

### Features

- Low start-up power supply voltage :1.7V(CH6)
- Wide supply voltage range from 2.4V to 6.5V (CH6); 3.6V to 6.5V(CH1~5)
- Up to 1MHz operating frequency
- Supports for down and up/down Zeta synchronous rectification conversion(CH1)
- Supports for up and up/down SEPIC synchronous rectification conversion(CH2, CH5)
- Supports for up, flyback and up/down SEPIC conversion
- AT1393/C: CH2,CH3, CH4 , CH5 and CH6
- AT1393A/B:CH2,CH3,CH5 and CH6
- Supports for inverting conversion
- AT1393A:CH4
- Synchronized rectification on CH1,CH2,CH5
- Power ON/OFF control function
- Built-in Soft-Start function
- Built-in Short-Circuit Protection circuit.
- LQFP 48 package

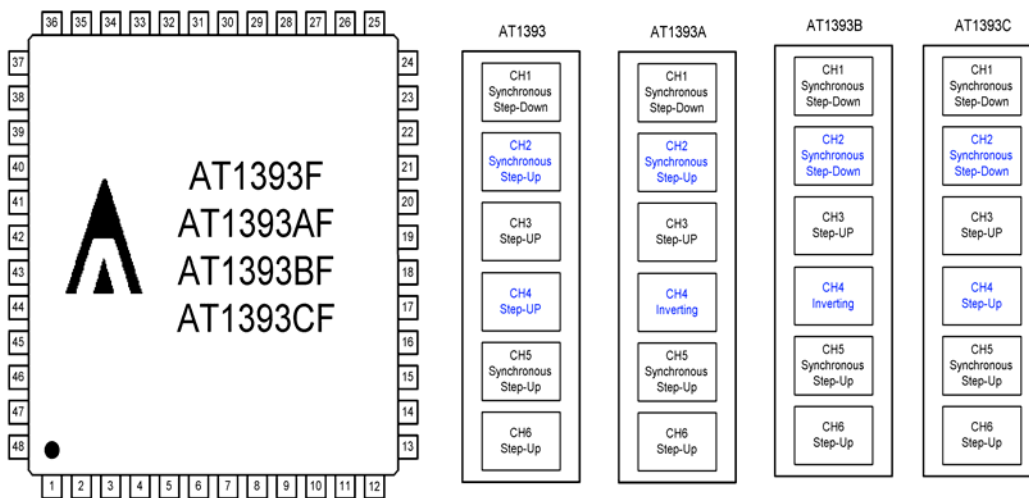
### General Description

The AT1393 provides a complete power solution for digital still and video cameras through the integration of synchronous rectification topology , soft start function and short circuit detection function. This IC is ideal for applications that use either 2 or 3 alkaline or NIMH batteries as well as those using a single Li-ion battery.

### Applications

- Digital Cameras
- CCD Imaging Devices
- Camcorders

### Pin Assignment



### Ordering Information

Part Number	Package	Marking
AT1393F	LQFP48	AT1393F
AT1393F_PBF	LQFP48, PB-Free	AT1393F,date code with one bottom line
AT1393F_GRE	LQFP48,Green	AT1393F,date code with two bottom line
AT1393AF	LQFP48	AT1393AF
AT1393AF_PBF	LQFP48, PB-Free	AT1393AF,date code with one bottom line
AT1393AF_GRE	LQFP48,Green	AT1393AF,date code with two bottom line

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**Pin Description**

Pin No.	Pin name	Function
1	SWOUT	Output Switch Control Circuit Output
2	SWIN	Output Switch Control Circuit Input
3	FB6	CH6 Error Amplifier Output
4	IN6	CH6 Error Amplifier Inverted Input
5	CIN6	CH6 Soft Start Setting
6	DTC5	CH5 Dead Time Control
7	FB5	CH5 Error Amplifier Output
8	IN5	CH5 Error Amplifier Inverted Input
9	INA4	CH4 Inverting Amplifier Input
10	OUTA4	CH4 Inverting Amplifier Output
11	FB4	CH4 Error Amplifier Output
12	IN4	CH4 Error Amplifier Inverted Input
13	INS4	CH4 Short Detection Comparator Inverter Input
14	DTC4	CH4 Dead Time Control
15	CS	CH1 to CH5 Soft Start Setting
16	VREF	Reference 2.5V Output
17	AGND	Ground
18	CSCP	Timer Latch Shout-Circuit Detection Input
19	VCC	Power Supply
20	CTL	CH6 Power Supply Control Input
21	CTL1_2	CH1 and CH2 ON/OFF Control Input
22	CTL3	CH3 ON/OFF Control Input
23	CTL4	CH4 ON/OFF Control Input
24	CTL5	CH5 ON/OFF Control Input
25	RT	Oscillation Frequency Setting Resistor
26	CT	Oscillation Frequency Setting Capacitor
27	VB	Triangular Wave Oscillator Regulator Output
28	IN3	CH3 Error Amplifier Inverted Input
29	FB3	CH3 Error Amplifier Output
30	DTC3	CH3 Dead Time Control
31	IN2	CH2 Error Amplifier Inverted Input
32	FB2	CH2 Error Amplifier Output
33	DTC2	CH2 Dead Time Control
34	IN1	CH1 Error Amplifier Inverted Input
35	FB1	CH1 Error Amplifier Output
36	DTC1	CH1 Dead Time Control
37	OUT1-1	CH1 Main Side Output(P-CH MOSFET)
38	OUT1-2	CH1 Synchronous Rectifier Side Output
39	OUT2-1	CH2 Main Side Output
40	OUT2-2	CH2 Synchronous Rectifier Side Output
41	OUT3	CH3 Output(N-CH MOSFET)
42	PVCC	Output Circuit Power Supply
43	OUT4	CH4 Output AT1393/C:Drive N-CH MOSFET for boost converter AT1393A/B:Drive P-CH MOSFET for inverting
44	PGND	Output Circuit Ground
45	OUT5-1	CH5 Main Side Output(N-CH MOSFET)
46	OUT5-2	CH5 Synchronous Rectifier Side Output
47	OUT6	CH6 Output
48	RB	Output Current Setting Resistor

### Absolute Maximum Ratings

Parameter	Symbol	Condition	Rating		Unit
			Min	Max	
Power supply voltage	V <sub>CC</sub>	--	--	7	V
Output current	I <sub>O</sub>	Output pin	--	20	mA
Output peak current	I <sub>O</sub>	Output pin, Duty ≤ 5%	--	200	mA
Power dissipation	P <sub>D</sub>	T <sub>a</sub> ≤ 25°C (LQFP-48P)	--	860	mW
Operating temperature	T <sub>OPT</sub>	--	-30	85	°C
Storage temperature	T <sub>STG</sub>	--	-55	125	°C
ESD Susceptibility (HBM)		--	--	2	KV
ESD Susceptibility (MM)		--	--	200	V

### Recommended Operating Conditions

Parameter	Symbol	Condition	Value			Unit
			Min	Typ	Max	
Startup power supply voltage	V <sub>CC</sub>	CH6	1.7	--	5.5	V
Power supply voltage	V <sub>CC</sub>	CH6	2.4	5.0	5.5	V
		CH1 to CH5	3.6	5.0	5.5	V
Reference voltage output current	I <sub>OR</sub>	VREF pin	-1	--	0	mA
VB pin output current	I <sub>B</sub>	VB pin	-0.5	--	0	mA
Input voltage	V <sub>IN</sub>	IN1 to IN5, INA4, INS4 pins	0	--	V <sub>CC</sub>	V
		IN6 pin	0	--	V <sub>CC</sub> -0.9	V
Control input voltage	V <sub>CTL</sub>	CTL pin	0	--	7	V
Output current	I <sub>O</sub>	OUT pin (CH1 to CH5)	--	2	15	mA
		OUT pin (CH6)	1	2	15	mA
		OUT pin	--	1	4	mA
Output current setting resistor	R <sub>B</sub>	RB6 pin	2.4	24	51	kΩ
Oscillator	f <sub>OSC</sub>	--	100	500	1000	kHz
Timing capacitor	C <sub>T</sub>	--	47	100	560	pF
Timing resistor	R <sub>T</sub>	--	8.2	18	100	kΩ
Soft start capacitor	C <sub>S</sub>	CH1 to CH5	--	0.027	1.0	μF
	C <sub>+IN6</sub>	CH6	--	0.47	1.0	μF
Short detection capacitor	C <sub>SCP</sub>	--	--	0.1	1.0	μF
VB pin capacitor	C <sub>VB</sub>	--	0.082	0.1	--	μF
Operating ambient temperature	T <sub>a</sub>	--	-20	25	85	°C

### Electrical characteristics

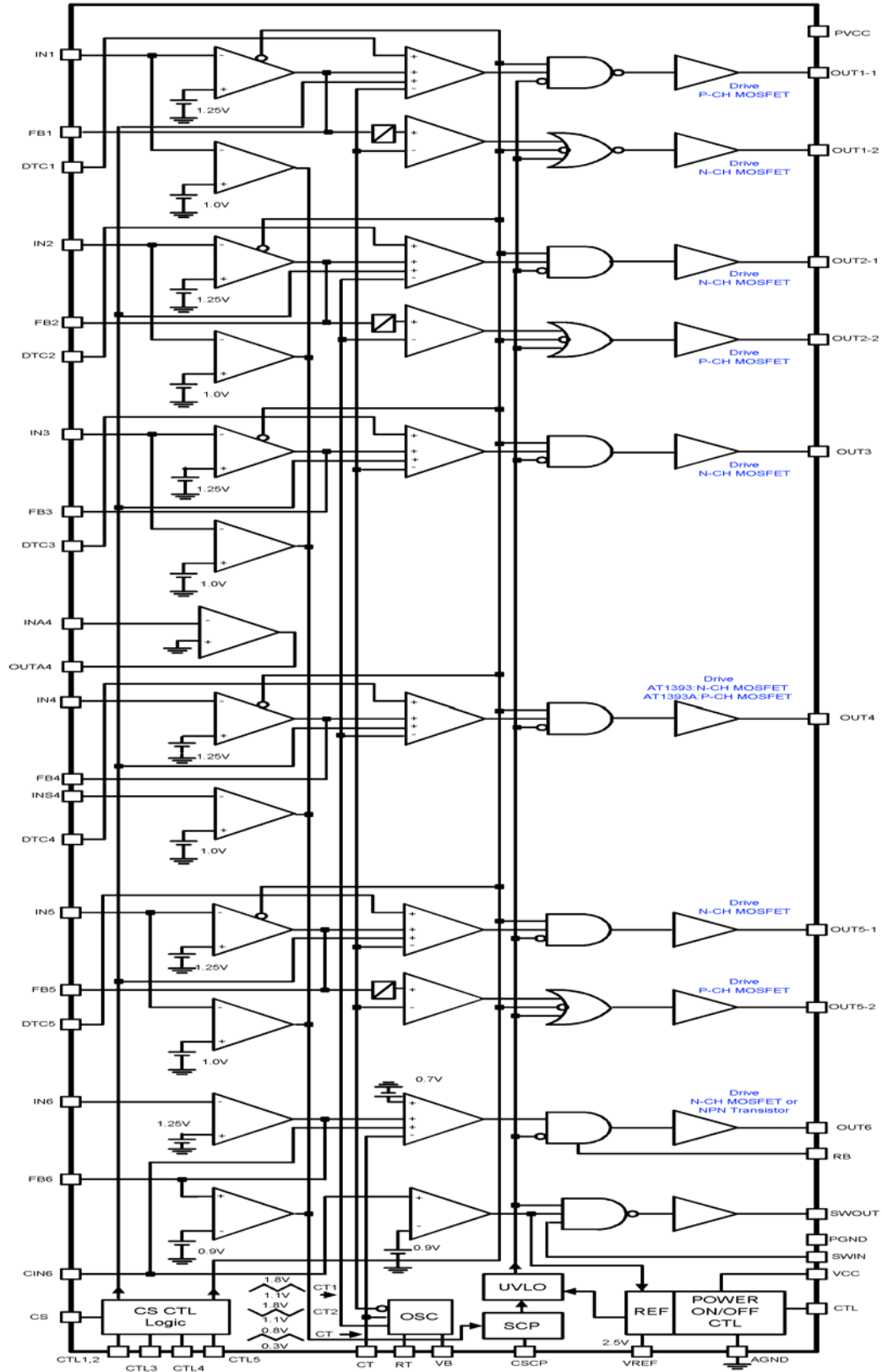
(Ta=25°C, VCC=PVCC=5V)

Parameter		Symbol	Condition	Value			Unit	
				Min	Typ	Max		
Reference voltage block [REF]	Reference voltage	$V_{REF}$	--	2.40	2.50	2.60	V	
	Output voltage temperature stability	$\frac{\Delta V_{REF}}{V_{REF}}$	Ta = -30°C to 85°C	--	0.5	--	%	
	Input stability	Line	VCC=3.6 to 5.5V	-10	--	10	mV	
	Load stability	Load	VREF=0mA to -1mA	-10	--	10	mV	
Under voltage lockout block [U.V.L.O.]	CH1 to CH5	Threshold voltage	$V_{TH}$	VIN=0V to VCC	2.6	2.8	3.0	V
		Hysteresis width	$V_H$	--	--	0.2	--	V
	CH6	Reset voltage	$V_{RST}$	VIN=VCC to 0V	1.20	1.30	1.40	V
		Threshold voltage	$V_{TH}$	VIN=0V to VCC	1.35	1.5	1.65	V
Soft start block [CS]	Charge current	$I_{CS}$	--	-1.4	-1.0	-0.6	$\mu A$	
Soft start block [CIN6]	Charge current	$I_{CIN6}$	--	-3.0	-2.5	-2.0	$\mu A$	
Short circuit detection block [SCP]	Threshold voltage	$V_{TH}$	--	0.65	0.70	0.75	V	
	Input standby voltage	$V_{STB}$	--	--	50	100	mV	
	Input latch voltage	$V_I$	--	--	50	100	mV	
	Input source current	$I_{CSCP}$	--	-1.4	-1.0	-0.6	$\mu A$	
Triangular wave oscillator block [OSC]	Oscillator frequency	$f_{OSC}$	CT=100pF, RT=18k $\Omega$	450	500	550	kHz	
	Frequency stability for voltage	$\frac{\Delta f}{f_{dv}}$	VCC=4V to 5.5V	--	1	10	%	
	Frequency stability for temperature	$\frac{\Delta f}{f_{dt}}$	Ta=-30°C to 85°C	--	1	20	%	
	Threshold voltage	$V_{TH}$	FB=IN	1.24	1.25	1.26	V	
	$V_T$ temperature stability	$\frac{\Delta V_T}{V_T}$	Ta = -30°C to 85°C	--	0.5	--	%	

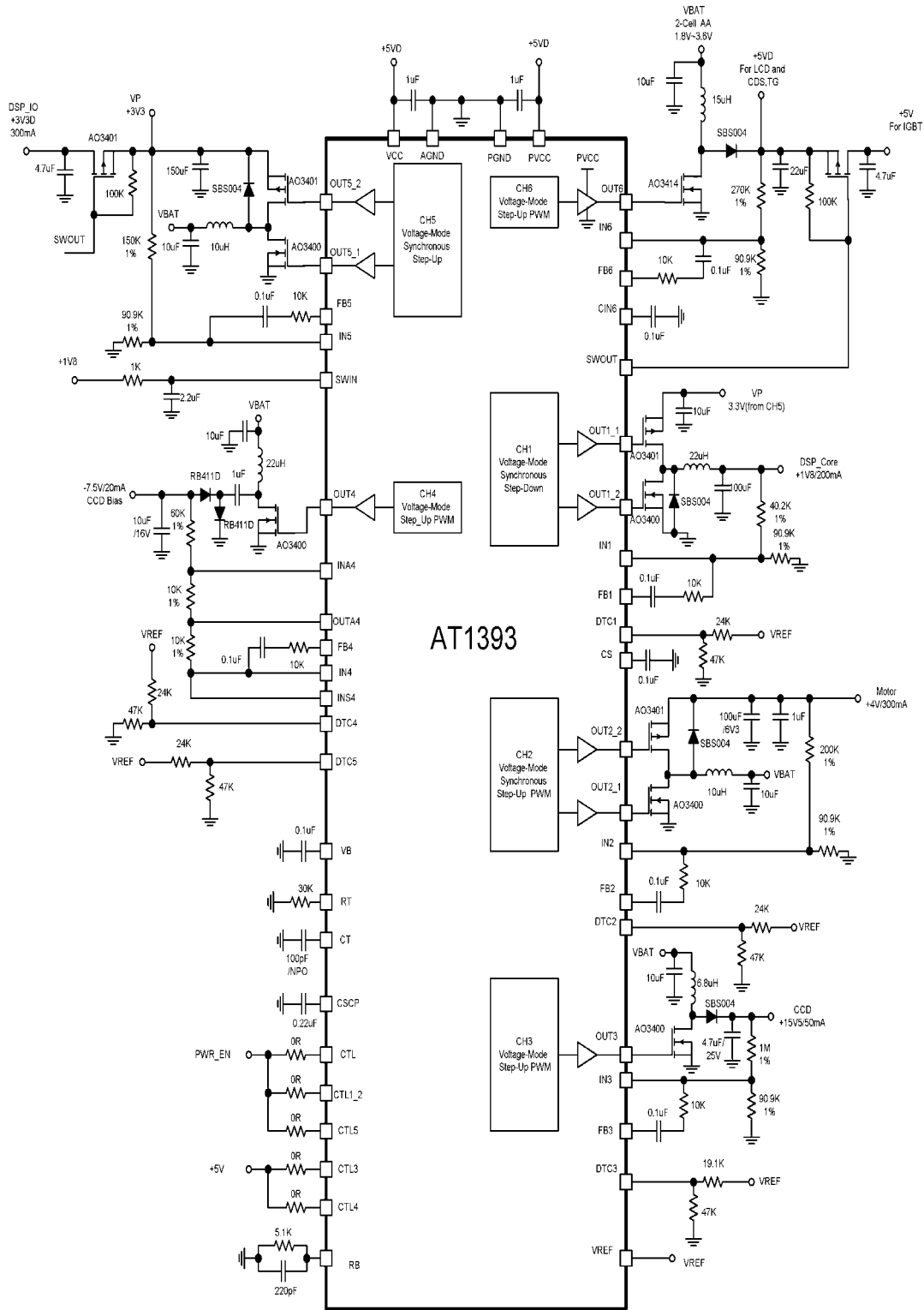
Error Amplifier block (CH1 to CH5) [Error Amp]	Input bias current	$I_B$	IN=0V (CH1 to CH3, CH5)	-320	-80	--	nA
			IN=0V (CH4)	-120	-30	--	nA
	Voltage gain	$A_V$	DC	60	100	--	dB
	Frequency bandwidth	BW	$A_V=0\text{dB}$	--	1.0	--	MHz
	Output voltage	$V_{OH}$	--	2.2	2.4	--	V
			$V_{OL}$	--	--	50	200
	Output source current	$I_{SOURCE}$	FB=2.3V	--	-2.0	-1.0	mA
Output sink current	$I_{SINK}$	FB=1.45V	70	140	--	$\mu\text{A}$	
Error amplifier block (CH6) [Error Amp]	Threshold voltage	$V_{TH}$	FB=0.55	1.24	1.25	1.26	V
	Temperature stability	$\Delta V_T/V_T$	Ta = -30°C to 85°C	--	0.5	--	%
	Input bias current	$I_B$	IN=0V	-100	-20	--	nA
	Voltage gain	$A_V$	DC	60	75	--	dB
	Frequency bandwidth	BW	$A_V=0\text{dB}$	--	1.0	--	MHz
	Output voltage	$V_{OH}$	--	1.1	1.3	--	V
			$V_{OL}$	--	--	0	200
	Output source current	$I_{SOURCE}$	FB=0.55V	--	-2.0	-1.0	mA
Output sink current	$I_{SINK}$	FB=0.55V	60	120	--	$\mu\text{A}$	
Inverting amplifier block (CH4) [Inv Amp]	Input offset voltage	$V_{IO}$	OUT=1.25V	-10	0	10	mV
	Input bias current	$I_B$	IN=0V	-120	-30	--	nA
	Voltage gain	$A_V$	DC	60	100	--	dB
	Frequency bandwidth	BW	$A_V=0\text{dB}$	--	1.0	--	MHz
	Output voltage	$V_{OH}$	--	2.2	2.4	--	V
			$V_{OL}$	--	--	50	200
	Output source current	$I_{SOURCE}$	OUT=1.25V	--	-2.0	-1.0	mA
Output sink current	$I_{SINK}$	OUT=1.25V	70	140	--	$\mu\text{A}$	
Short detect comparator (CH1 to CH5) [SCP Comp]	Threshold voltage	$V_{TH}$	CH1 to CH5	0.97	1.00	1.03	%
	Input bias current	$I_B$	IN=0V (CH1 to CH3, CH5)	-320	-80	--	nA
			IN=0V (CH4)	-200	-50	--	nA
Short detect comparator (CH6)	Threshold voltage	$V_{TH}$	--	0.8	0.9	1.0	V

PWM Comp. (CH1 to CH5) [PWM Comp]	Threshold voltage	$V_{T0}$	Duty = 0 %	1.0	1.1	--	V
		$V_{Tmax}$	Duty = 100 %	--	1.8	1.9	V
	Input current	$I_{DTC}$	DTC=0.4V (CH1 to CH5)	-1.0	-0.3	--	$\mu A$
PWM Comp. (CH6) [PWM Comp]	Threshold voltage	$V_{T0}$	Duty = 0 %	0.2	0.3	--	V
		$V_{Tmax}$	Duty = 100 %	--	0.74	0.84	V
	Maximum duty cycle	Dtr	CT=100pF, RT=18k $\Omega$ RB=24k $\Omega$	70	80	--	%
Output block (CH1,2,4,5) [Pch MOS]	Output source current	$I_{SOURCE}$	OUT=VCC/2	--	-130	--	mA
	Output sink current	$I_{SINK}$	OUT=VCC/2	--	100	--	mA
	Output ON resistor	$R_{OH}$	OUT = -15mA	--	18	30	$\Omega$
		$R_{OL}$	OUT = 15mA	--	16	25	$\Omega$
Output block (CH1 to CH5) [Nch MOS]	Output source current	$I_{SOURCE}$	OUT=VCC/2	--	-130	--	mA
	Output sink current	$I_{SINK}$	OUT=VCC/2	--	100	--	mA
	Output ON resistor	$R_{OH}$	OUT = -15mA	--	18	30	$\Omega$
		$R_{OL}$	OUT = 15mA	--	16	25	$\Omega$
Output block (CH6) [Drive]	Output source current	$I_{SOURCE}$	OUT=0.7V, RB=24k $\Omega$	-2.6	-2.0	-1.4	mA
	Output sink current	$I_{SINK}$	Duty $\leq$ 5%, OUT=0.7V	--	40	--	mA
Output switch control block [SW]	SW input voltage	$V_{IH}$	SWOUT = "L" level	1.5	--	6.5	V
		$V_{IL}$	SWOUT = "H" level	0	--	0.4	V
	Input current	$I_{SWIN}$	SWIN = 5V	--	100	200	$\mu A$
	Output source current	$I_{SOURCE}$	Duty $\geq$ 95%, SWOUT=0V	--	-9	--	mA
	Output sink current	$I_{SINK}$	Duty $\leq$ 5%, SWOUT=5V	--	17	--	mA
	Output ON resistor	$R_{OH}$	SWOUT = -4mA	--	250	400	$\Omega$
$R_{OL}$		SWOUT = 4mA	--	100	150	$\Omega$	
Control block (CTL, CTL1 to CTL5) [CTL]	CTL input voltage	$V_{IH}$	Active mode	1.5	--	6.5	V
		$V_{IL}$	Standby mode	0	--	0.4	V
	Input current	$I_{CTL}$	CTL = 5V	--	100	200	$\mu A$
General	VCC Standby current	Icss	CTL=0V	--	--	10	$\mu A$
	PVCC Standby current	Icss(o)	CTL=0V	--	--	10	$\mu A$
	VCC Nominal Supply current	Icc	CTL, CTL1 to CTL5 = 5V	--	6	9	mA

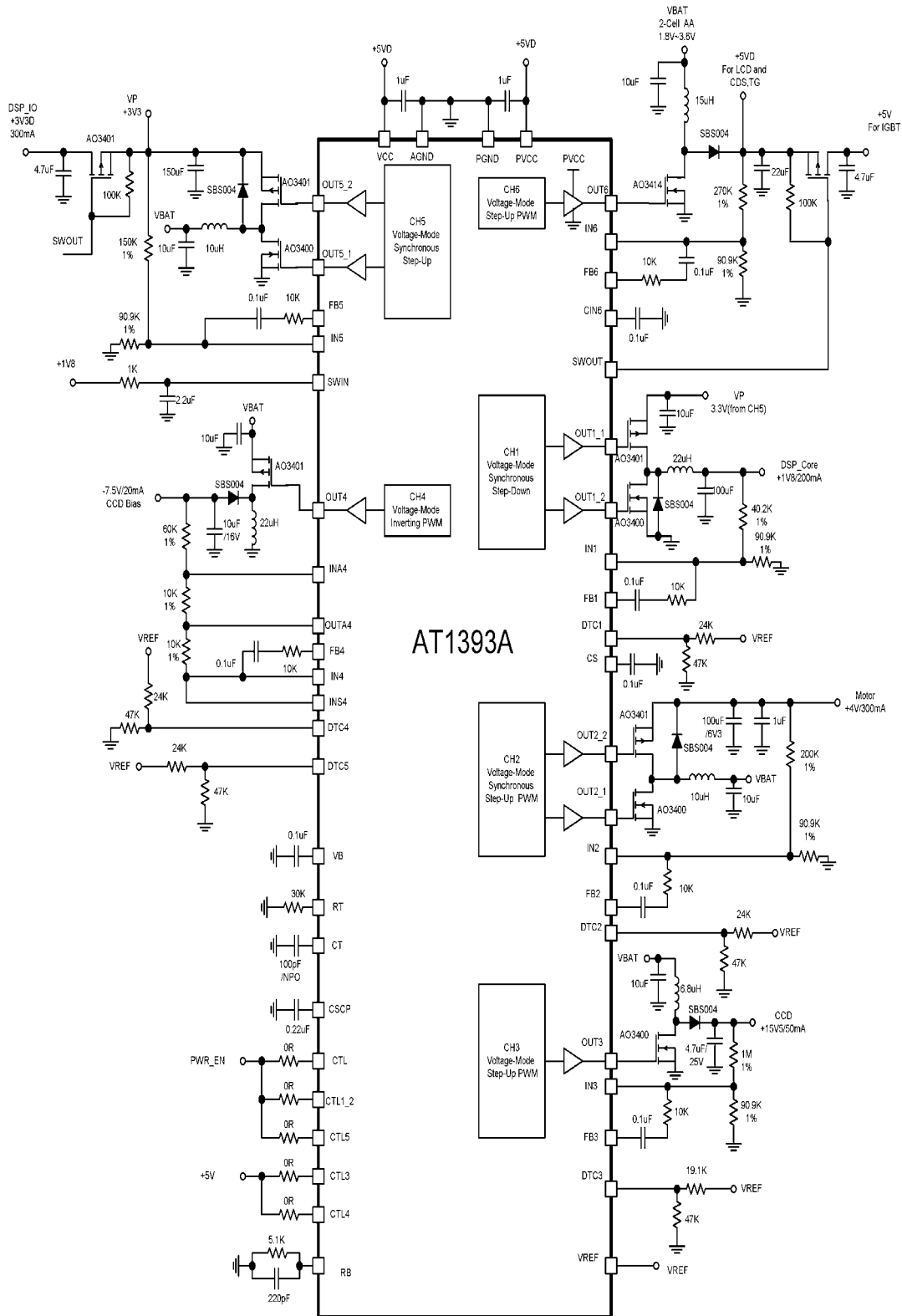
**Block Diagram**



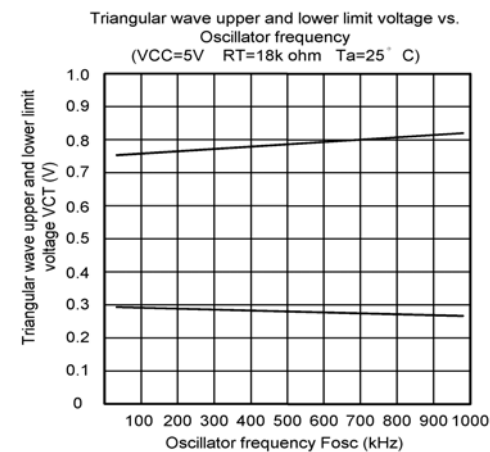
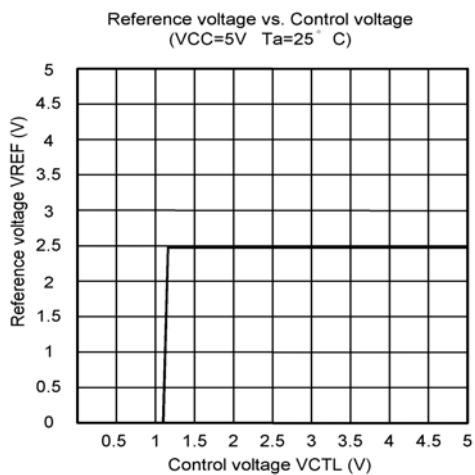
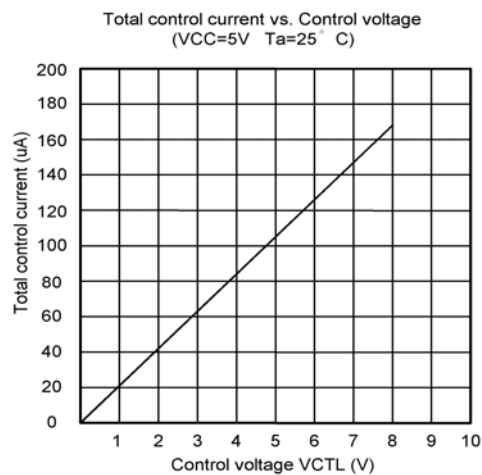
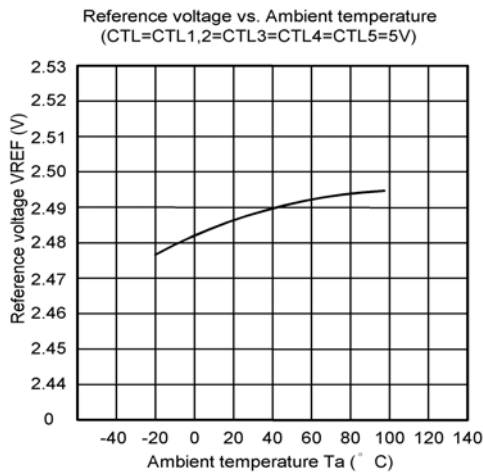
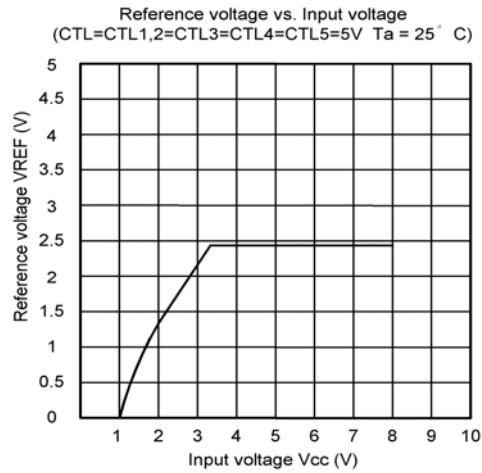
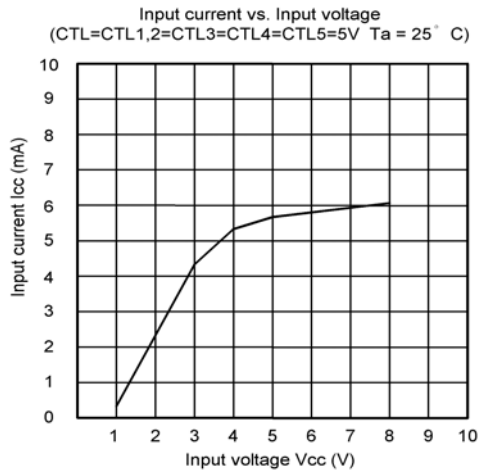
**Application Circuit**

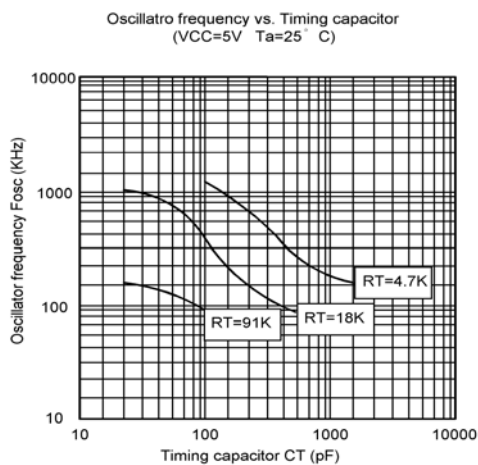
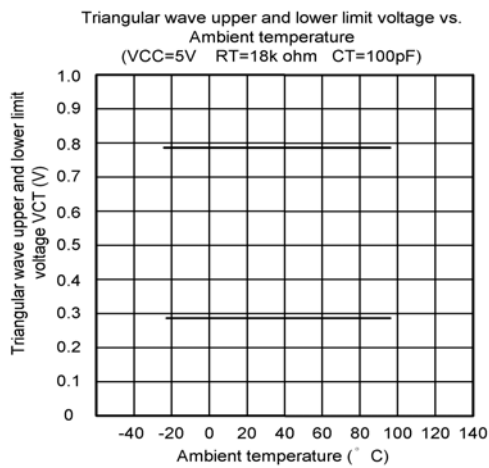
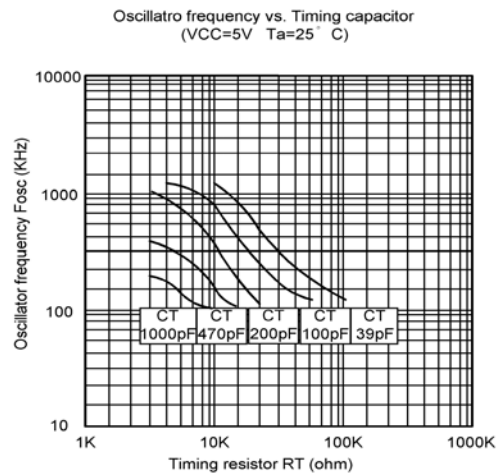
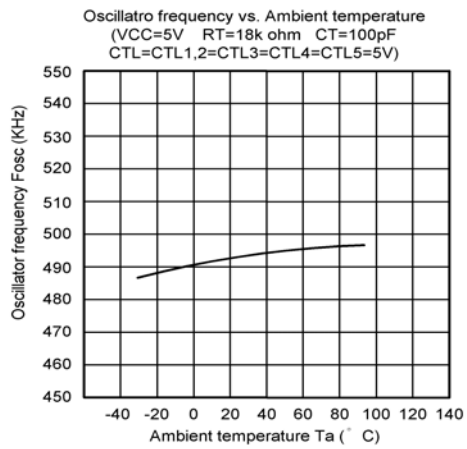






Typical Characteristics





## Function Description

### 1. Power Converter

\* Reference voltage block

A temperature independent voltage of typical value at 2.50V is generated from the power source by the reference voltage circuit, which is used as a reference voltage for all internal circuitry and supplies load current to external device up to 1 mA.

\* Triangular oscillator block

A triangular oscillation waveform is generated by connecting a timing resistor (RT) to pin 25 and a timing capacitor (CT) to pin 26. The resulting waveforms CT (amplitude at 0.3V to 0.8V), CT1 (in phase with CT with amplitude at 1.1V to 1.8V) and CT2 (reverse phase with CT with amplitude at 1.1V to 1.8V) serve as input to the PWM comparator.

\* Error amplifier block

The error amplifier controls the error signal to the PWM comparator by sensing the DC/DC converter output voltage. Furthermore, by connecting feedback resistor and capacitor from the output pin to the inverted input pin of the error amplifier, an arbitrary loop gain can be set to make the system stable.

\* Inverting amplifier block

The inverting amplifier detects the negative DC/DC converter output voltage and sends a control signal to the error amplifier.

\* PWM comparator block

The PWM comparator converts the input voltage to pulse width and thereby the duty cycle of the DC/DC converter.

Channels 1, 2, and 5 main sides, channel 3, 4, and 6 : The comparator keeps the output transistor turn on while the error amplifier output voltage and DTC voltage are higher than the triangular wave voltage.

Channels 1, 2, and 5 synchronous rectification sides : The comparator keeps the output transistor turn on while the error amplifier output voltage are lower than the triangular wave voltage.

\* Output block

A totem pole configuration is designed for the output block and can drive external MOSFET or transistor.

**2. Channel Control**

The channels are turned on and turned off according to the voltage levels at the CTL, CTL12, CTL3, CTL4, and CTL5 as described in the following table.

Voltage level at control (CTL) pin					Channel on/off status									
CTL	CTL1,2	CTL3	CTL4	CTL5	CH6	CH1,2	CH3	CH4	CH5					
L	X	X	X	X	OFF (standby state)									
H	L	L	L	L	ON	OFF	OFF	OFF	OFF					
				H					ON					
			H	L				OFF	OFF					
		H		ON				ON						
		H	L	L				L	ON	ON	OFF	OFF	OFF	
								H					ON	
	H			L		OFF	OFF							
			H	ON		ON								
	H		L	L		L	ON	ON				ON	OFF	OFF
						H								ON
		H		L		OFF			OFF					
			H	ON		ON								

X : Don't care

**3. Protective Functions**

\* Short circuit protection and timer latch

The comparator for short circuit detection in each channel detects the output voltage level of the power converter. When the output voltage falls below the short detection level, there will be a constant bias current charging the external capacitor  $C_{SCP}$  that is connected to the CSCP pin until the capacitor voltage level reaches about 0.7V and the output transistor turned off consequently. The actuated protection can be reset by restarting the power source.

\* Under-voltage lockout protection

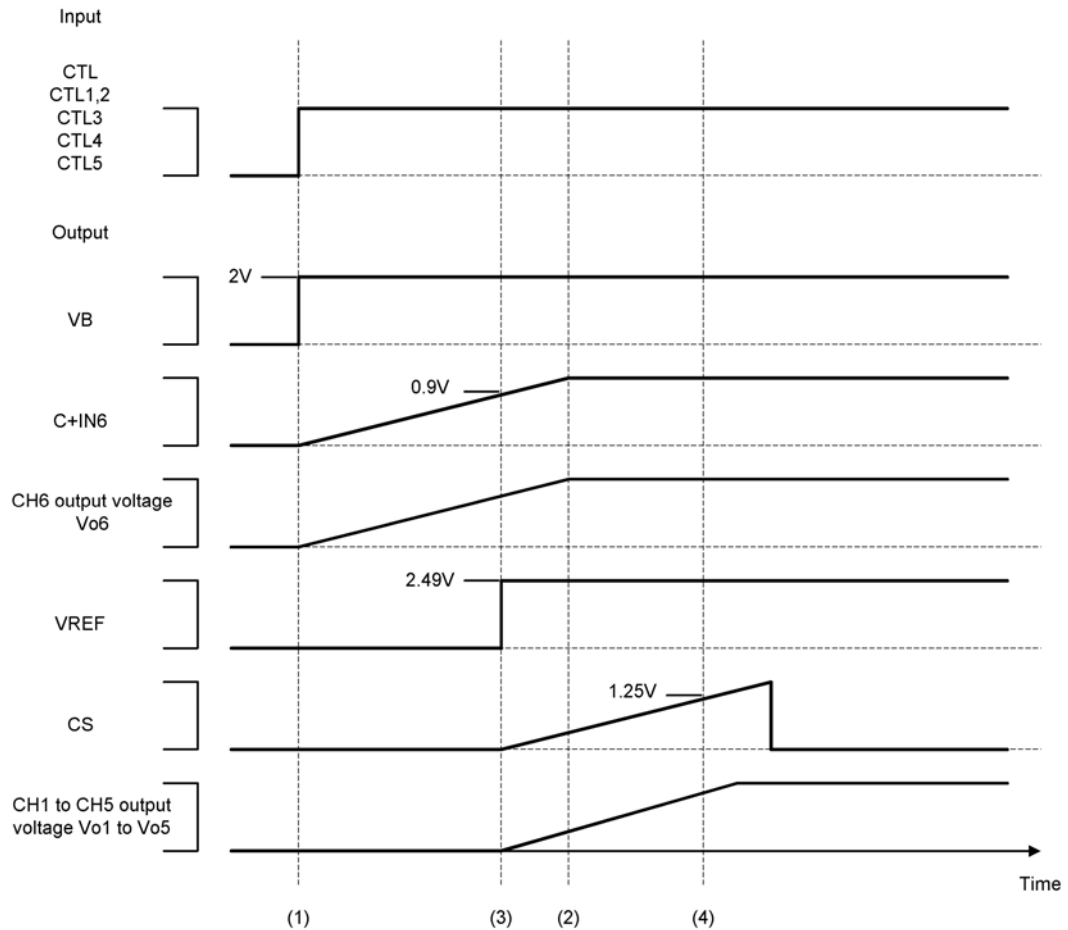
The under-voltage lockout protection is triggered when the supply voltage momentarily drops during transient, which may cause the IC to malfunction. To prevent such malfunctions, the under-voltage lockout protection circuit will turn off the output transistor, set the dead time to 100%, and hold the CSCP pin at the “L” level after detecting a decrease in internal reference voltage with respect to the power supply voltage,.

\* Output switch control

When the power is turned on, output switch control circuit (SWIN = “L”) prevents the reactive current from flowing to external CH5 and CH6. After releasing UVLO and the C+IN6 pin voltage goes above 0.9V, if SWIN is “H” then SWOUT becomes “L” to turn on the external MOSFET and generate output voltage.

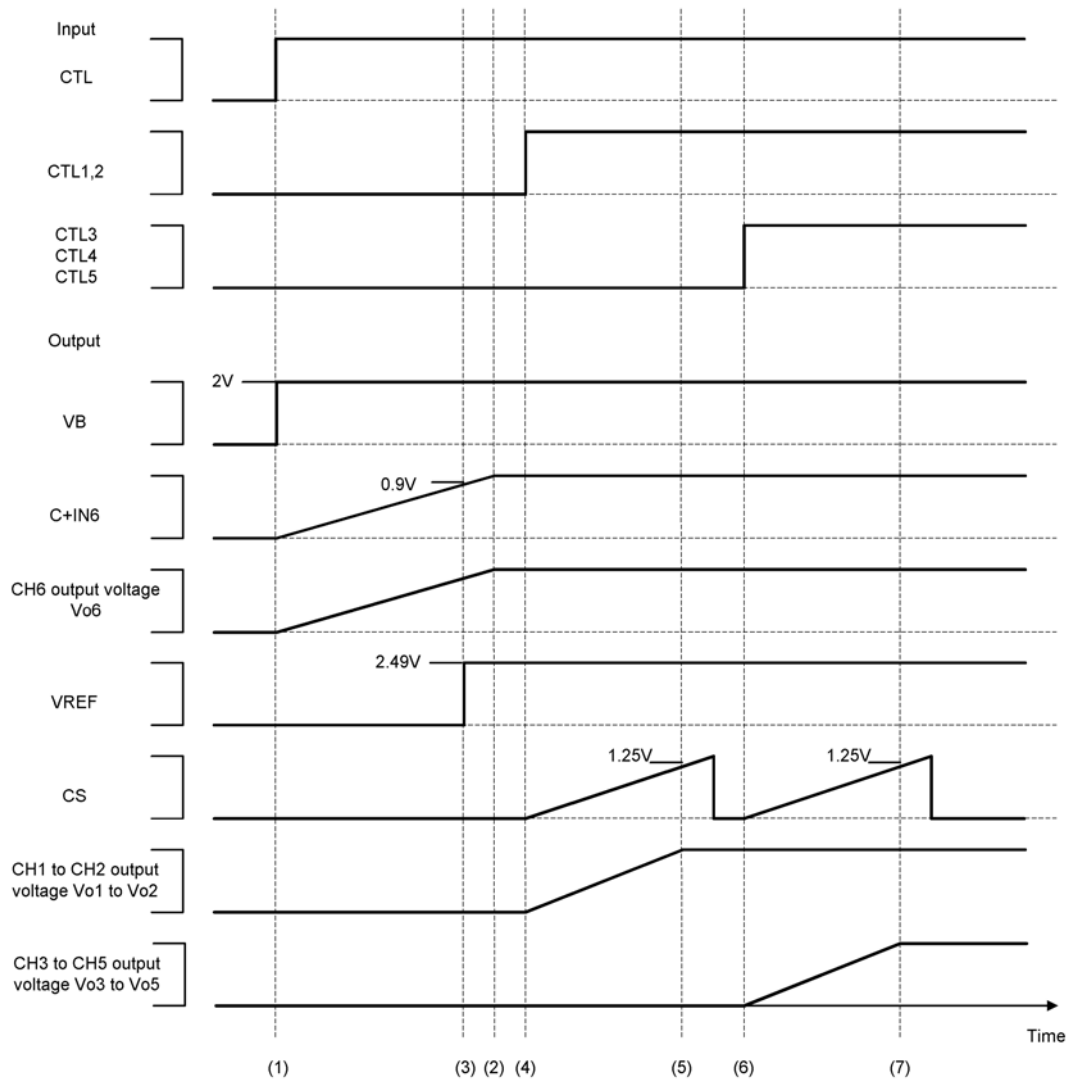
#### 4. Soft Start Function

\* The CTL, CTL1,2, CTL3, CTL4, and CTL5 terminals are driven to high level at the same time. The driving scheme is described in the following diagram.



(1) to (2) : CH6 soft start interval  
 (3) to (4) : CH1 to CH5 soft start interval

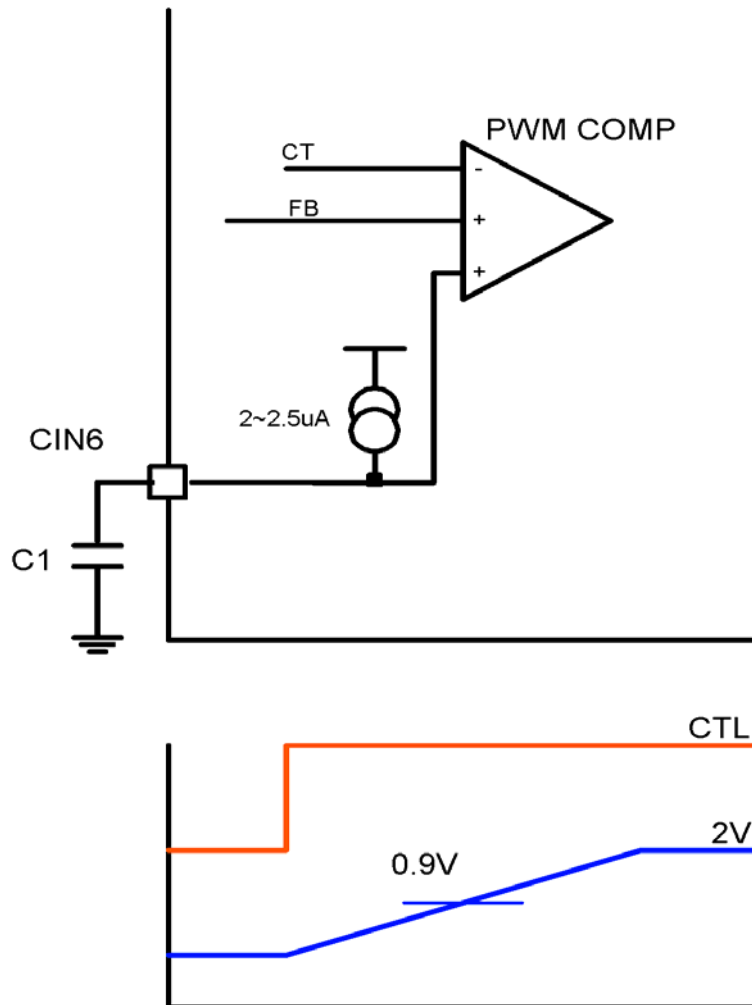
\* After CH6 soft start and driving the CTL1,2, CTL3, CTL4, and CTL5 to high level. The driving scheme is described in following diagram.



- (1) to (2) : CH6 soft start interval
- (3) : VREF output start
- (4) to (5) : CH1 to CH2 soft start interval
- (6) to (7) : CH3 to CH5 soft start interval



\* Soft start setting (for CH6)



Consider the input voltage and the load current to decide the value of the capacitor connected to the CIN6 pin. The soft start time  $T_s$ (s) until the DC/DC converter output voltage of CH6 reaches 95% can be calculated by:

$$T_s(s) = 0.45 * C_1(\mu F)$$

\* Soft start setting (for CH1 to CH5)

$$T_s(s) = 1.25 * C_s(\mu F)$$

Note : It could be disabled soft start function by floating CIN6 pin or CS pin.

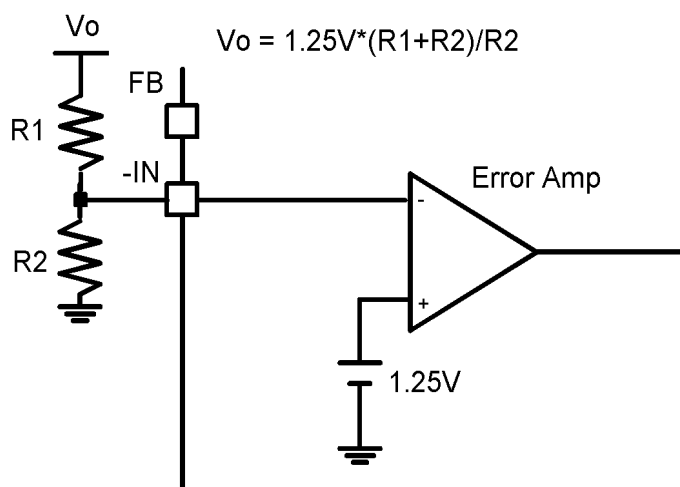
### Determine Oscillator Frequency

The triangular oscillator frequency is decided by the timing capacitor ( $C_T$ ) and timing resistor ( $R_T$ ) according to the following formula:

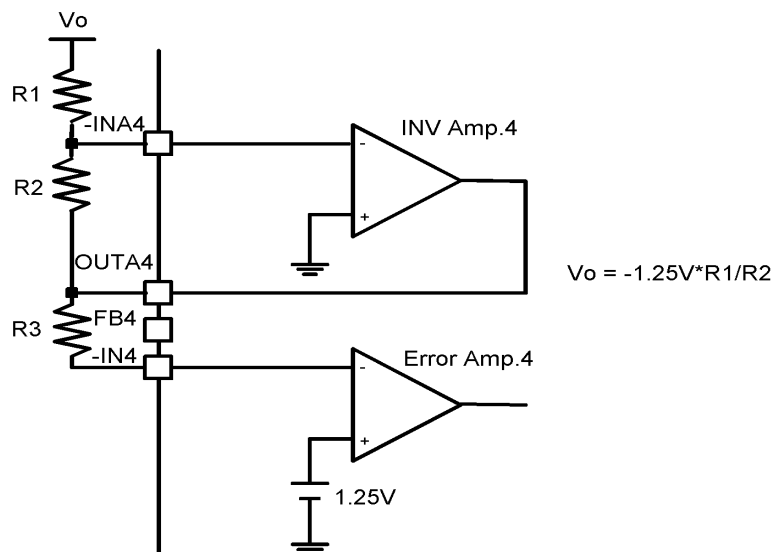
$$f_{osc}(KHz) = 900000 / (R_T(K\Omega) * C_T(pF))$$

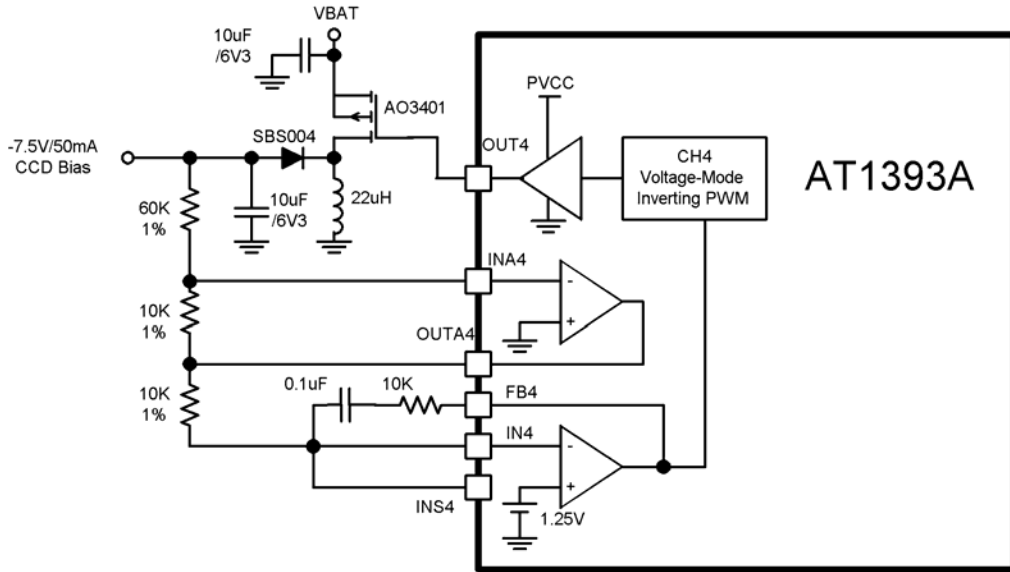
### DC/DC Output Voltage

\* For CH1 to CH3, CH5 and CH6

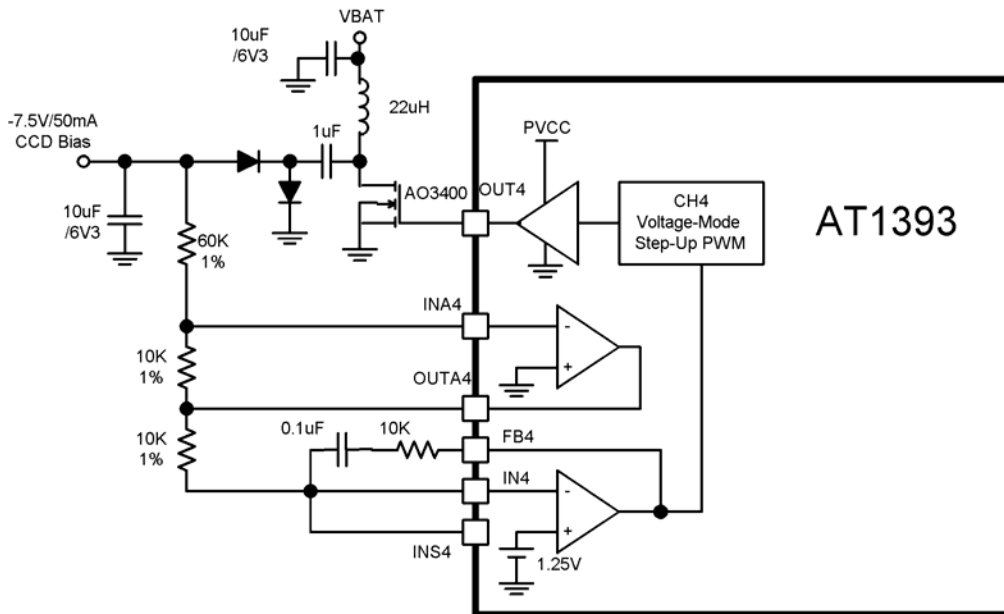


\* For CH4





\*Using AT1393A CH4 as Inverting structure



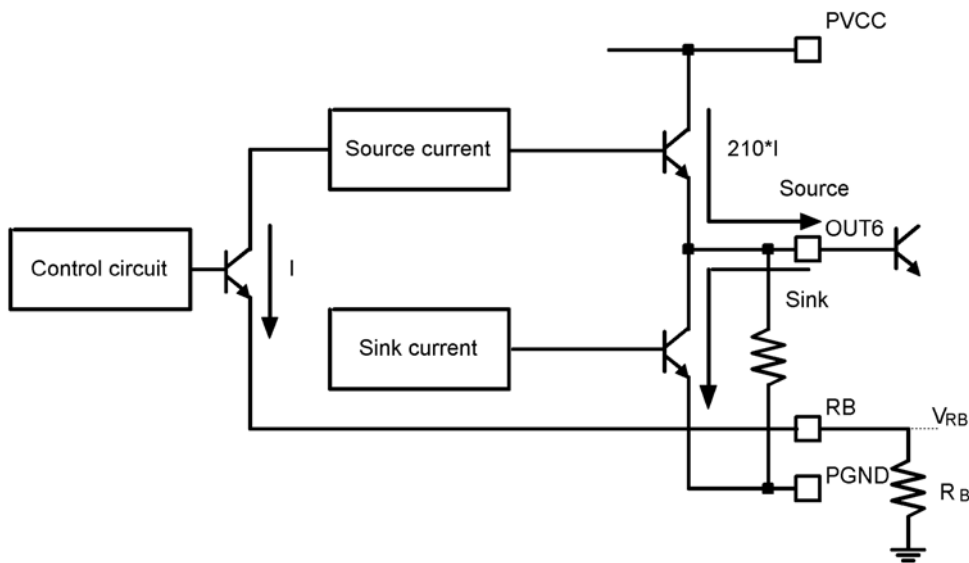
\*Using AT1383/AT1393 CH4 as negative voltage feedback structure

### The CH6 Source Current

The output circuit of CH6 is illustrated in the following diagram. It can determine the output source current by defining the value of resistor  $R_B$ .

Note that the source current can be calculated by the following equation.

$$\text{Output source current} = (V_{RB}/R_B) * 210 \quad (\text{A})$$



### Setting Time of Short Circuit Protection

The SCP comparator in each channel detects the output voltage to decide whether the power converter works at normal condition. At the same time, the voltage level of CSCP pin is held at low level. If the output load of these converters rapidly malfunction or become shorted, causing the output voltage to drop, the SCP comparator detects that and enables short circuit protection. The time period for short circuit protection is shown in the following equation.

Short detection time ( $t_{PE}(s)$ )

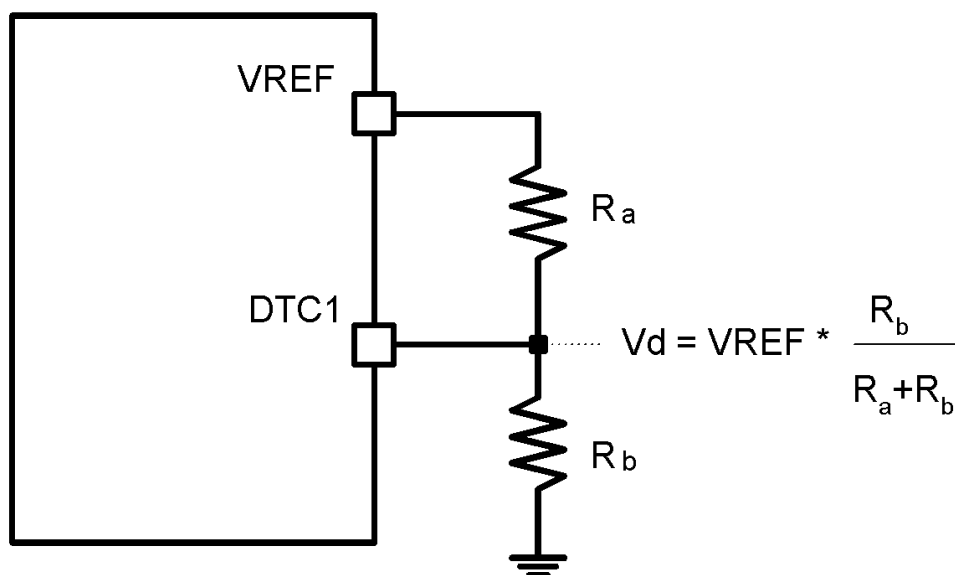
$$t_{PE}(s) = 0.7 * C_{SCP} (\mu F)$$

**Note : It could be disabled short circuit protection function by connecting CSCP pin into the ground.**

### Setting the Dead Time Control Level

When using step up or Zeta or flyback DC/DC converter, it must prevent that output transistor works at full-ON state (ON duty = 100%). To prevent this situation, set the maximum duty of these channels. The dead time control circuit is implemented as below. When the voltage at the DTC1 pin is higher than the triangular wave voltage (CT1), the output transistor is turned on. The maximum duty calculation formula assuming that triangular wave amplitude = 0.7V and triangular wave minimum voltage = 1.1V.

$$Duty = [(V_d - 1.1)/0.7] \times 100\%$$



Note 1 : The circuit is suitable at CH1 to CH5.

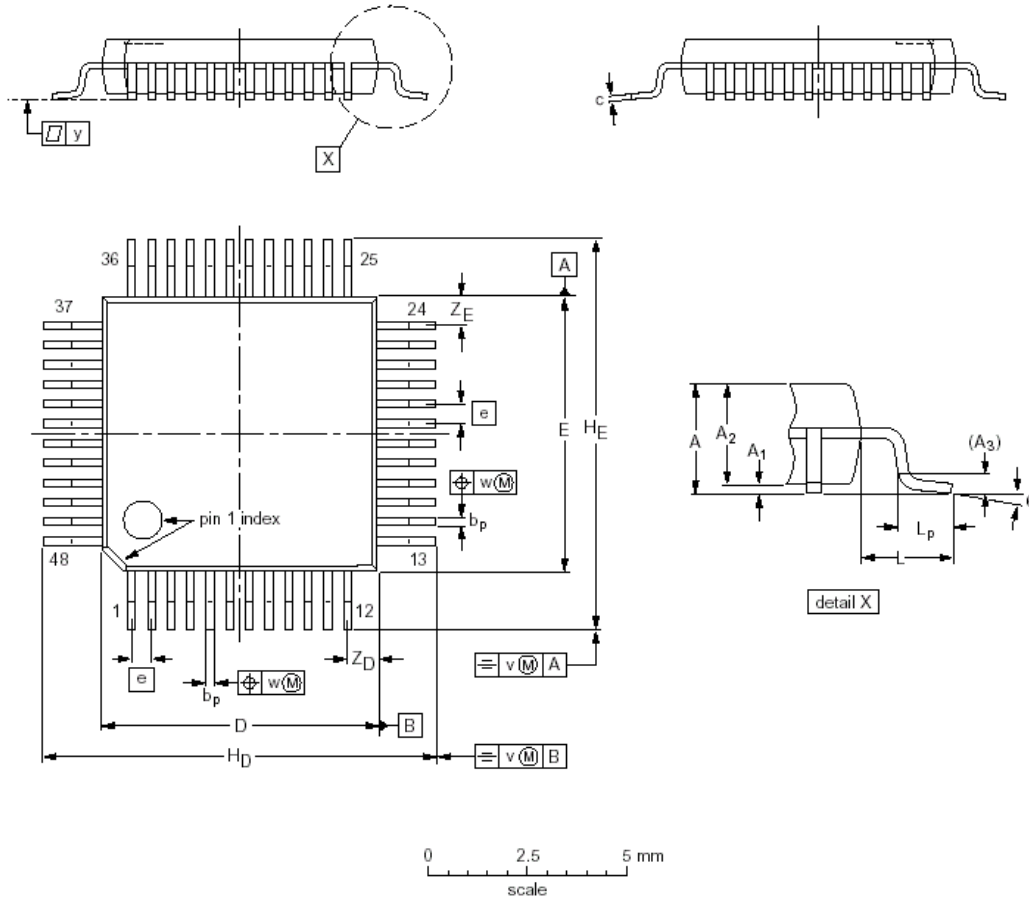
Note 2 : Shorting DTC and VREF to disable dead time control function.

### Using CH4 Inv Amp.

When not using the CH4 INV Amp., connect the INA4 and OUTA4 each other.

**Package Description**

LQFP48



DIMENSIONS (mm are the original dimensions)

UNIT	A <sub>max.</sub>	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	b <sub>p</sub>	c	D <sup>(1)</sup>	E <sup>(1)</sup>	e	H <sub>D</sub>	H <sub>E</sub>	L	L <sub>p</sub>	v	w	y	Z <sub>D</sub> <sup>(1)</sup>	Z <sub>E</sub> <sup>(1)</sup>	θ
mm	1.60	0.20 0.05	1.45 1.35	0.25	0.27 0.17	0.18 0.12	7.1 6.9	7.1 6.9	0.5	9.15 8.85	9.15 8.85	1.0	0.75 0.45	0.2	0.12	0.1	0.95 0.55	0.95 0.55	7° 0°