lower threshold voltage(Vcc)	V_{LOW}			3.0		V
Hysteresis (Vcc)	V_{HYS}		100	200		mV

Short-circuit protection control section

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SCP standby voltage	V_{SB}	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		25		μA
SCP re-start / hold time	T_{RS}/T_{HOLD}	V_{FB1} or V_{FB2} >1.5V		1/35		-
SCP comparator 1 threshold voltage	$V_{COMP(TH)}$			1.5		V

Oscillator section

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Frequency	f	C_T=330pF,R_T=10K		200		KH_Z
Frequency change with voltage	$\triangle f/\triangle V$	V_{CC}=3.6V to 40V		0.2		%
Frequency change with Temperature	$\triangle f/\triangle T$	T_A=-20°C to 25°C		-0.4	±2	%
		T_A=25°C to 85°C		-0.2	±2	%

DC ELECTRICAL CHARACTERISTICS (Cont.)

Dead-time control section

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
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	1.35		

Error –amplifier section

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
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
Open-loop voltage amplification	A_{VO}		70	80		dB
Unity-gain bandwidth	BW			1.5		MH_Z
Positive output voltage swing	V_{POS}		Vref-0.3			V
Negative output voltage swing	V_{NEG}				1	V
Output (sink) current (FEEDBACK)	I_{SINK}	V_{ID}=—0.1V,V_O=1.25V	2	3		mA
Output (source) current (FEEDBACK)	I_{SOURCE}	V_{ID}=0.1V, V_O=1.25V	-100	-140		μA

Output section

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Vout Low Voltage	V_{OL}	I_{SINK}=20mA		0.15	0.2	V
		I_{SINK} =130mA Vcc=15V		1.7	2.0	
Vout High Voltage	V_{OH}	I_{SOURCE}=20mA	4.0	4.5		V
		I_{SOURCE}=130mA Vcc=15V	12.8	13.4		
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

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input threshold voltage at f=10kHz(FEEDBACK)	V_{TH}	Zero duty cycle		2.0	2.20	V
		Maximum duty cycle	1.2	1.35		

Total device

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
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 CHATACTERISTICS

TRIANGLE OSCILLATOR FREQUENCY
VS
TIMING RESISTANCE

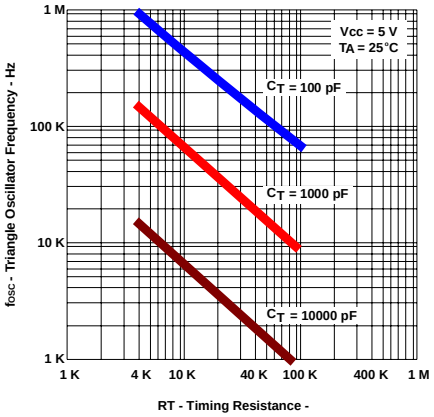


Figure 1

OSCILLATOR FREQUENCY VARIATION
VS
FREE-AIR TEMPERATURE

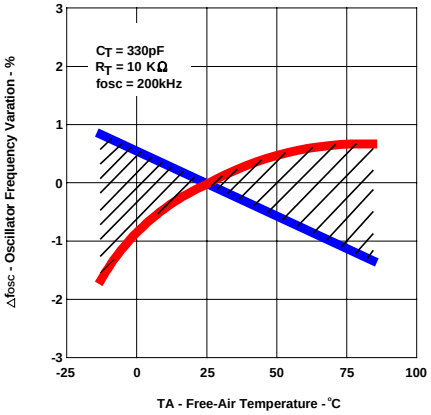


Figure 2

TRIANGLE WAVEFORM SWING VOLTAGE
VS
TIMING CAPACITANCE

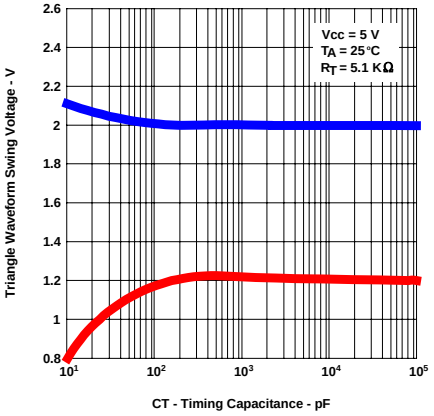


Figure 3

TRIANGLE WAVEFORM PERIOD
VS
TIMING CAPACITANCE

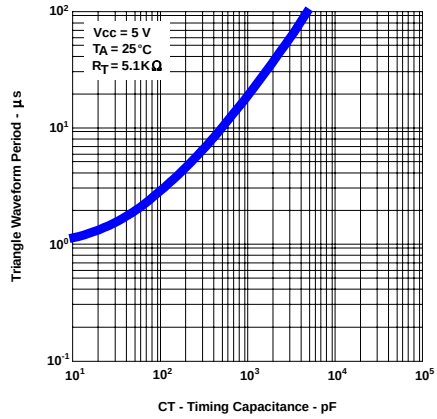


Figure 4

REFERENCE OUTPUT VOLTAGE VARIATION
VS
FREE-AIR TEMPERATURE

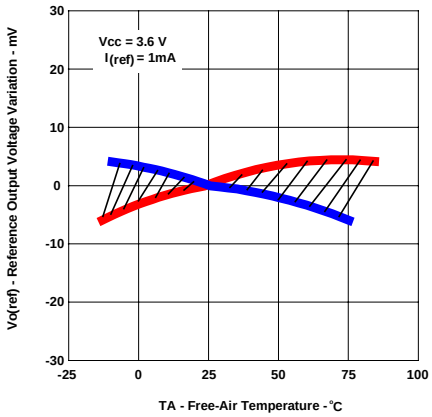


Figure 5

REFERENCE OUTPUT VOLTAGE VARIATION
VS
FREE-AIR TEMPERATURE

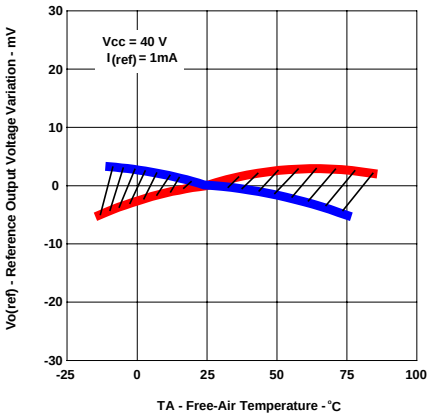


Figure 6

TYPICAL CHATACTERISTICS (Cont.)

REFERENCE OUTPUT VOLTAGE
VS
SUPPLY VOLTAGE

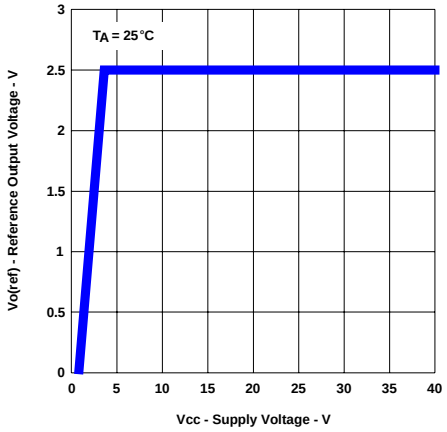


Figure 7

UNDERVOLTAGE LOCKOUT
HYSTERESIS CHARACTERISTICS

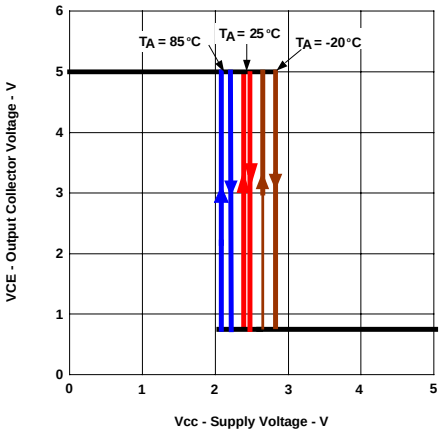


Figure 8

ERROR AMP MAXIMUM
OUTPUT VOLTAGE SWING
VS
FREQUENCY

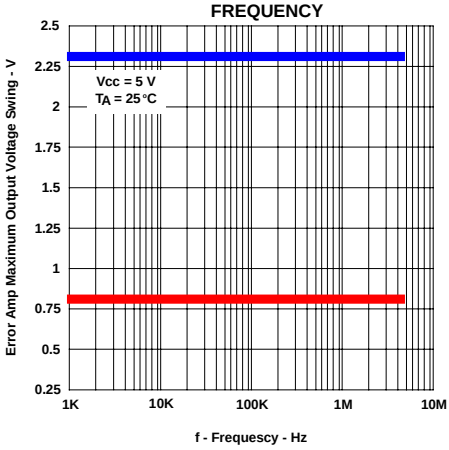


Figure 9

OUTPUT TRANSISTOR ON DUTY CYCLE
VS
DEAD - TIME INPUT VOLTAGE

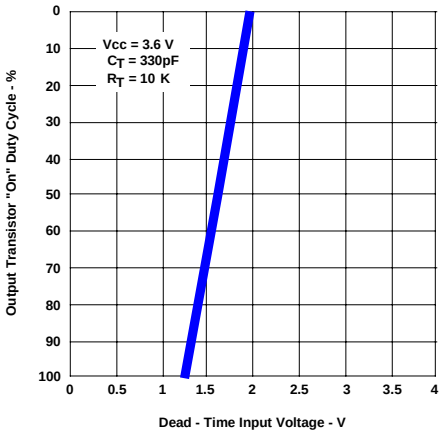


Figure 10

STANDBY CURRENT
VS
SUPPLY VOLTAGE

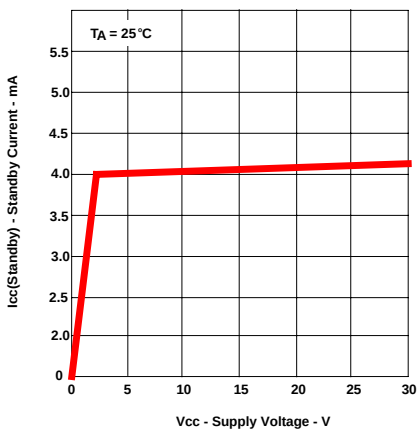


Figure 11

STANDBY CURRENT
VS
FREE - AIR TEMPERATURE

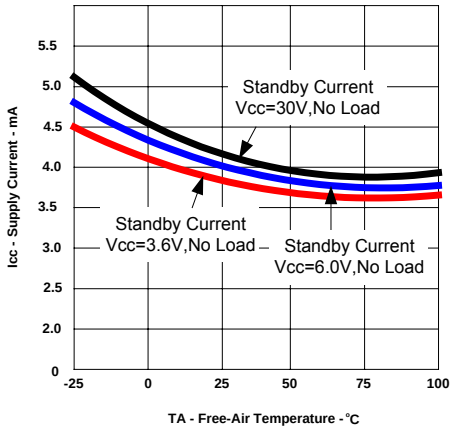


Figure 12

TIMING WAVEFORM

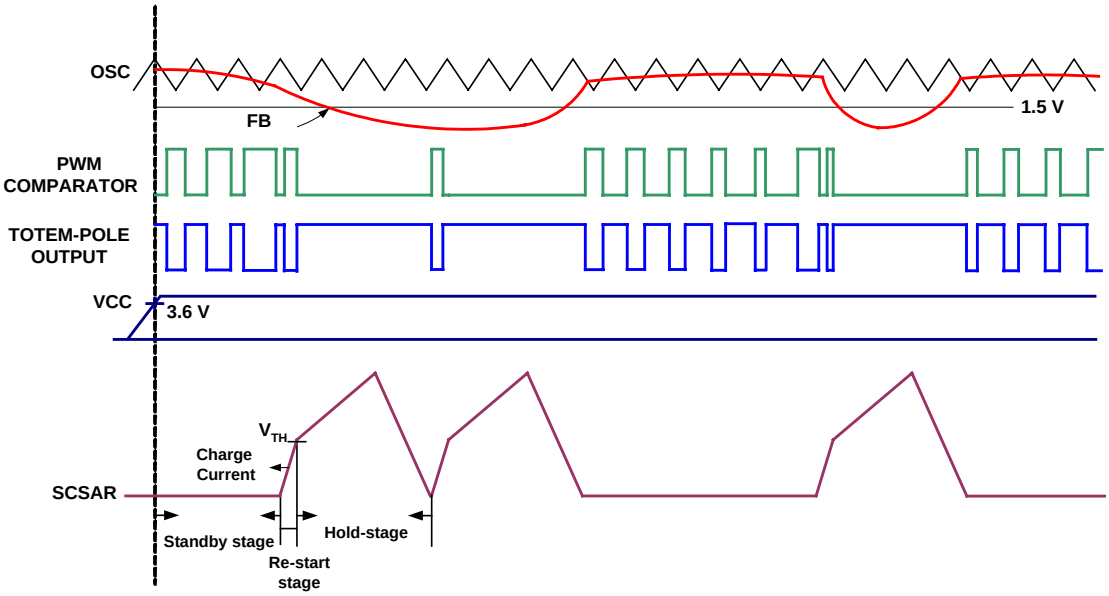


Figure 13. FP5453 Timing Diagram

DETAILED DESCRIPTION

Voltage Reference

FP5453 has an internal 2.5V reference regulator using for the internal circuits' voltage bias, and another function is using with the resistive divider connecting to the IC error amplifier inverting input for output feedback reference(see Fig 14).

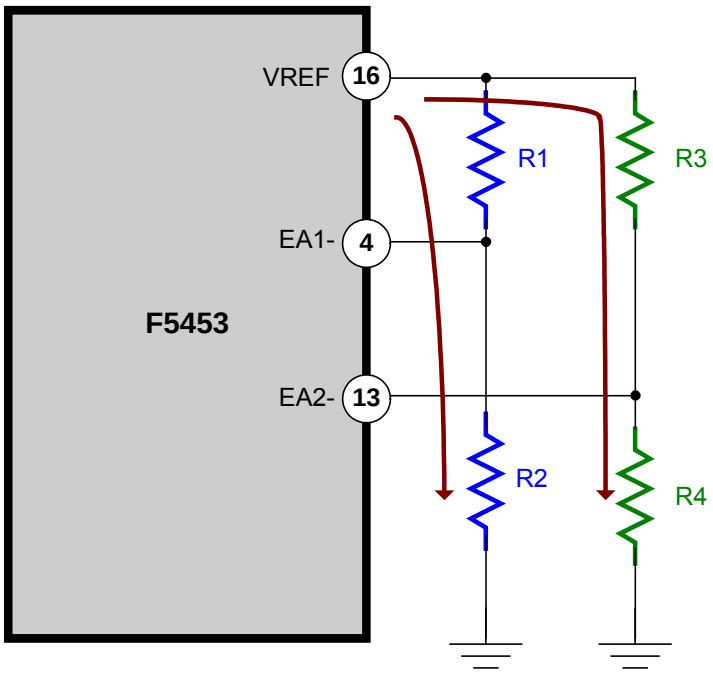


Figure 14. Reference and error amplifiers with resistive dividers

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

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

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

And we will discuss both relationship of the output voltage and error amplifier reference voltage next page.

Error Amplifier

The error amplifiers of **FP5453** compare the feedback voltage from the resistive dividers of dc-dc converter output to the reference bias(see Fig 15), and generate the error signal for the PWM comparator, the relation formulas are shown as below:

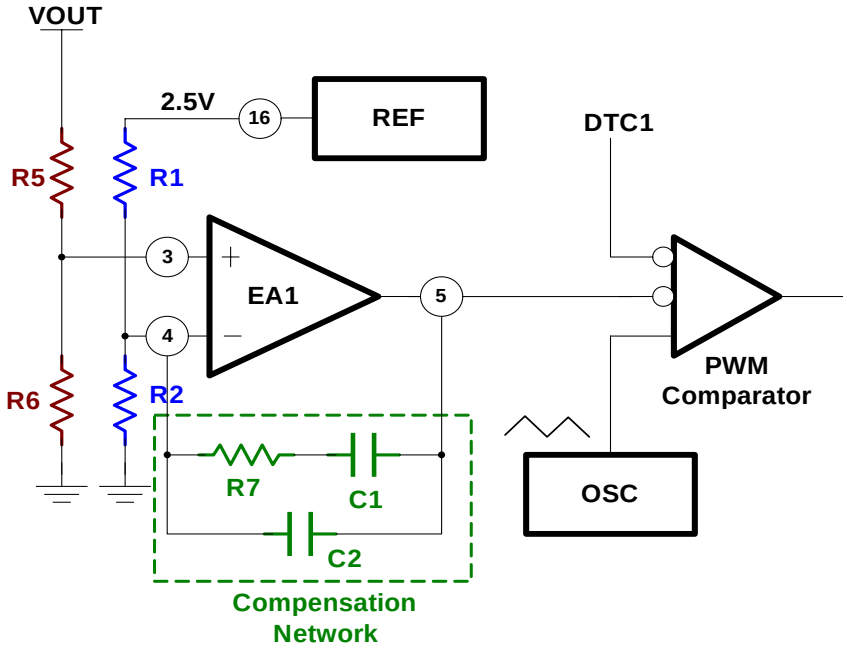


Figure 15. Error amplifier with Feedback/Compensation Circuits

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:

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

Error Amplifier Zero and Pole Frequency:

$$Fz = \frac{1}{2\Pi R7C1} \quad , \quad Fp = \frac{1}{2\Pi R7C2}$$

Oscillator/PWM Comparator

The oscillator frequency can be decided from 20KHz to 1.2MHz by the resistor (RT) and capacitor (CT) which are connected with pin1 and pin2 of **FP5453,** a sawtooth waveform would compare with feedback signal of the error amplifier and dead-time control voltage, the figure 16 is the relationship of oscillator, error amplifier and PWM comparator, and figure 17 is the waveforms of **FP5453**.

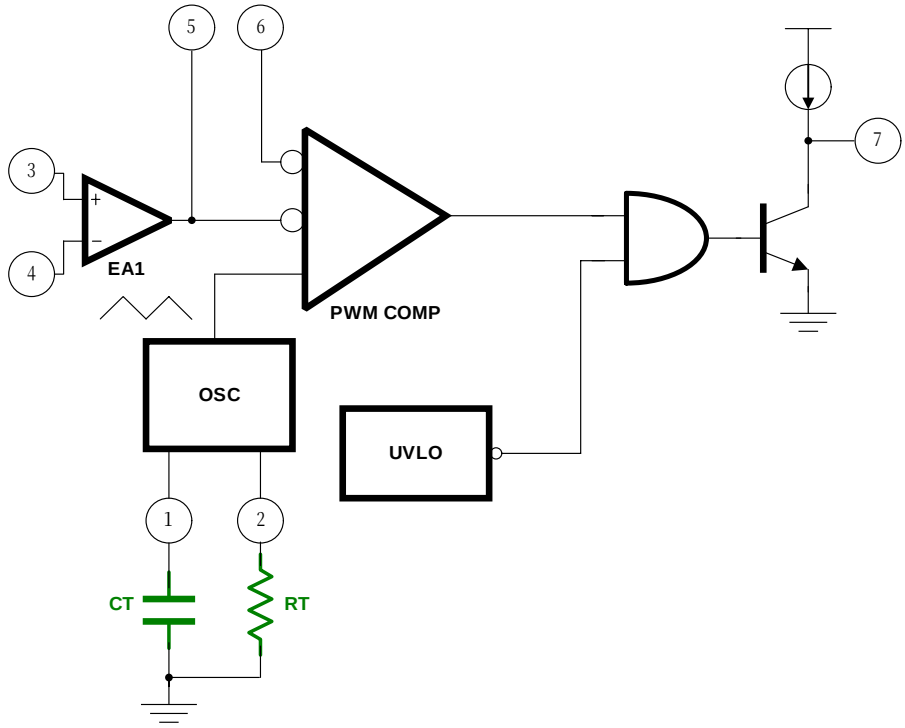


Figure 16. Oscillator/PWM Comparator with Frequency RC circuits

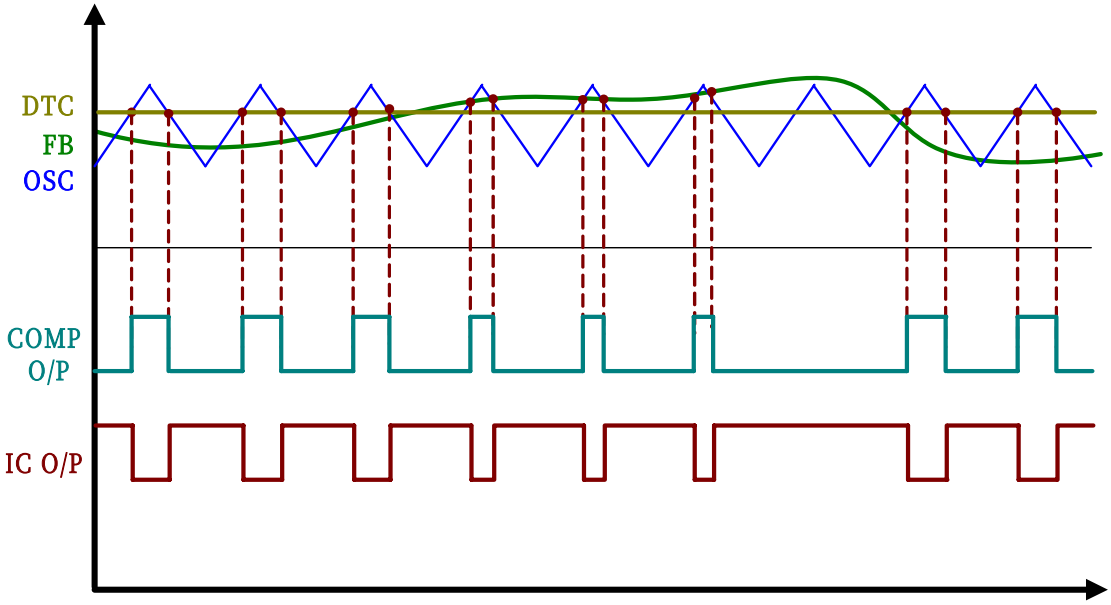


Figure 17. FP5453 Timing Waveforms

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

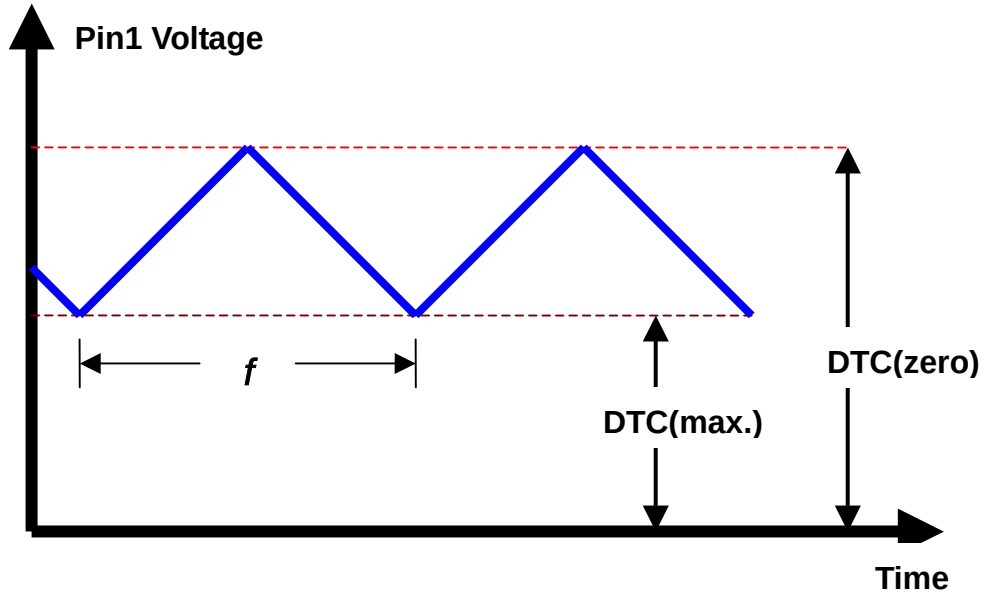


Figure 18. Oscillator Frequency with DTC voltage

The oscillator frequency calculation formula is shown as below:

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

Dead-Time Control/Soft-Start

The dead-time control (DTC) is a function for the PWM duty cycle limitation, if the DTC voltage is lower than DTC maximum voltage (typ. 1.35V), the PWM duty cycle can change to 100% cycle; and if the DTC voltage is higher than DTC zero voltage (typ. 2.0V), the PWM duty cycle should always turn-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) and a simple formula to calculate the soft-start time.

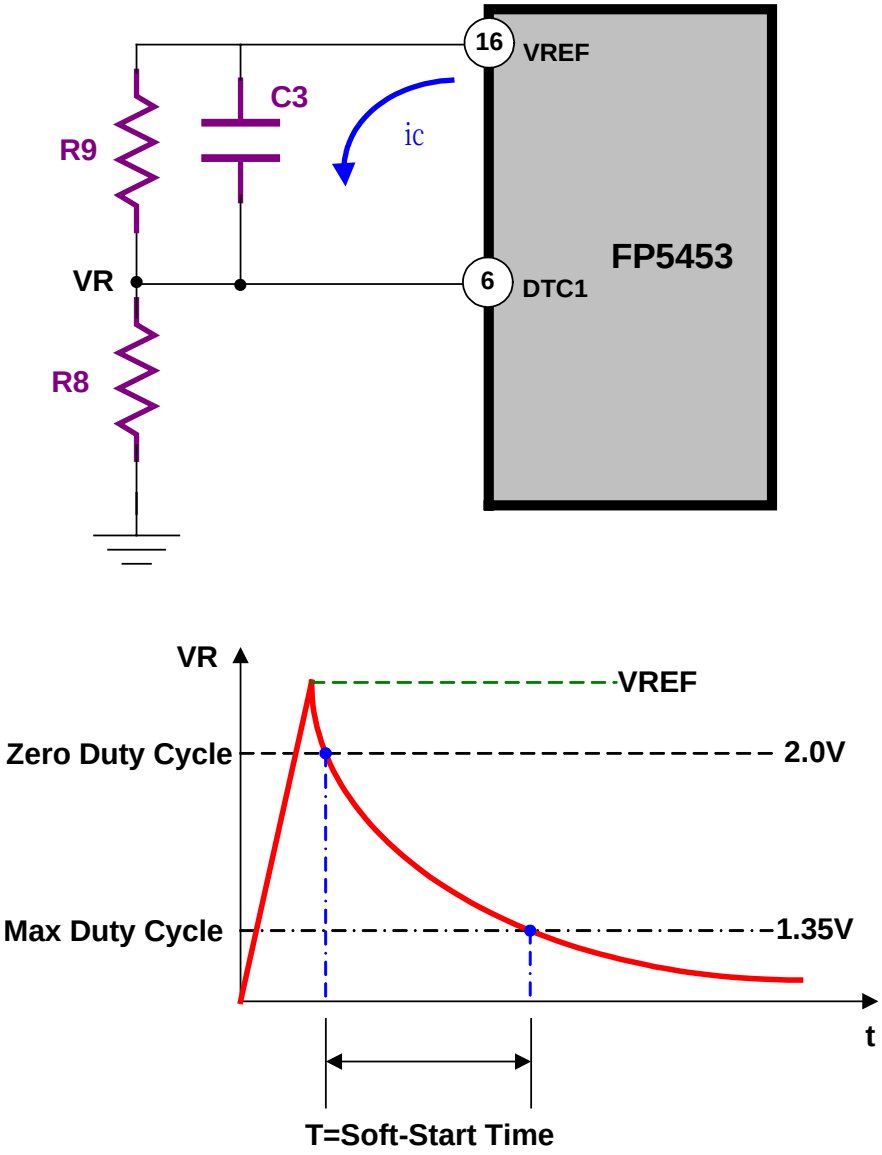


Figure 19. DTC Soft-start RC circuit and waveform

The soft-start time formula:

$$t = 0.616 * R8C3$$

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.

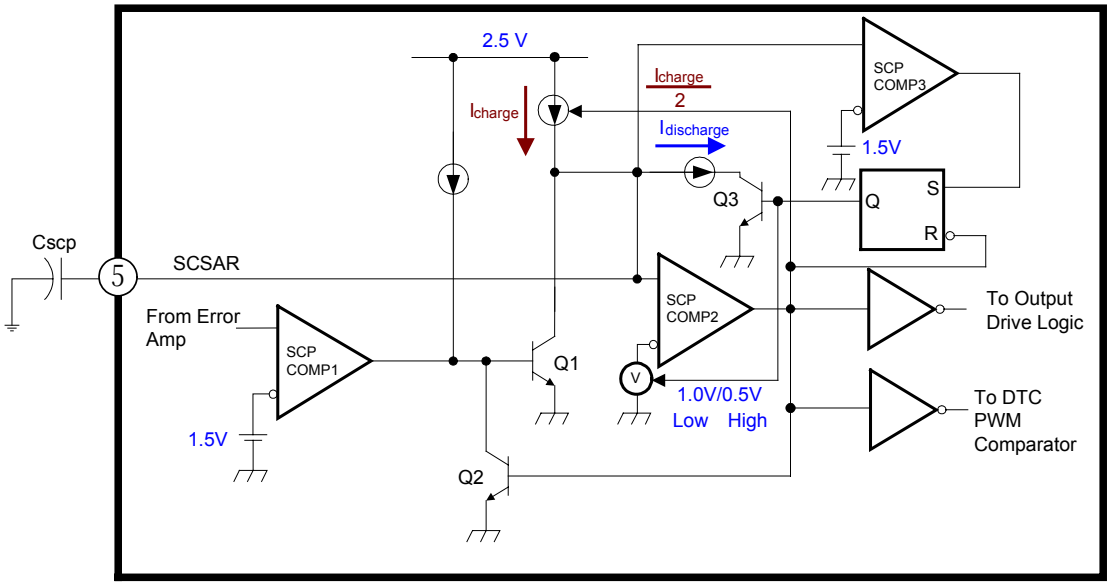


Figure 20. SCSAR Protection Circuit

Generally, error amplifier output voltage is hgiher than 1.5V, and SCP comparator 1 output keeps a high state and Q1 is turn-on, C_{SCP} cannot be charged. When short circuit occurs, the COMP pin of error-amplifier would under more than 1.50V, SCP comparator 1 output changes to low state and C_{SCP} is charged by I_{CHARGE} current. The SC function of **FP5453** is release because short circuit is removed before Q2 active and SCP comparator 2 is latch. When C_{SCP} is charged until a 1.0V threshold voltage and SCP comparator 2 output changes to high state and Q2 is turn-on to keep Q1 off in latch mode. Meanwhile, the source current of C_{SCP} would change half of original current for the first shutdown phase, **FP5453** output is turn-off and DTC pin is pull-low. When C_{SCP} voltage is greater than 1.5V of SCP comparator 3, the output of S-R Latch would turn on Q3 and change SCP comparator 2 from 1.0V to 0.5V, when SCP comparator 3 is active, C_{SCP} is discharged until SCP comparator 2 is release the latch state, output of **FP5453** is active and DTC pin is working in soft-start state or limitation of duty cycle.

C_{SCP} discharging time from 1.5V to 0.5V is the second shutdown phase which finishes and **FP5453** would be release shutdown state and re-start the normal operation. Figure 21 is a relation description about SCSAR pin and the other pins of **FP5453**.

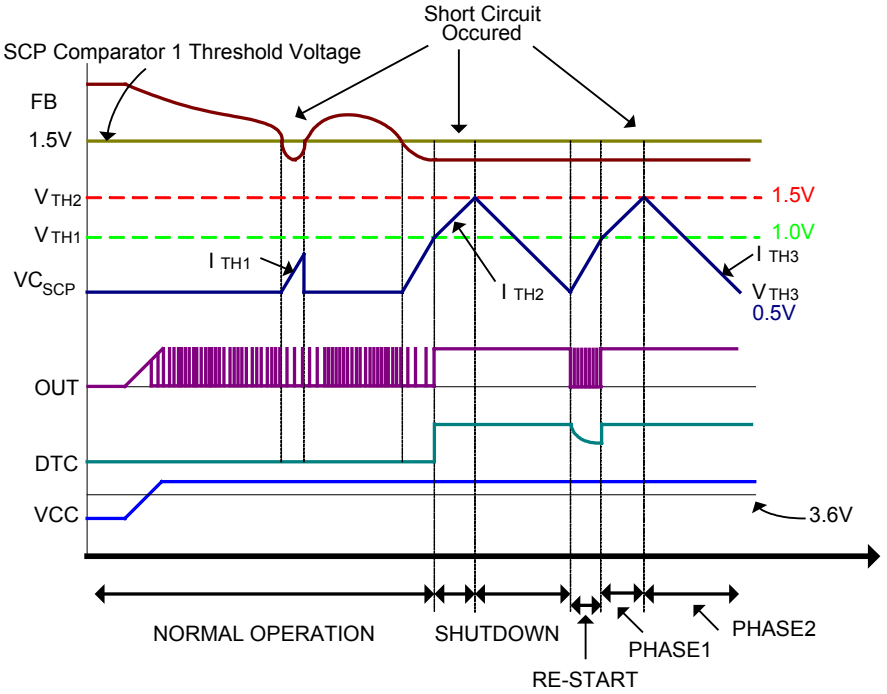


Figure 21. Shutdown and Re-start waveform

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

AUTO RE-START time equation:

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

SHUTDOWN time equation:

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

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, the both of on and off time of MOSFET also are different.

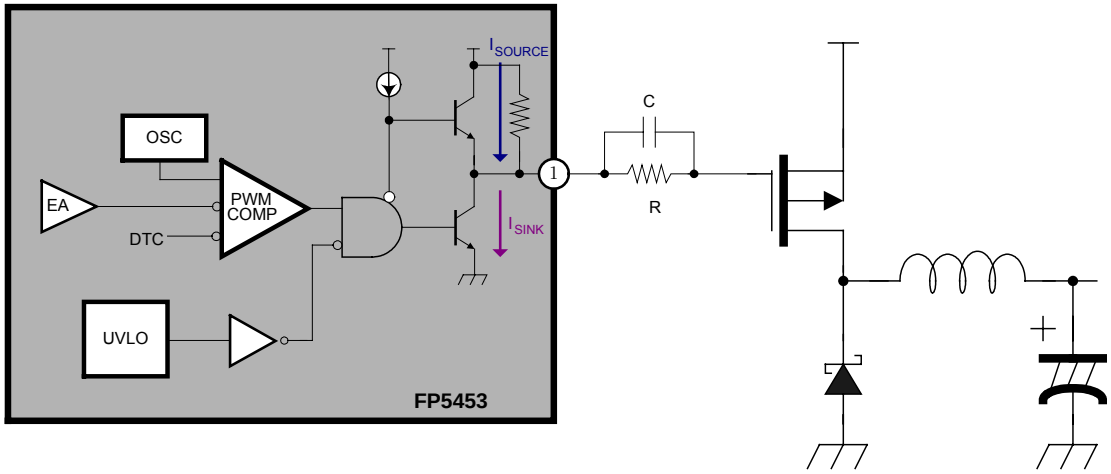


Figure 22. FP5453 MOSFET Output Driving Cricuit

Note:

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

APPLICATION NOTE

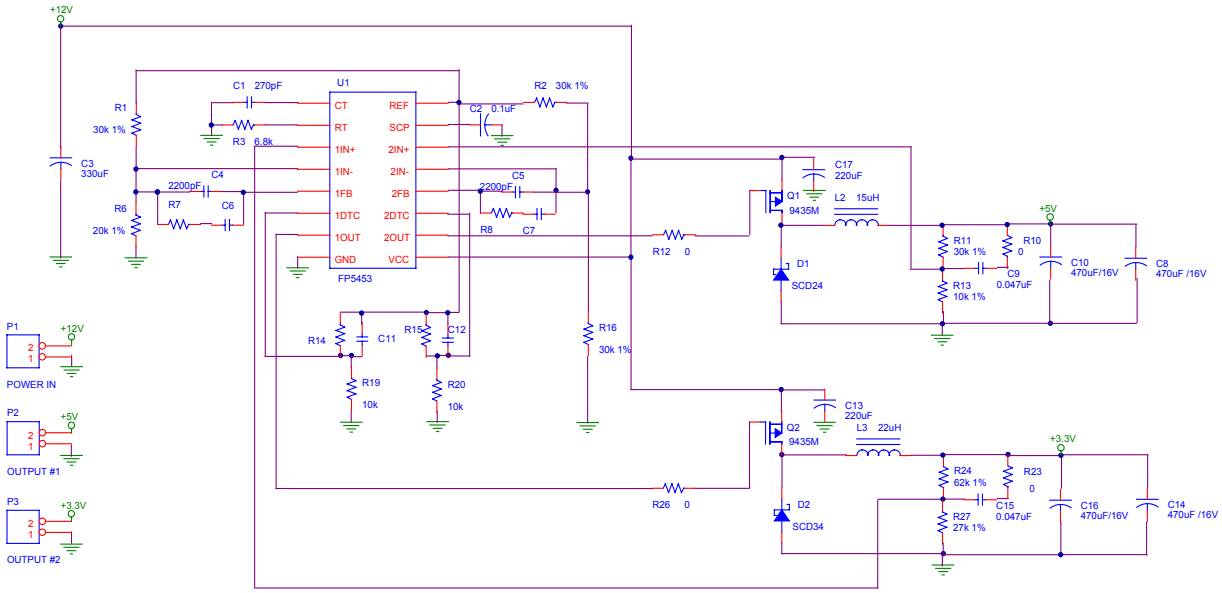


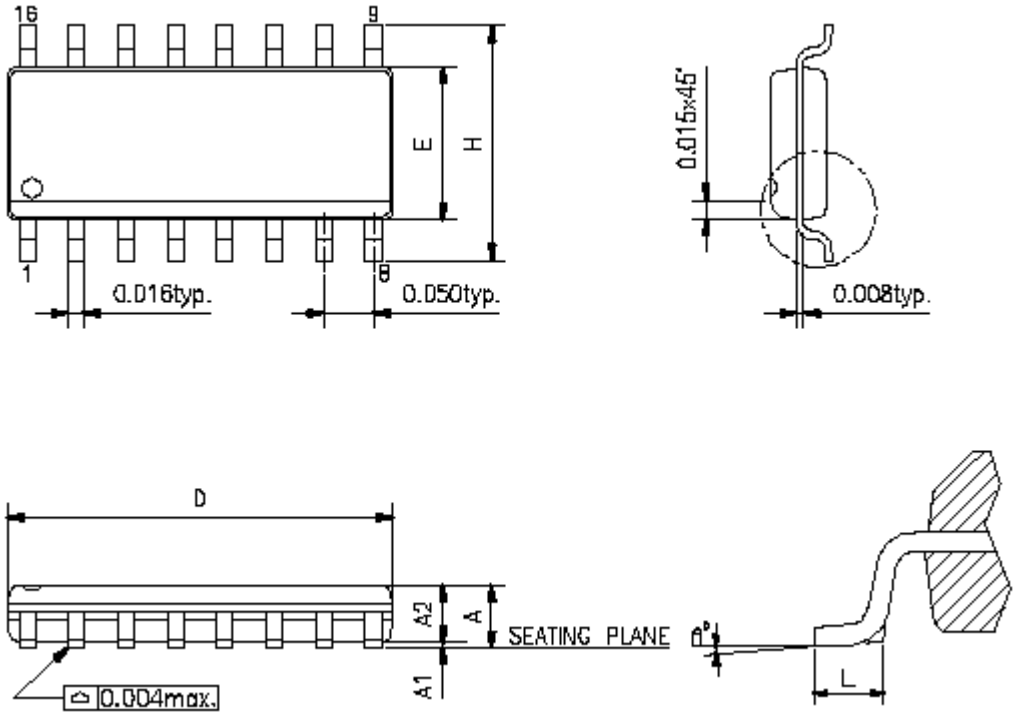
Figure 23. 2-channel dc-dc converter circuit

Note

1. The IN1- and IN2- is 1.25V a half of VREF 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



SYMBOLS	MIN	MAX
A	0.053	0.069
A1	0.004	0.010
D	0.386	0.394
E	0.150	0.157
H	0.228	0.244
L	0.016	0.050
θ°	0	8

UNIT:INCH

NOTE:

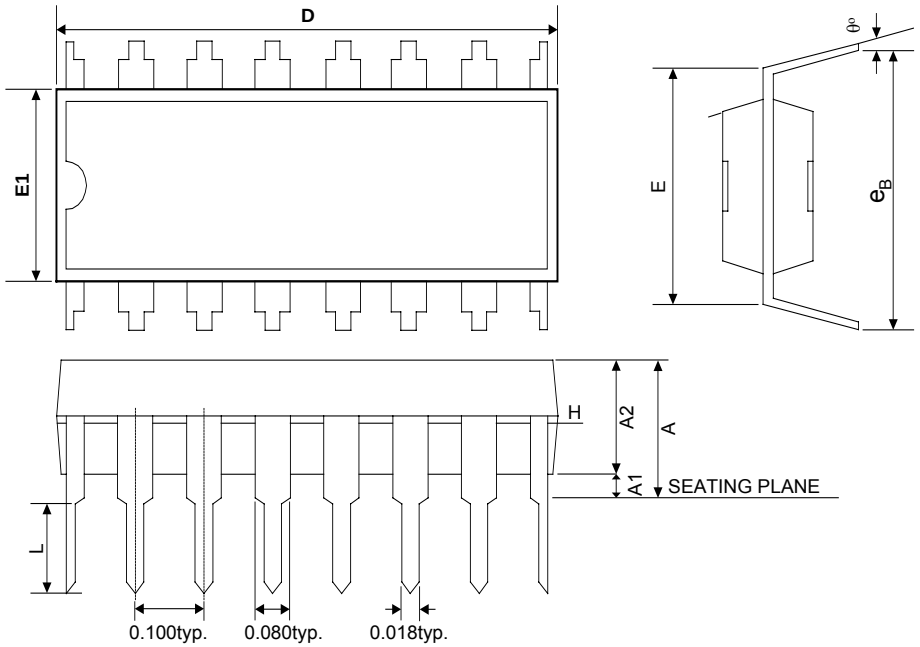
1.JEDEC OUTLINE:MS-012 AC

2.DIMENSIONS “D” DOES NOT INCLUDE MOLD FLASH,PROTRUSIONS OR GATE BURRS.MOLD FLASH,PROTRUSIONS AND GATE BURRS SHALL NOT EXCEED .15mm (.0.06in) PER SIDE

3.DIMENSIONS “E” DOES NOT INCLUDE INTER-LEAD FLASH,OR PROTRUSIONS.

4.INTER-LEAD FLASH AND PROTRUSIONS SHALL NOT EXCEED .25mm (.0.10in) PER SIDE.

PDIP-16L



SYMBOLS	MIN.	NOR.	MAX.
A	—	—	0.210
A1	0.015	—	—
A2	0.125	0.130	0.135
D	0.735	0.755	0.775
E		0.300 BSC.	
E1	0.245	0.250	0.255
L	0.115	0.130	0.150
e_θ	0.335	0.355	0.375
θ°	0	7	15

UNIT:INCH

NOTES:

1.JEDEC OUTLINE: MS-001 BB

2.“D”, “E1” DIMENSIONS DO NOT INCLUDE MOLD FALSH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH.

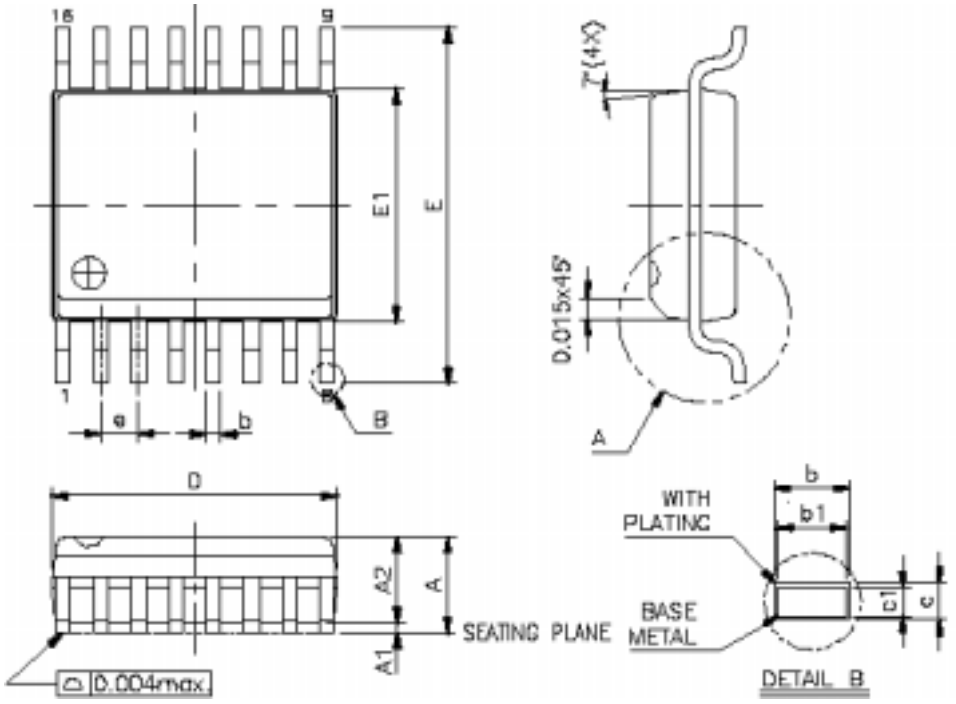
eB IS MEASURED AT THE LEAD TIPS WITH THE LEADS UNCONSTRAINED.

POINTED OR ROUNDED LEAD TIPS ARE PREFERRED TO EASE INSERTION.

3.DISTANCE BETWEEN LEADS INCLUDING DAM BAR PROTRUSIONS TO BE .005 INCH MININUM.

4.DATUM PLANE CONCIDENT WITH THE BOTTOM OF LEAD, WHERE LEAD EXITS BODY.

SSOP-16L



SYMBOLS	MIN.	MAX.
A	0.053	0.069
A1	0.004	0.010
A2	—	0.059
b	0.008	0.012
b1	0.008	0.011
c	0.007	0.010
c1	0.007	0.009
D	0.189	0.197
E	0.228	0.244
E1	0.150	0.157
L	0.016	0.050
e	0.025 Basic	
θ°	0	8

UNIT:INCH

NOTES:

1.JEDEC OUTLINE: MO-137 AB

2.“D”,DIMENSIONS DO NOT INCLUDE MOLD FALSH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .15mm(006in).

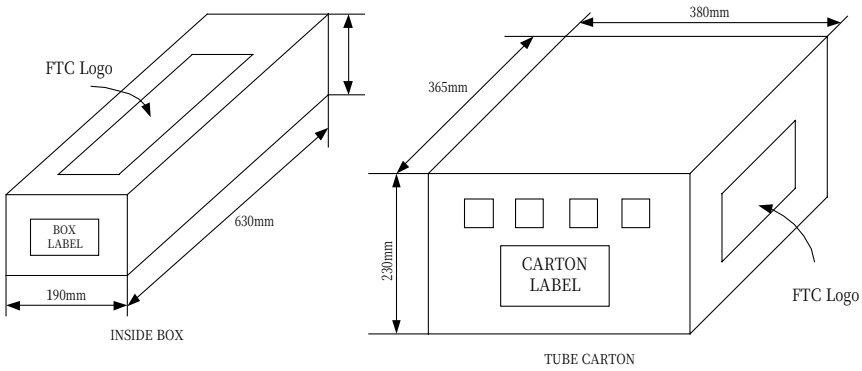
3.“E”,DIMENSIONS DO NOT INCLUDE MOLD FALSH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .25mm(010in) PER SIDE.

4.DATUM PLANE CONCIDENT WITH THE BOTTOM OF LEAD, WHERE LEAD EXITS BODY.

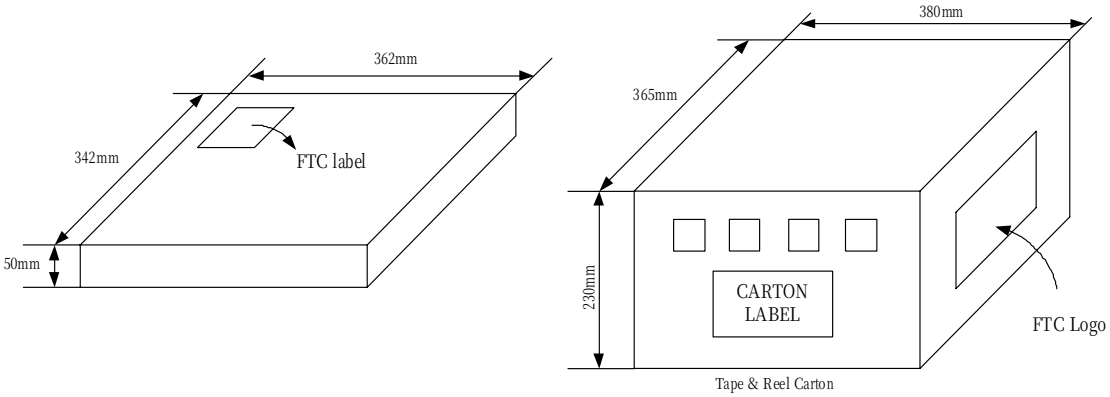
PACKING SPECIFICATIONS

BOX DIMENSION

TUBE INSIDE BOX AND CARTON



TAPE AND REEL INSIDE BOX AND CARTON



PACKING QUANTITY SPECIFICATIONS

50 EA/TUBE	2500 EA / REEL
50 TUBES / INSIDE BOX	4 INSIDE BOXES / CARTON
4 INSIDE BOXES / CARTON	

LABEL SPECIFICATIONS

TAPPING & REEL

Feeling Technology Corp.
Product FP5453DR-LF
Lot No A3311C62-L
D/C 4Xx-XXL
Q'ty ◎ ◎

無鉛
Lead Free

CARTON

Feeling Technology Corp.

Product Type: FP5453DR-LF

Lot No: A3311C62-L

Date Code: 4Xx-XXL

Package Type: SOP-8L

Marking Type: Laser

Total Q'ty: 10,000

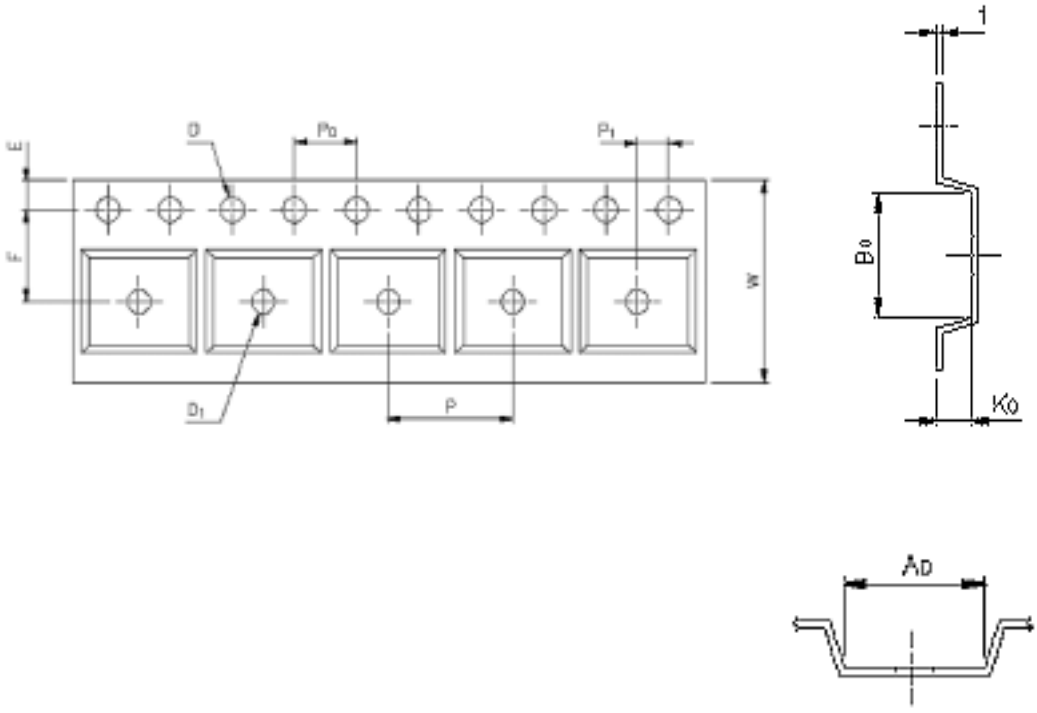
無鉛
Lead Free

SOP16

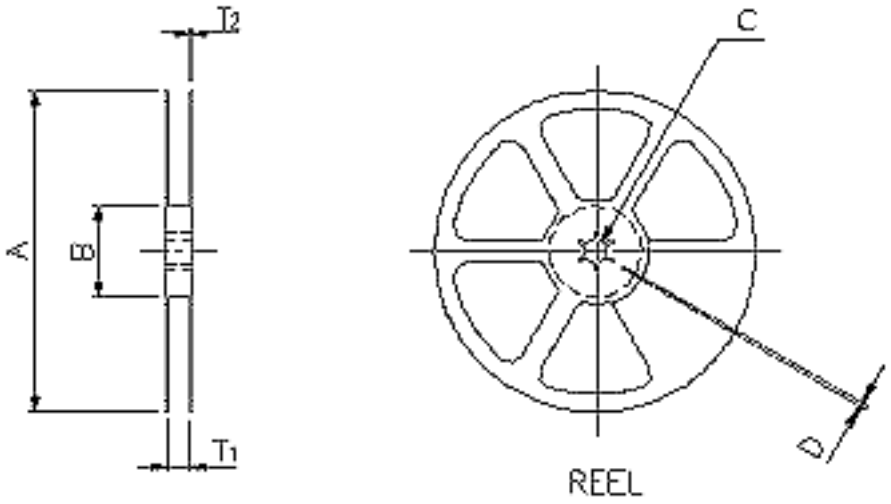
CARRIER TAPE DIMENSIONS

APPLICATION	W	P	E	F	D	D_1
SOP16	16.0±0.3	8.0±0.1	1.75±0.1	7.5±0.1	$1.55^{+0.1}$	$1.5^{+0.25}$

APPLICATION	P_0	P_1	A_0	B_0	K_0	t
SOP16	4.0±0.1	2.0±0.1	6.5±0.1	10.3±0.1	2.1±0.1	0.30±0.05



REEL DIMENISIONS



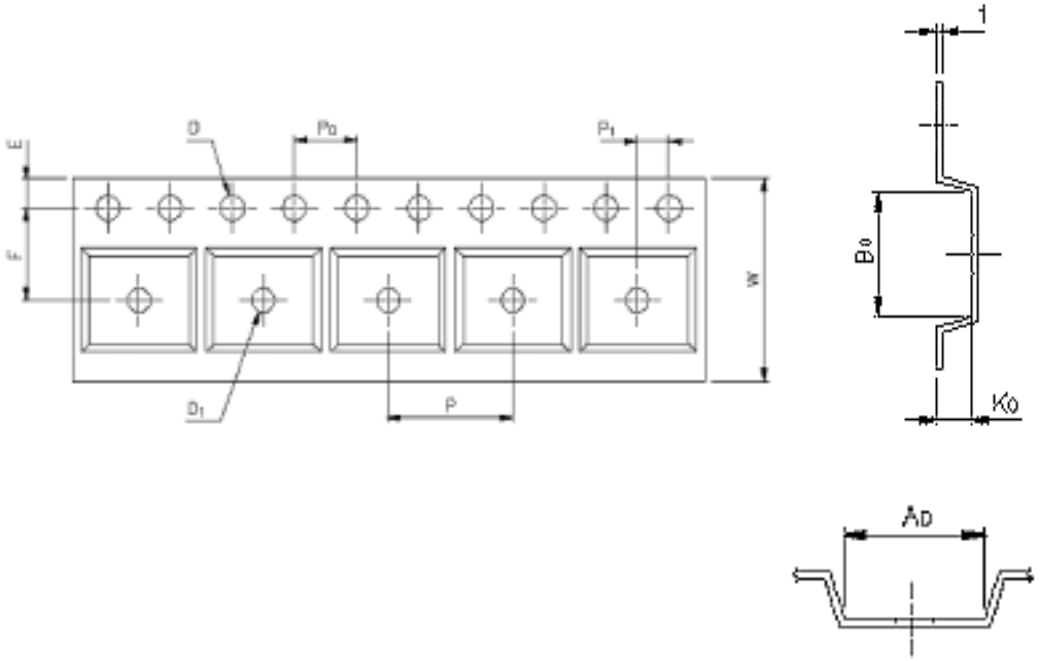
APPLICATION	MATERIAL	A	B	C	D	T1	T2
SOP16	PLASTIC REEL	330±3	100±2.0	13.0±0.5	2.0±0.5	16.4 $^{+0.3}_{-0.2}$	2.5±0.5

SSOP16

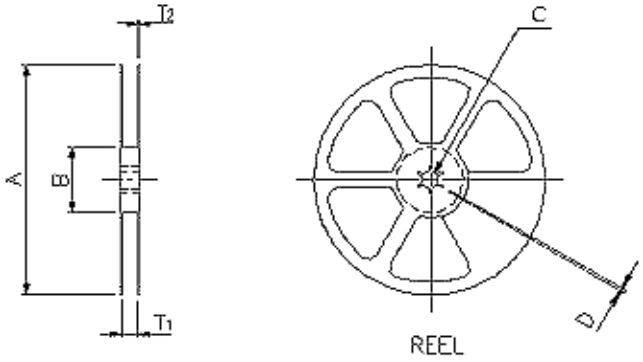
CARRIER TAPE DIMENSIONS

APPLICATION	W	P	E	F	D	D_1
SSOP16	12.0±0.3	8.0±0.1	1.75±0.1	5.5±0.05	$1.5^{+0.1}$	$1.5^{+0.25}$

APPLICATION	P_0	P_1	A_0	B_0	K_0	t
SSOP16	4.0±0.1	2.0±0.05	6.5±0.1	10.3±0.1	2.1±0.1	0.30±0.05



REEL DIMENISIONS



APPLICATION	MATERIAL	A	B	C	D	T1	T2
SSOP16	PLASTIC REEL	330	62	$12.75^{+0.15}$	2.0±0.15	12.4	16.8