

MB3778

SWITCHING REGULATOR CONTROLLER

2-CHANNEL LOW-VOLTAGE OPERATION WITH ON-CHIP STAND-BY FUNCTION

The MB3778 is a dual switching regulator control IC. It has a basic circuit that controls PWM system switching regulator power for two channels. Complete synchronization is achieved by using the same oscillator output.

This IC can accept any two of the following types of output voltage: step-down, step-up, or voltage inversion (inverting voltage can be output to only one circuit). The MB3778's low power consumption makes it ideal for use in portable equipment.

- Wide input voltage range: 3.6V to 18V
- Low current consumption: 1.7 mA typical at operation, 10A maximum at stand-by
- Wide oscillation frequency range: 1 kHz to 500 kHz
- On-chip timer latched short-circuit sensing circuit
- Under-voltage lockout for low V_{CC} conditions
- On-chip 2.46V reference voltage circuit: 1.23V output can be obtained from R_T terminal
- Variable dead-time provides control over total range
- On-chip standby function: power on/off function

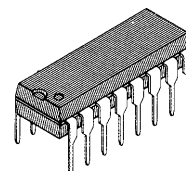
ABSOLUTE MAXIMUM RATINGS (see Note)

($T_A = 25^\circ\text{C}$)

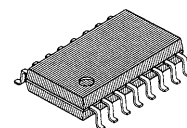
Rating	Symbol	Condition	Value	Unit
Power Supply Voltage	V_{CC}		20	V
Error Amp. Input Voltage	V_{IN}		-0.3 to +10	V
Control Input Voltage	V_{CTL}		-0.3 to +20	V
Collector Output Voltage	V_{OUT}		20	V
Collector Output Current	I_{OUT}		75	mA
Power Dissipation	P_D	$T_A \leq 25^\circ\text{C (SOP)}$	*620	mW
		$T_A \leq 25^\circ\text{C (DIP)}$	1000	
Operating Temperature	T_{op}		-30 to +85	$^\circ\text{C}$
Storage Temperature	T_{STG}		-55 to +125	$^\circ\text{C}$

*The packages are mounted on the epoxy board (4 cm x 4 cm x 1.5 mm)

Note : Permanent device damage may occur if the above Absolute Maximum Ratings are exceeded. Functional operation should be restricted to the conditions as detailed in the operational sections data sheet. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

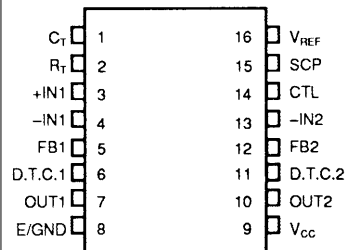


(DIP-16P-M04)



(FPT-16P-M06)

PIN ASSIGNMENT (TOP VIEW)



This device contains circuitry to protect the inputs against damage due to high static voltages or electric fields. However, it is advised that normal precautions be taken to avoid application of any voltage higher than maximum rated voltages to this high impedance circuit.

PIN/ASSIGNMENT

No.	Pin	Function
1	C _T	Oscillator timing capacitor pin (150 to 15,000 pF)
2	R _T	Oscillator timing resistor pin (5.1 to 100 kΩ). V _{REF} × 1/2 is also available at this pin for error amplifier reference input.
3	+IN1	Non-inverted input error amplifier 1
4	−IN1	Inverted input error amplifier 1
5	FB1	Output pin error amplifier 1. A resistor and a capacitor are connected between this terminal and the −IN1 terminal to adjust gain and frequency
6	DTC1	OUT1 dead-time control. Dead-time control is adjusted by an external resistive divider connected to the V _{REF} pin. A capacitor connected between this terminal and GND enables soft-start operation.
7	OUT1	Open collector output. Output transistor has common ground independent of signal ground. This output can source or sink up to 50 mA.
8	E/GND	Ground.
9	V _{CC}	Power (3.6 to 18V)
10	OUT2	Open collector output. Output transistor has common ground independent of signal ground. This output can source or sink up to 50 mA.
11	DTC2	Sets the dead-time of OUT2. The use of this terminal is the same as that of DTC1.
12	FB2	Output terminal of error amplifier 2. Sets the gain and adjusts the frequency when a resistor and a capacitor are connected between this terminal and the −IN2 terminal. Voltage of V _{REF} × 1/2 is internally connected to the non-inverting input of error amplifier 2. Use error amplifier 2 for positive voltage output.
13	−IN2	Inverting input terminal of error amplifier 2.
14	CTL	Power control terminal. The IC is put in the stand-by state when this terminal is pulled Low. Current consumption is 10 μA or lower in the stand by state. The input can be driven by TTL or CMOS.
15	SCP	Connects the time constant setting capacitor of the timer latch short-circuit protection circuit. Connect a capacitor between this pin and GND. For details, see “How to set time constant for timer latch short-circuit protective circuit”.
16	V _{REF}	2.46V reference voltage output terminal which can source up to 1 mA. This pin is used to set the reference input and idle period of the error amplifiers.

BLOCK DIAGRAM

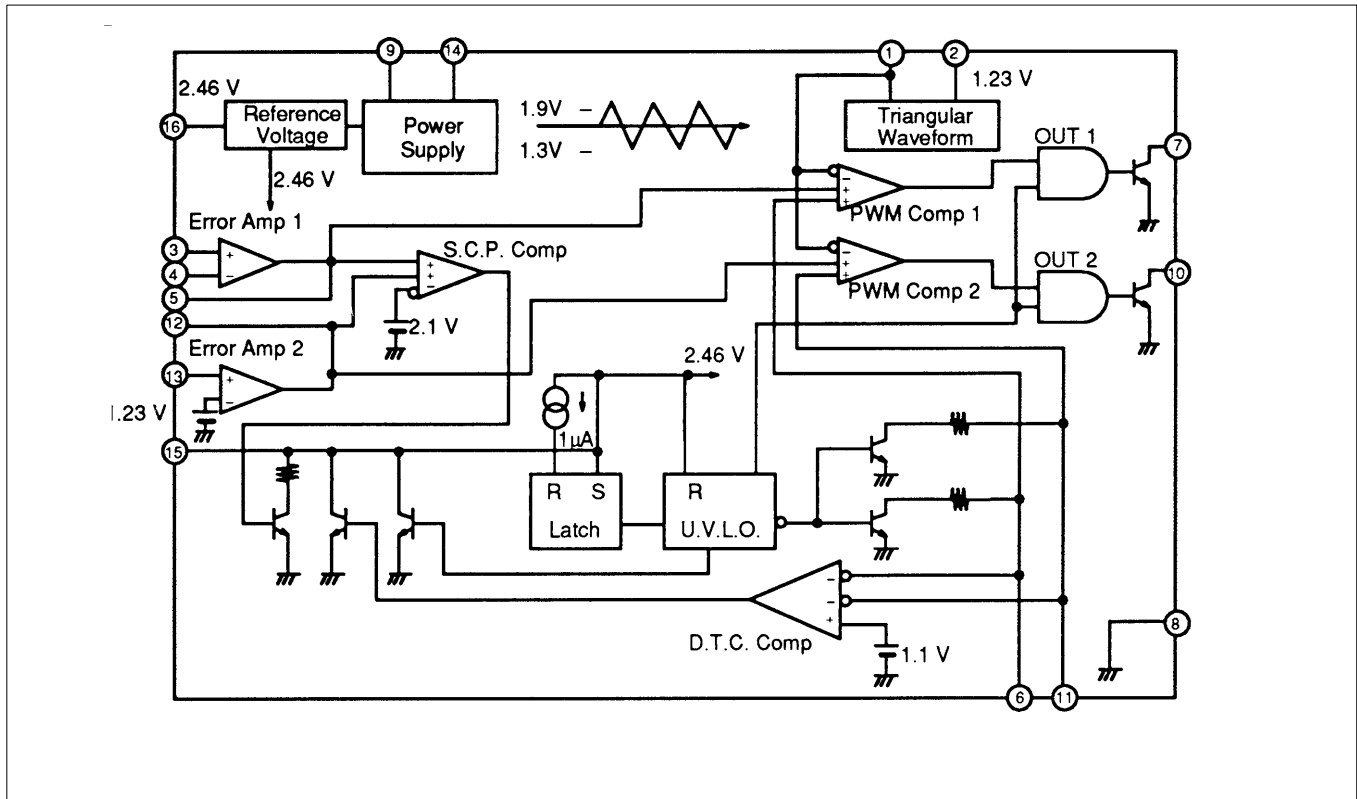


Figure 1. MB3778 Block Diagram

RECOMMENDED OPERATING CONDITIONS

Parameter	Symbol	Value			Unit
		Min	Typ	Max	
Power Supply Voltage	V_{CC}	3.6	6.0	18	V
Error Amplifier Input Voltage	V_{IN}	1.05		1.45	V
Control Input Voltage	V_{CTL}	0		18	V
Collector Output Voltage	V_{OUT}			18	V
Collector Output Current	I_{OUT}	0.3		50	mA
Timing Capacitor	C_T	150		15000	pF
Timing Resistor	R_T	5.1		100	K Ω
Oscillator Frequency	f_{OSC}	1		500	kHz
Operating Temperature	T_{op}	-30	25	85	°C

OPERATION DESCRIPTION

1. Reference voltage circuit

The reference voltage circuit generates a temperature-compensated reference voltage (= 2.46V) from V_{CC} (pin 9). The reference voltage is used for internal circuit.

The reference is obtained from the V_{REF} terminal (pin 16).

2. Triangular wave oscillator

Triangular waveforms can be generated at any frequency by connecting a timing capacitor and resistor to the C_T terminal (pin 1) and to the R terminal (pin 2).

The amplitude of this waveform is from 1.3V to 1.9V. These waveforms are connected to the non-inverting inputs of the PWM comparator and can be output through the C_T terminal.

3. Error amplifiers (Error Amp.)

The error amplifier detects the output voltage of the switching regulator and outputs PWM control signals.

The in-phase input voltage range is from 1.05V to 1.45V.

The reference voltage obtained by dividing the reference voltage output (recommended value: $V_{REF}/2$) or the R_T pin voltage (1.23V) is supplied to the non-inverting input.

The $V_{REF}/2$ voltage is internally connected to non-inverting input of the other error amplifier.

Any loop gain can be chosen by connecting the feedback resistor and capacitor to the inverting input terminal from the output terminal of the error amplifier.

Stable phase compensation is possible.

4. Timer latch short circuit protection circuit

This circuit detects the output levels of each error amplifier. If the output level of one or both of the error amplifiers is 2.1V or higher, the timer circuit begins charging the externally connected protection enable-capacitor.

If the output level of the error amplifier does not drop below the normal voltage range before the capacitor voltage reaches the transistor base-emitter voltage, V_{BE} ($\approx 0.65V$), the latch circuit turns the output drive transistor off and sets the idle period to 100/0.

5. Under-voltage lock-out circuit

The transition state at power-on or a momentary power fluctuation may cause the control IC to malfunction, which may adversely affect or even destroy the system. The under voltage lockout circuit monitors V_{CC} with reference to the internal reference voltage and resets the latch circuit to turn the output drive transistor off. The idle period is set to 100 It also pulls the protection enable terminal (pin 15) low.

6. PWM comparator unit

Each PWM comparator has one inverting input and two non-inverting inputs. This voltage-to-pulse-width converter controls the output pulse width according to the input voltage.

The PWM comparator turns the output drive transistor on while triangular waveforms from the oscillator are lower than the error amplifier output and the dead time control terminal voltage.

7. Output drive transistor

The output drive transistors have open collector outputs with common source supply and common grounds independent of V_{CC} and signal ground. The output drive transistors can sink or source up to 50 mA.

8. Power control unit

The power control terminal (pin 14) controls power on/off modes (the power supply current in stand-by mode is 10 μA or lower).

ELECTRICAL CHARACTERISTICS

(T_A = 25°C, V_{CC} = 6 V)

Parameter	Condition	Symbol	Value			Unit
			Min	Typ	Max	
Reference Section						
Output Voltage	I _{OR} = −1 mA	V _{REF}	2.41	2.46	2.51	V
Output Temp. Stability	T _A = −30°C to +85°C	V _{RTC}	−2	±10.2	2	%
Input Stability	V _{CC} = 3.6V to 18V	Line		2	10	mV
Load Stability	I _{OR} = 0.1 mA to −1 mA	Load		1	7.5	mV
Under Voltage Lockout Protection Section						
Threshold Voltage	I _{OR} = −0.1 mA	V _{tH}		2.72		V
	I _{OR} = −0.1 mA	V _{tL}		2.60		
Hysteresis Width	I _{OR} = −0.1 mA	V _{HYS}	80	120		mV
Reset Voltage (V _{CC})		V _R	1.5	1.9		V
Protection Circuit Section						
Input Threshold Voltage		V _{tPC}	0.60	0.65	0.7	V
Input Standby Voltage	No pull up	V _{STB}		50	100	mV
Input Latch Voltage	No pull up	V _{IN}		50	100	mV
Input Source Current		I _{bpc}	−1.4	−1.0	−0.6	μA
Comparator Threshold Voltage	Pin 5, Pin 12	V _{tC}		2.1		V
Triangular Waveform Oscillator Section						
Oscillator Frequency	C _T = 330 pF, R _T = 15 kΩ	f _{OSC}	160	200	240	kHz
Frequency Deviation	C _T = 330 pF, R _T = 15 kΩ	f _{dev}		±5		%
Frequency Stability (V _{CC})	V _{CC} = 3.6V to 18V	f _{dv}		±1		%
Frequency Stability (T _A)	T _A = −30±°C to +85°C	f _{dT}	−4		+4	%
Dead-Time control Section						
Input Threshold Voltage f _{OSC} =10 kHz)	Duty Cycle = 0%	V _{t0}		1.9	2.25	V
	Duty Cycle = 100%	V _{t100}	1.05	1.3		V
On Duty Cycle	V _{dt} = V _R /1.45V	D _{tr}	55	65	75	%
Input Bias Current		I _{bdt}		0.2	1	μA
Latch Mode Sink Current	V _{dt} = 2.5 V	I _{Dt}	150	500		μA
Latch Input Voltage	I _{dt} = 100 pA	V _{dt}			0.3	A

ELECTRICAL CHARACTERISTICS, continued

(T_A = 25°C = 6 V)

Parameter	Condition	Symbol	Value			Unit
			Min	Typ	Max	
Error Amplifier Section						
Input Offset Voltage	V _O = 1.6V	V _{IO}	−6		6	mV
Input Offset Current	V _O = 1.6V	I _{IO}	−100		100	nA
Input Bias Current	V _O = 1.6V	I _B	−500	−100		nA
Common Mode Input Voltage Range	V _{CC} =3.6V to 18V	V _{ICR}	1.05		1.45	V
Voltage Gain	R _{NF} = 200 kΩ	A _V	70	80		dB
Frequency Band Width	A _V = 0 dB	BW		1.0		MHz
Common Mode Rejection Ratio		CMRR	60	80		dB
Maximum Output Voltage Width		V _{OM+}	V _{REF} −0.3			V
		V _{OM−}		0.7	0.9	
Output Sink Current	V _O = 1.6V	I _{OM+}		1.0		mA
Output Source Current	V _O = 1.6V	I _{OM−}		−60		μA
PWM Comparator Section						
Input Threshold Voltage f _{OSC} = 10 kHz	Duty Cycle = 0 %	V _{t0}		1.9	2.25	V
	Duty Cycle =100%	V _{t100}	1.05	1.3		
Input Sink Current	Pin 5, Pin 12 = 1.6V	I _{IN+}		1.0		mA
Input Source Current	Pin 5, Pin 12 = 1.6V	I _{IN−}		−60		μA
Control Section						
Input Off Condition		V _{OFF}			0.7	V
Input On Condition		V _{ON}	2.1			V
Control Terminal Current	V _{CTL} = 10V	I _{CTL}		200	400	μA
Output Section						
Output Leak Current	V _O = 18V	Leak			10	μA
Output Saturation Voltage	I _O = 50 mA	V _{SAT}		1.1	1.4	V
All Device Section						
Stand by Current	V _{CTL} = 0V	I _{CCS}			10	μA
Average Supply Current	V _{CTL} = V _{CC} , No Output Load	I _{CCa}		1.7	2.4	mA

TEST CIRCUIT

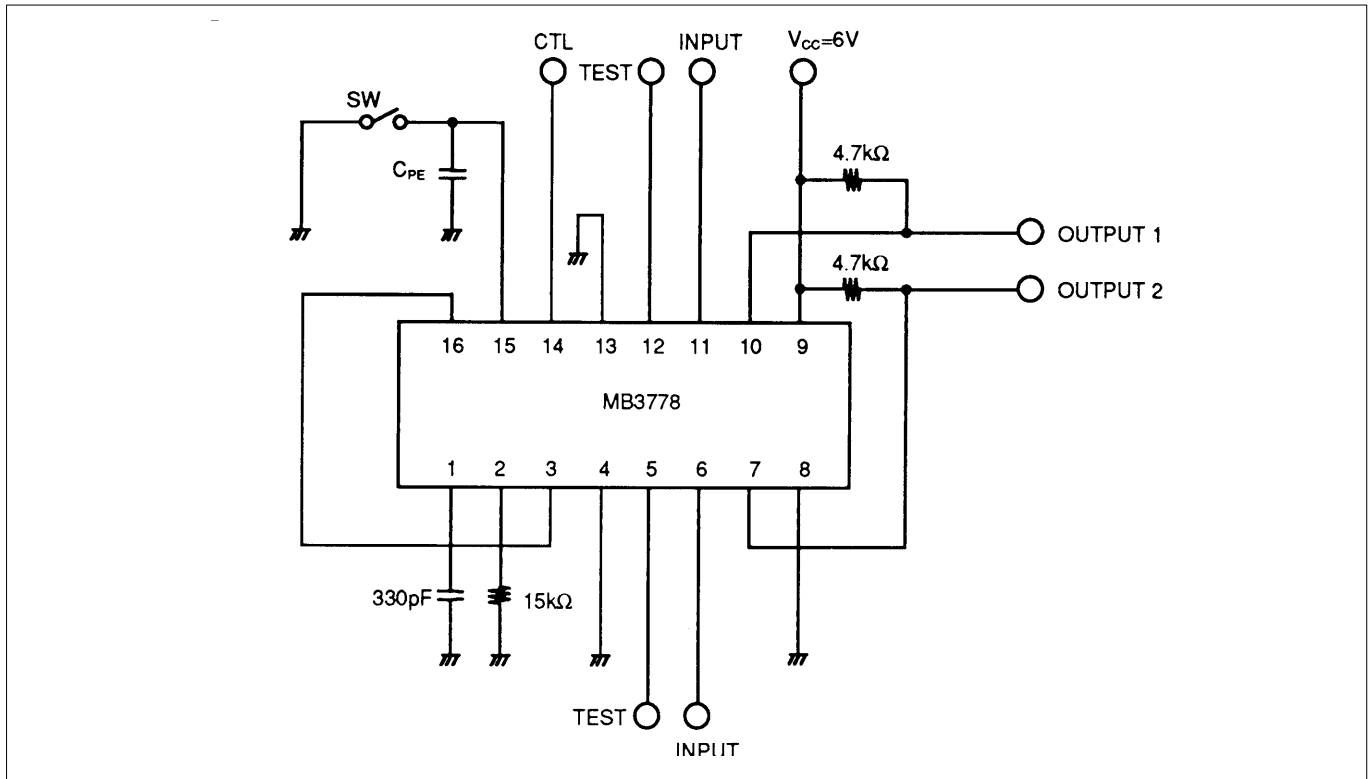


Figure 2. MB37788 Test Circuit

TIMING CHART (Internal Waveform)

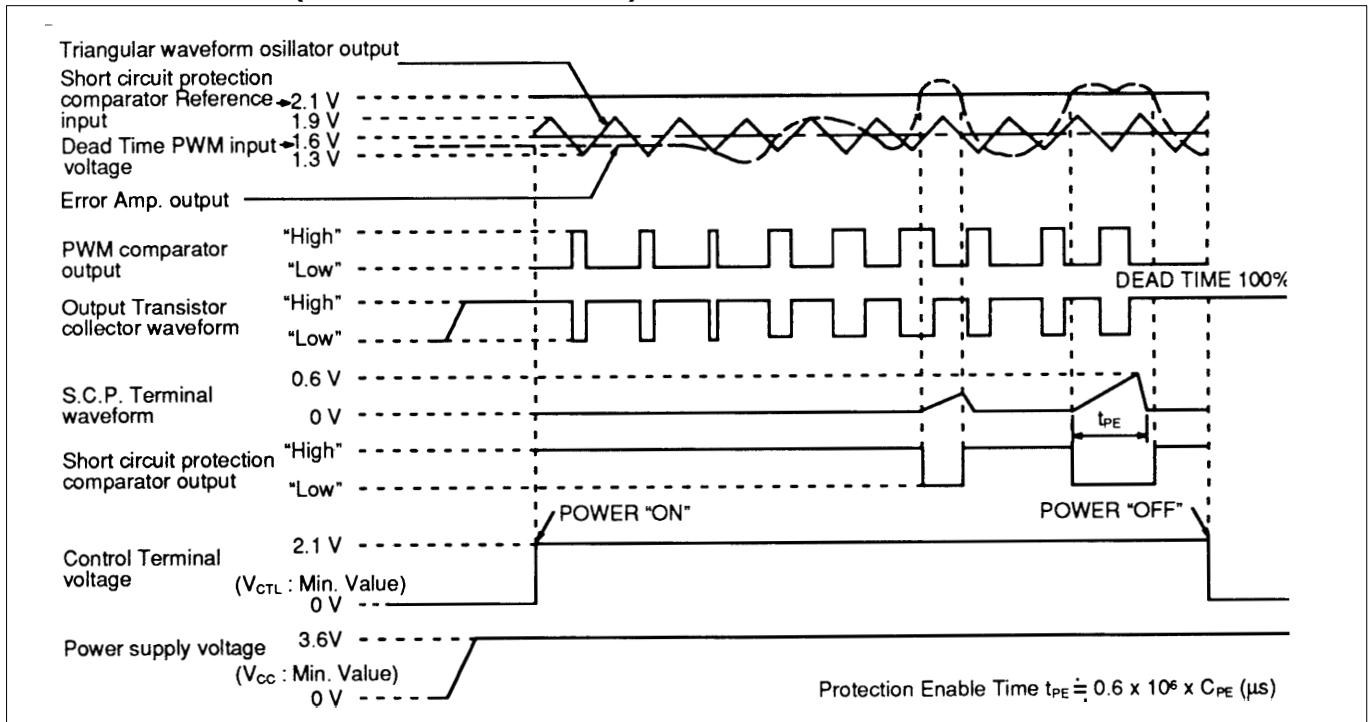


Figure 3. MB37788 Timing Chart

APPLICATION CIRCUIT

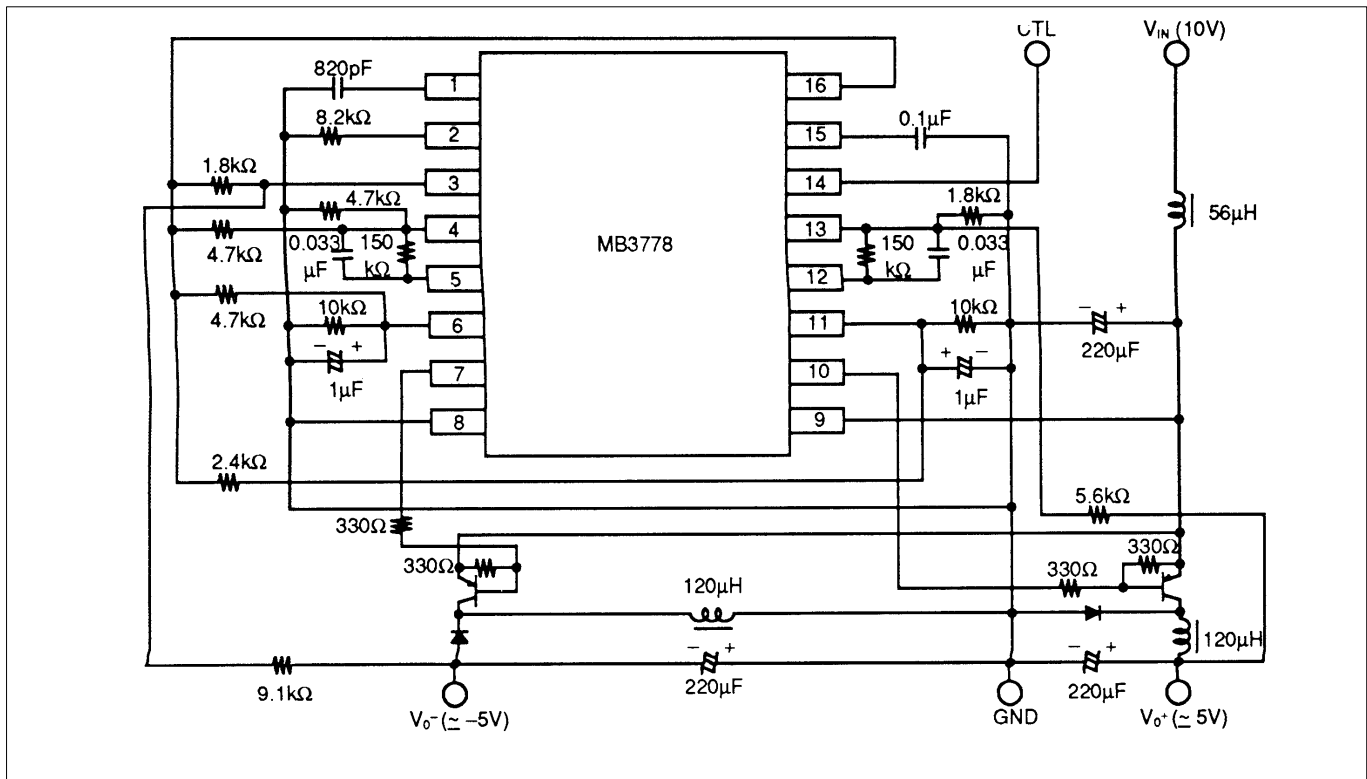


Figure 4 – Chopper Type Step Down/Inverting

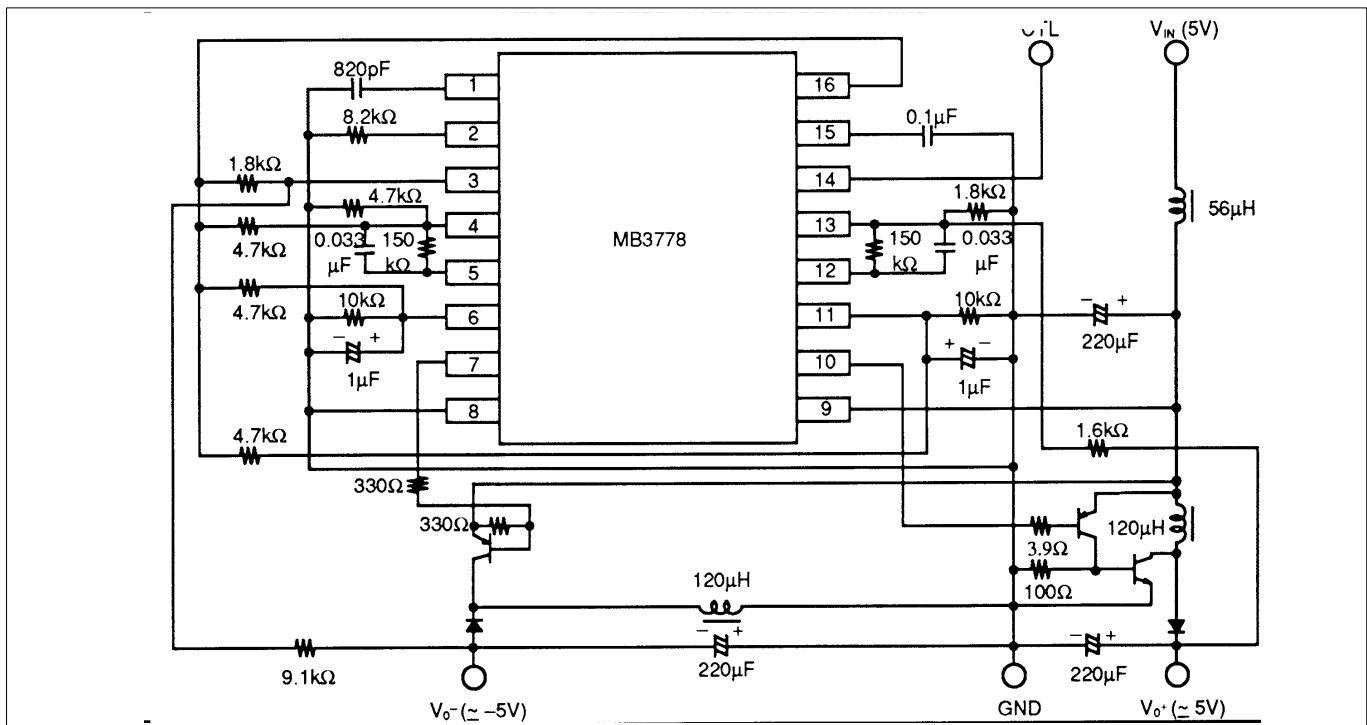


Figure 5. Chopper Type Step Up/Inverting

APPLICATION CIRCUIT, continued

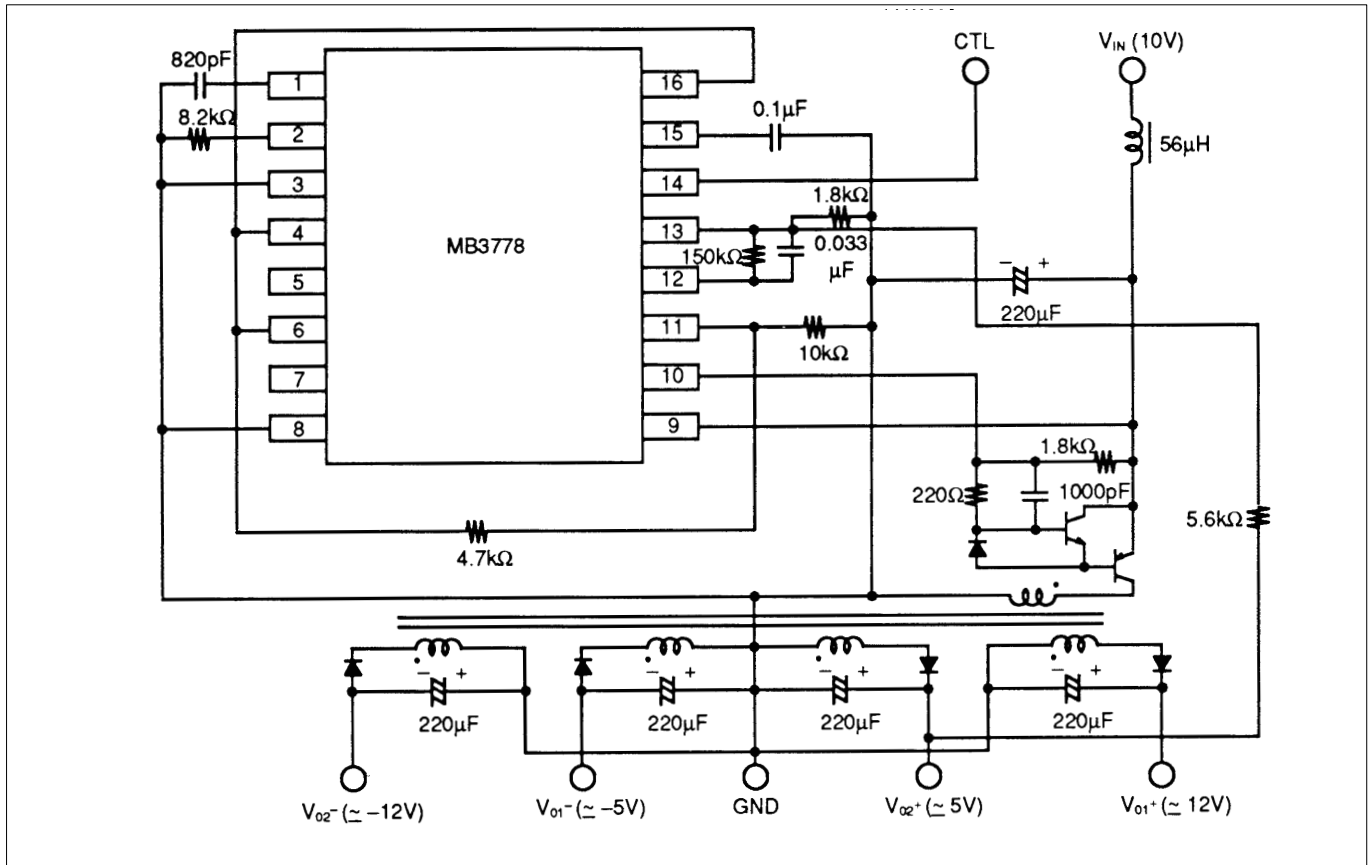


Figure 6. Multi-Output Type (Apply Transformer)

HOW TO SET THE OUTPUT VOLTAGE

The output voltage is set using the connections shown in Figures 7 and 8.

The error amplifier power is supplied by the reference voltage circuit as are the other internal circuits. The in-phase voltage range is from 1.05V to 1.45V.

Set 1.23 V ($V_{REF}/2$) to the reference input voltage that is connected to either inverting or non-inverting input terminals.

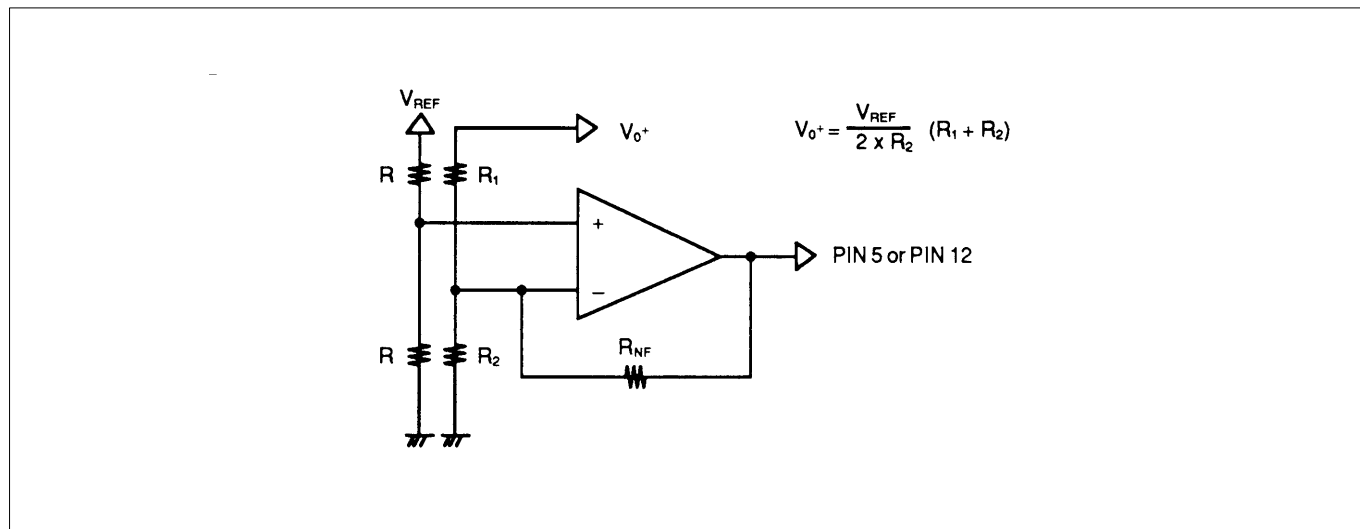


Figure 7. Connection of Error Amplifier Output Voltage $V_0 \geq 0$

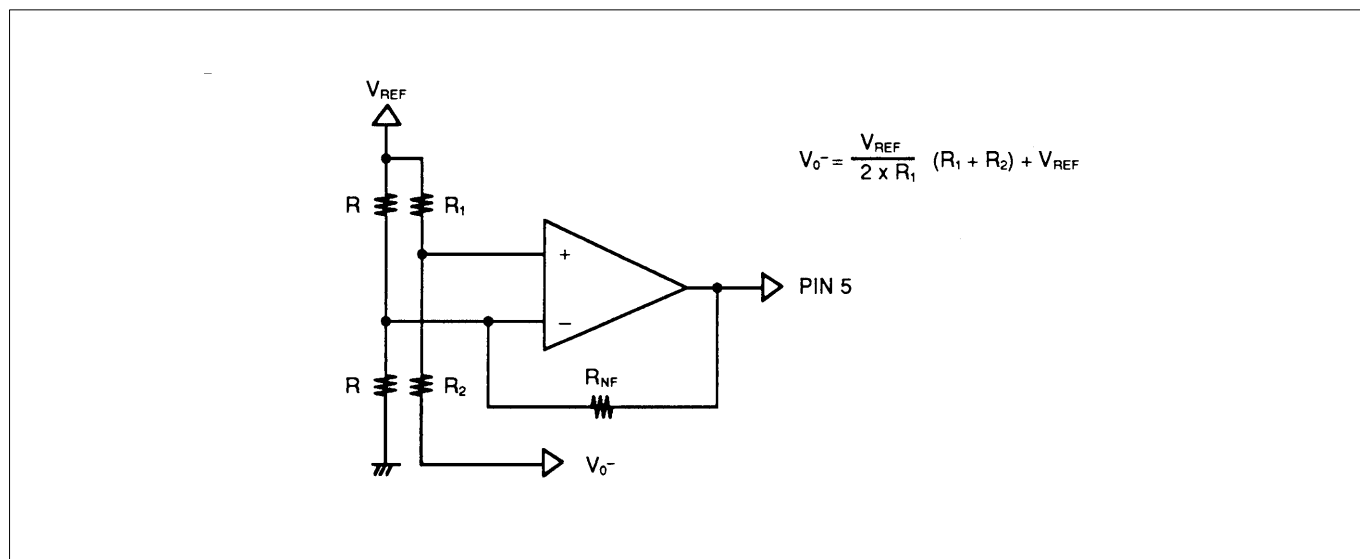
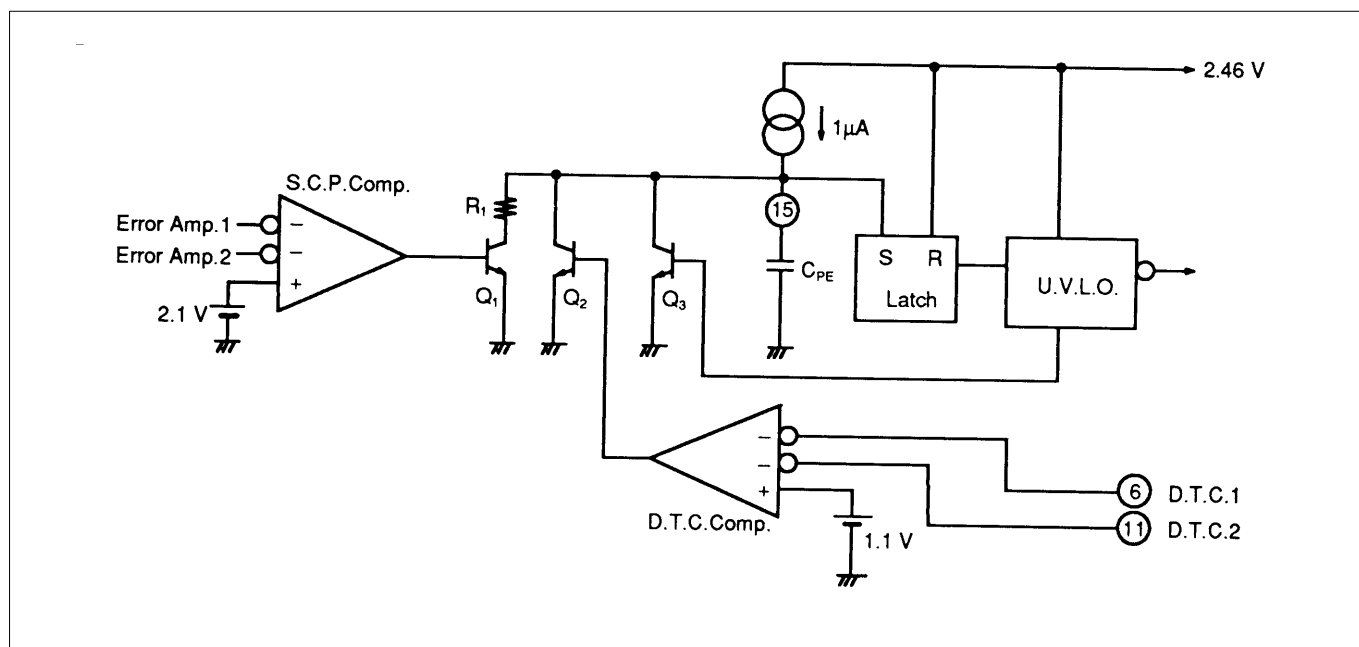


Figure 8. Connection of Error Amplifier Output Voltage $V < 0$

To prevent malfunction of the short-circuit protection circuit under soft-start operation the D.T.C. comparator outputs a high level until the D.T.C. terminal voltage reaches about 1.1V, and then closes the protection enable terminal by turning transistor Q₂ on.



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SYNCHRONIZATION OF ICs

To synchronize M193778 ICs, the specified capacitor and resistor are connected to the C_T and R_T terminals of the master IC. The R_T terminals (pin 2) of the slave ICs are connected to the V_{REF} terminal (pin 16) to disable the charge/discharge circuit for triangular wave oscillation. The C_T terminals of the master and slave ICs are connected together.

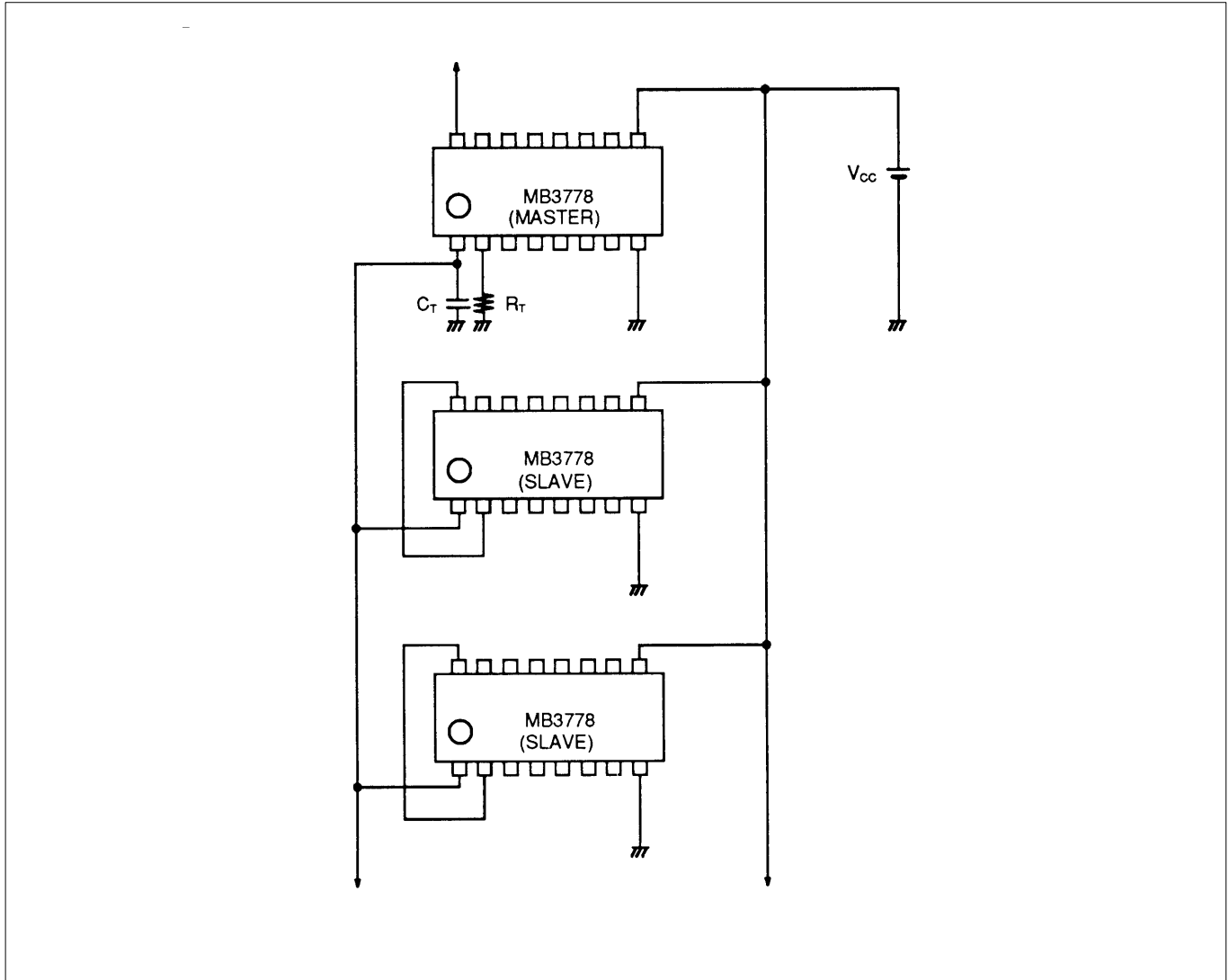


Figure 10. Connection of Master, Slave

TYPICAL PERFORMANCE CHARACTERISTICS

Figure 11. Power Supply Voltage vs. Reference Voltage

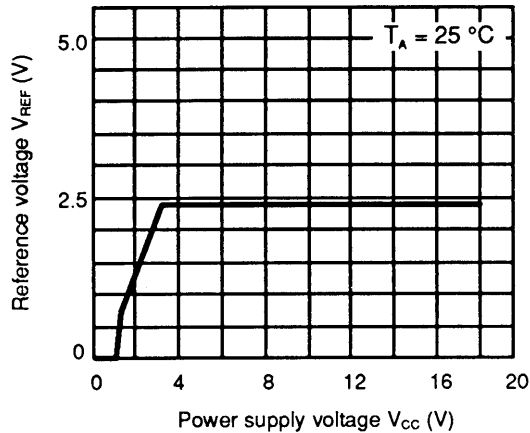


Figure 12. Power Supply Voltage vs. Average Supply Current

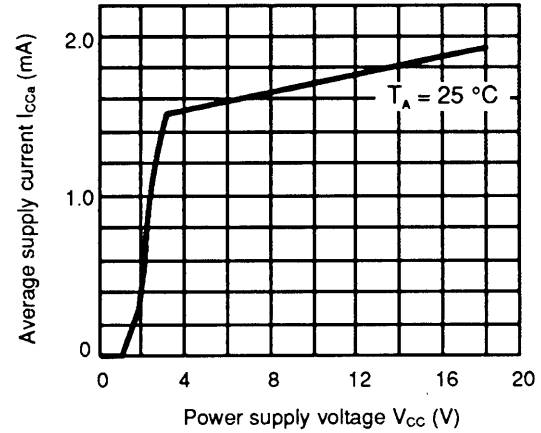


Figure 13. Reference Voltage vs. Temperature

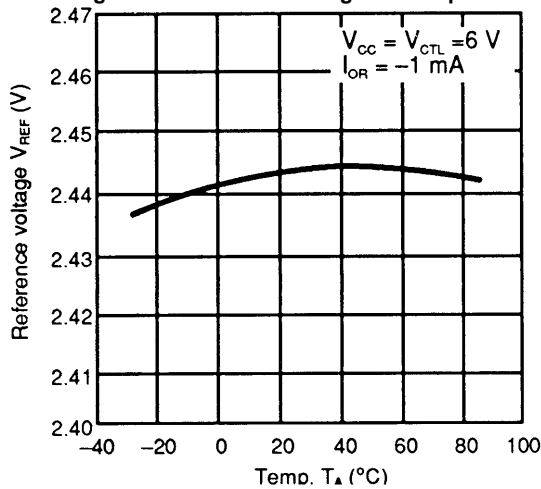


Figure 14. Timing Capacitor vs. Triangular Waveform Maximum Amplitude Voltage

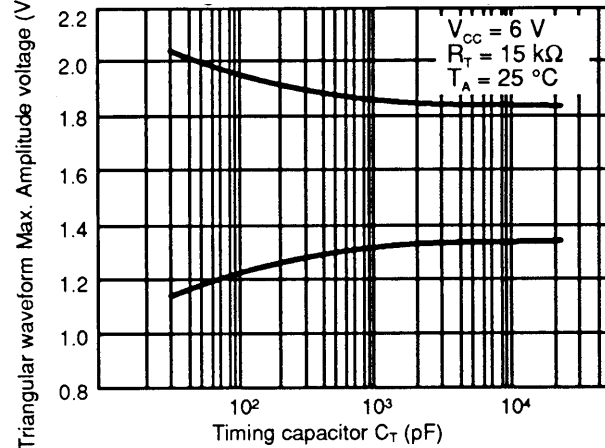


Figure 15. Collector Saturation Voltage vs. Sink Current

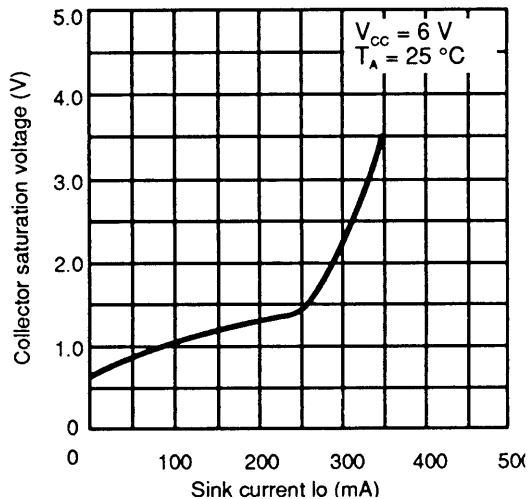
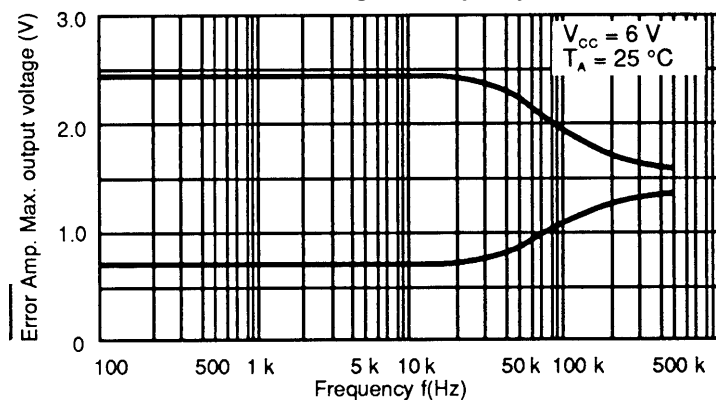


Figure 16. Error Amplifier Maximum Output Voltage vs. Frequency



TYPICAL PERFORMANCE CHARACTERISTICS, continued

Figure 17. Timing Resistor vs. Oscillation Frequency

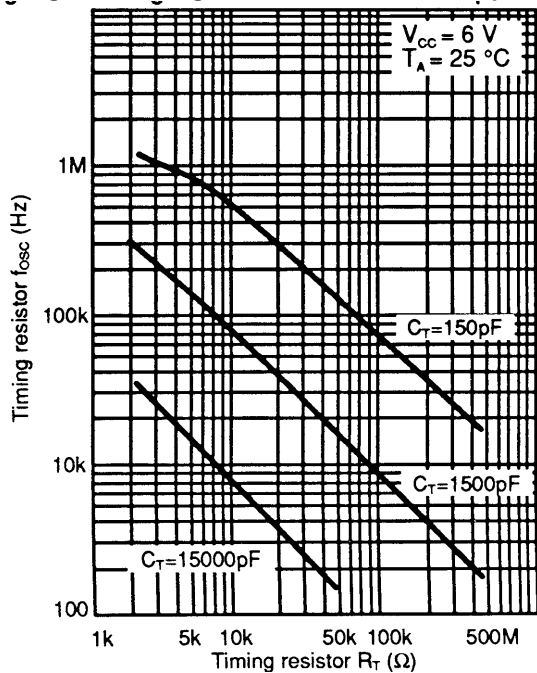


Figure 18. Triangular Waveform Cycle vs. Timing Capacitor

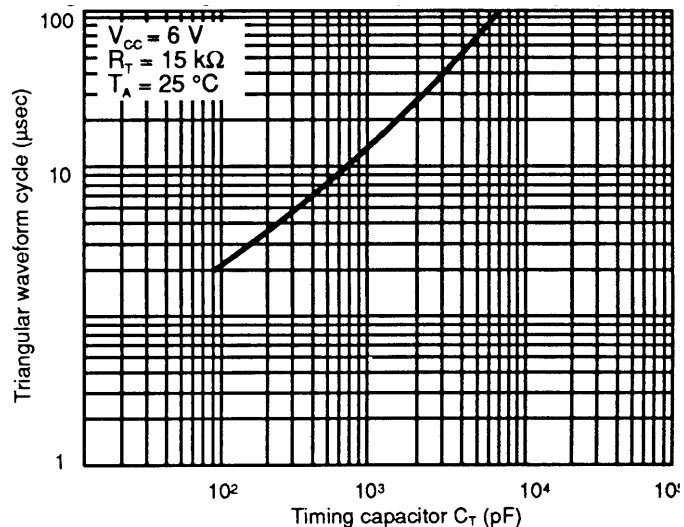


Figure 19. Temperature vs. Oscillation Frequency

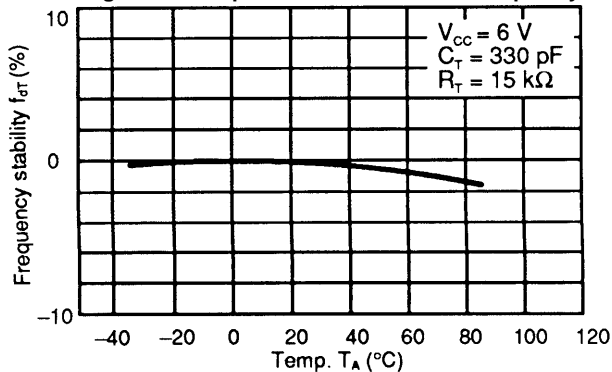


Figure 20. Oscillation Frequency vs. Duty

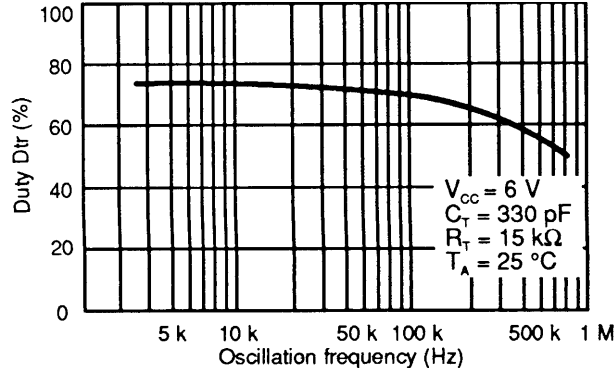


Figure 21. Control Voltage vs. Reference Voltage

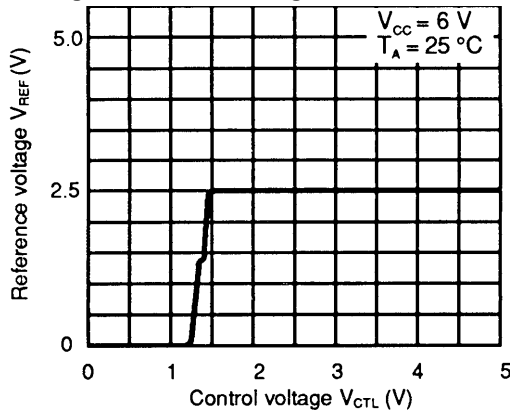
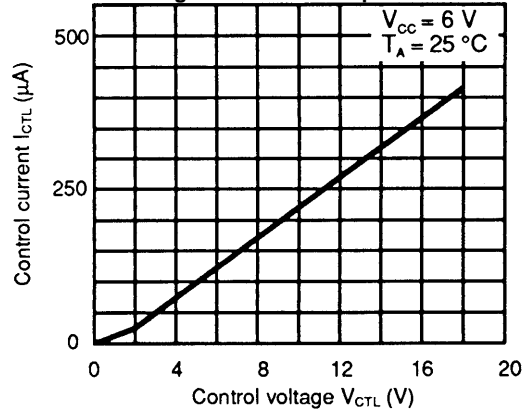


Figure 22. Control Input Current



TYPICAL PERFORMANCE CHARACTERISTICS, continued

Figure 23. Frequency vs. Gain/Phase

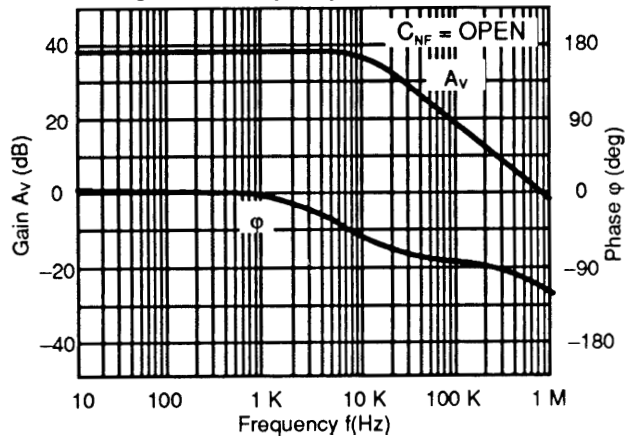


Figure 24. Frequency vs. Gain/Phase (Actual Data)

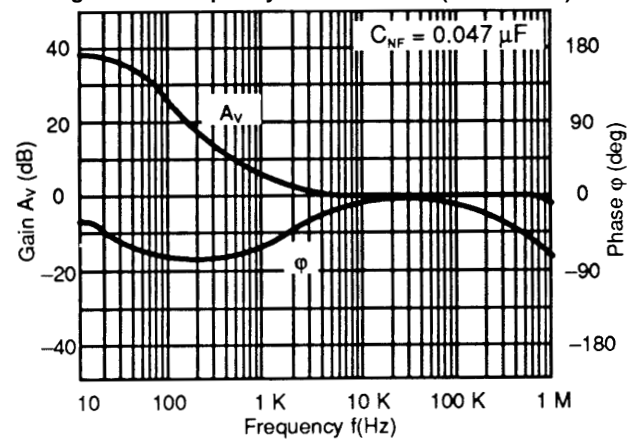


Figure 25. Frequency vs. Gain/Phase (Actual Data)

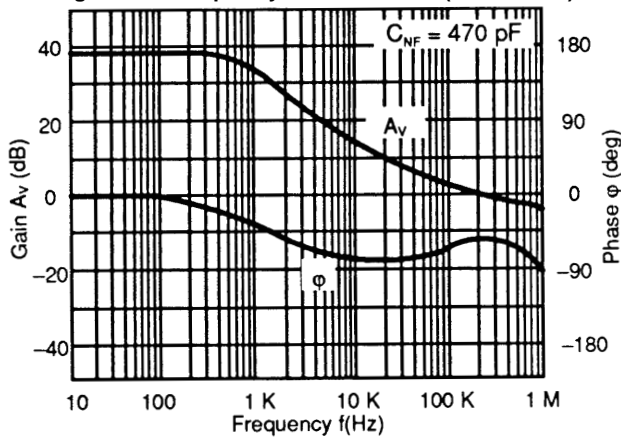


Figure 26. Frequency vs. Gain/Phase (Actual Data)

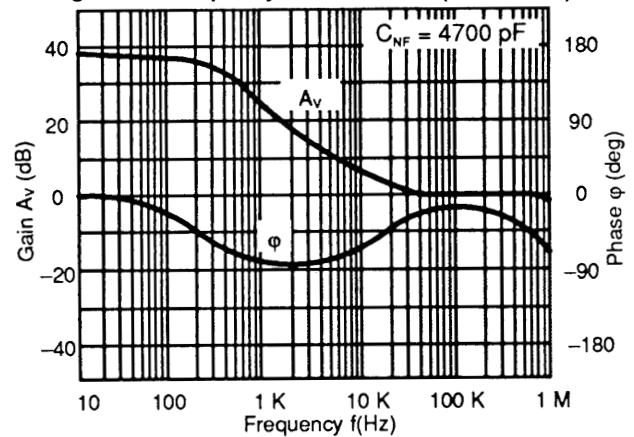
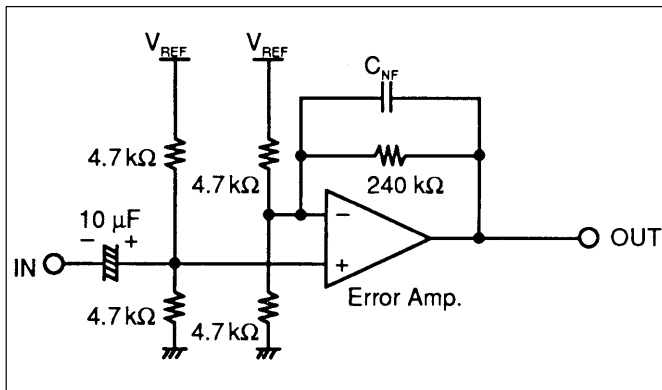


Figure 27. Actual Circuit



APPLICATION

Equivalent series resistance and stability of smoothing capacitor

The equivalent series resistance (ESR) of the smoothing capacitor in the DC/DC converter greatly affects the loop phase characteristic.

A smoothing capacitor with a high ESR improves system stability because the phase is advanced into the high-frequency range of an ideal capacitor (see Figures 29 and 30). A smoothing capacitor with a low ESR reduces system stability. Use care when using low ESR electrolytic capacitors (OS capacitors) and tantalum capacitors.

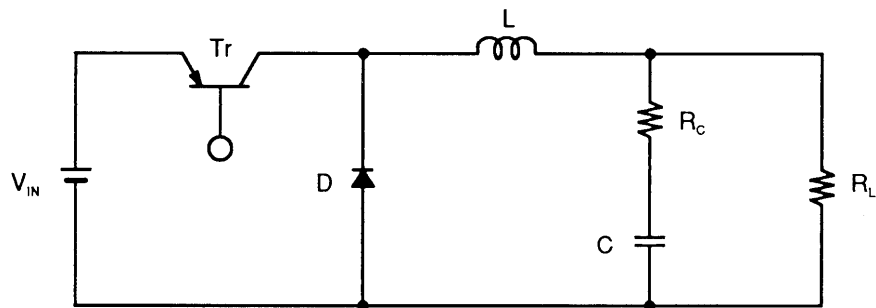


Figure 28. DC/DC Converter Basic Circuit

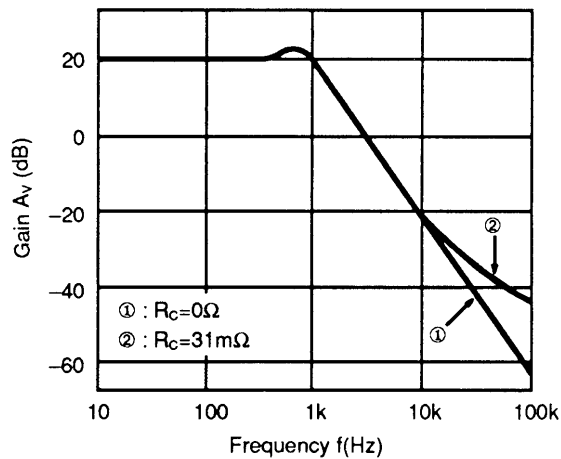


Figure 29. Gain vs. Frequency

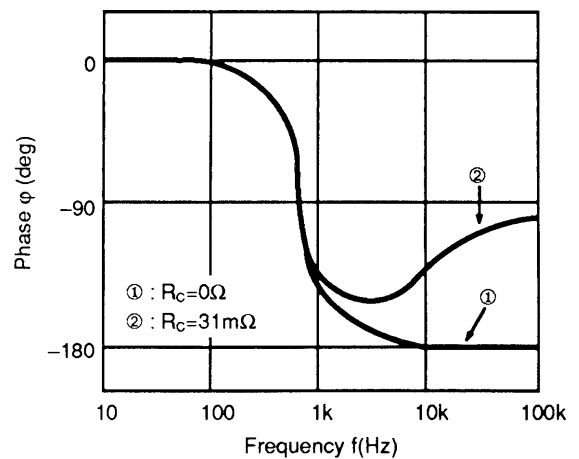


Figure 30. Phase vs. Frequency

Reference data

If an aluminum electrolytic smoothing capacitor ($R_C \approx 1.0\Omega$) is replaced with a low ESR electrolytic capacitor (OS capacitor: $R_C \approx 0.2\Omega$), the phase margin is reduced by half (see Figures 32 and 33).

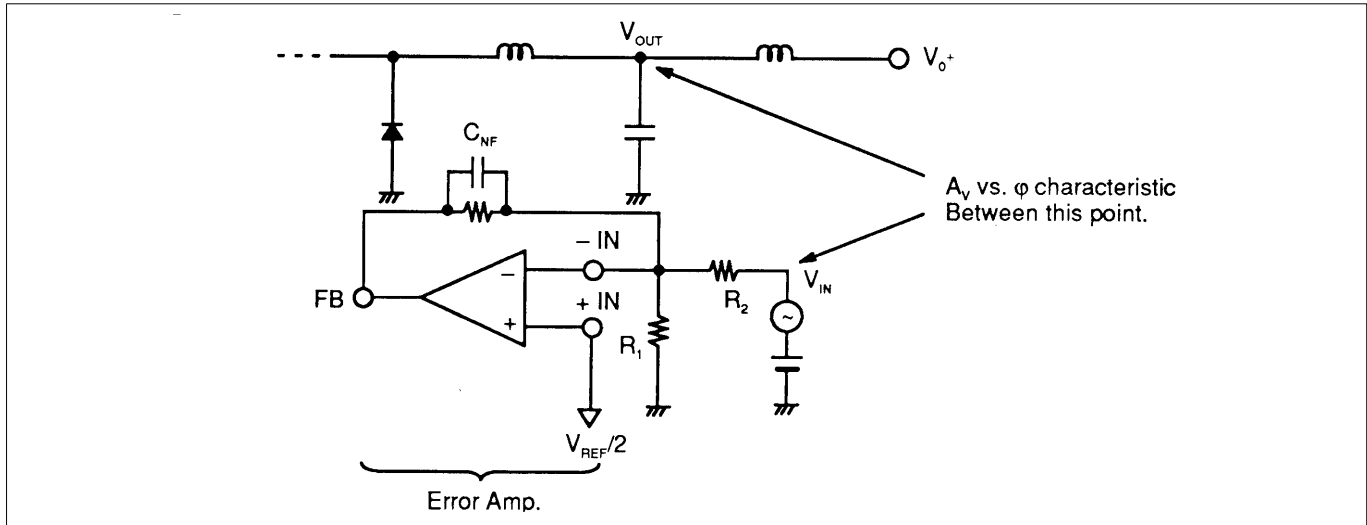


Figure 31. DC/DC Converter A_v vs. ϕ Characteristic Test Circuit

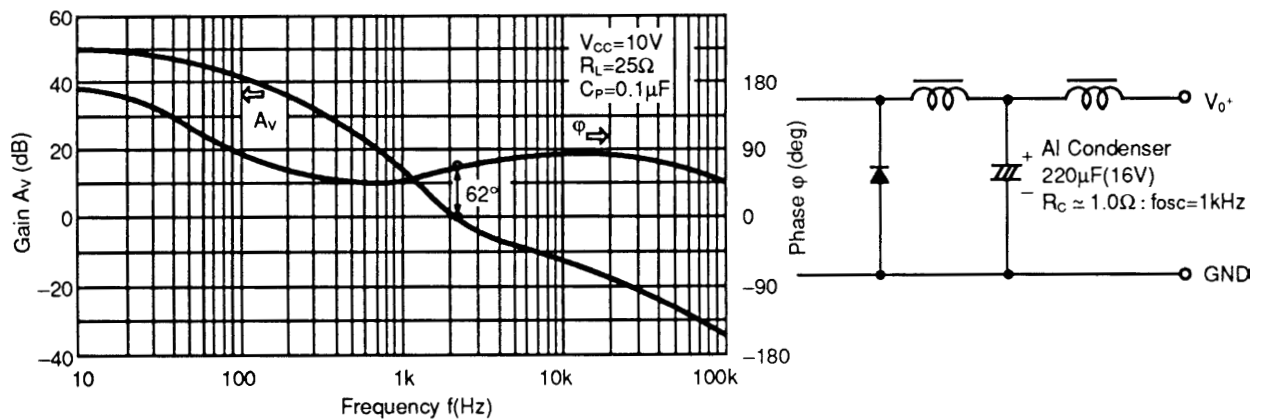


Figure 32. DC/DC Converter -5V Output Gain vs. Phase

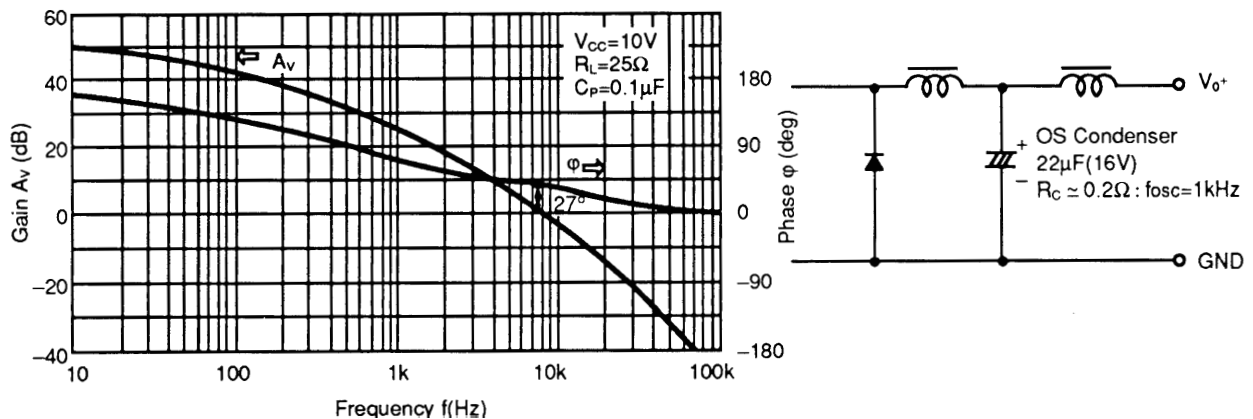


Figure 33. DC/DC Converter -5V Output Gain vs. Phase

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