Step Up Current Mode PWM Converter with 4+1 Operational Amplifiers

Features

- Built in 1.6A, 0.23Ω Switching NMOS
- Fault and Thermal Protection
- Internal Soft-Start Function
- Selectable Frequency：600 kHz or 1.25MHz
- Low Dissipation Current :
  Typical 1.6mA in Operation
- Four Channels V_{GAMMA} with Output Current: ±30mA (MAX)
- One channel V_{COM} with Output Current: ±100mA (MAX)
- TSSOP-20 Package Available

Pin Configuration

(Top View)

		AAT1160		
SW	1		20	GND1
V_{DD}	2		19	GND
SHDN	3		18	IN1
FREQ	4		17	EO
V_{DD1}	5		16	N.C
CIN+	6		15	COUT
GI1	7		14	GO1
GI2	8		13	GO2
GI3	9		12	GO3
GI4	10		11	GO4

TSSOP-20 PACKAGE

General Description

The AAT1160 is a step up current mode PWM converter that provides a one-channel step-up PWM controller, four Gamma buffers, and one V_{COM} buffer. Internal soft-start function can efficiently prevent inrush current when the power is on.

This PWM controller consists of an on-chip voltage reference, error amplifier, current sense, pulse width modulation controller, under-voltage lockout protection, thermal detect, soft-start, and fault protection circuits.

The AAT1160 contains 4+1 operational amplifiers: GO1, GO2, GO3, and GO4 for gamma corrections and COUT for V_{COM}.

V_{COM} and V_{GAMMA} are designed to increase driving capability for thin film transistor liquid crystal display (TFT LCD). Each buffer is capable of driving heavy load and offering fast current loading (V_{COM}: ±100mA, and V_{GAMMA}: ±30mA). With minimal external components, the AAT1160 offers a simple and economical power management solution for TFT LCD panels.

Pin Description

PIN NO.	NAME	I/O	DESCRIPTION
1	SW	O	High Voltage Switch Output
2	V_{DD}	-	Power Supply
3	SHDN	I	Shutdown Control Pin; High for Enable
4	FREQ	I	Frequency Select Pin
5	V_{DD1}	-	High Voltage Power Supply
6	CIN+	I	V_{COM} Buffer Input
7	GI1	I	Gamma Buffer 1 Input
8	GI2	I	Gamma Buffer 2 Input
9	GI3	I	Gamma Buffer 3 Input
10	GI4	I	Gamma Buffer 4 Input
11	GO4	O	Gamma Buffer 4 Output
12	GO3	O	Gamma Buffer 3 Output
13	GO2	O	Gamma Buffer 2 Output
14	GO1	O	Gamma Buffer 1 Output
15	COUT	O	V_{COM} Buffer Output
16	N.C	-	
17	EO	O	PWM Error Amplifier Output Pin
18	IN1	I	Inverting Input Pin of PWM Error Amplifier
19	GND	-	Ground
20	GND1	-	Ground

Absolute Maximum Ratings

PARAMETER	SYMBOL	VALUE	UNIT
V_{DD} to GND	V_{DD}	7	V
SW to GND	V_{SW}	18	V
V_{DD1} to GND	V_{DD1}	14	V
Input Voltage 1 (IN1, SHDN, FREQ)	V_{I1}	V_{DD} +0.3	V
Input Voltage 2 (CIN+, CI1, CI2, GI3, GI4)	V_{I2}	V_{DD1} +0.3	V
Output Voltage 1 (EO)	V_{O1}	V_{DD} +0.3	V
Output Voltage 2 (COUT, GO1, GO2, GO3, GO4, SW)	V_{O2}	V_{DD1} +0.3	V
Operating Free-Air Temperature Range	T_C	－20 to ＋85	°C
Storage Temperature Range	T_{DD1}	－45 to ＋125	°C
Power Dissipation	P_d	700	mW

Electrical Characteristics, V_{DD}= 3V, FREQ=GND, V_{DD1}= 10V

Operating Power

PARAMETER	SYMBOL	TEST CONDITION	MIN	TYP	MAX	UNIT
Input Supply Voltage Range	V_{DD}		2.6		5.5	V
VDD Under Voltage Lockout	V_{UVLO}	Falling	2.29	2.43	2.57	V
		Rising		2.58		V
Quiescent Current	I_{VDD}	V_{IN1}=1.3V, not switching		0.36	0.60	mA
		V_{IN1}=1.1V, switching		1.2	5.0	mA
Shutdown Current	I_{SHDN}	V_{SHDN} =GND		0.1	10.0	μA
Thermal Shutdown	T_{SHDN}			160		°C

EA (Error Amplifier)

PARAMETER	SYMBOL	TEST CONDITION	MIN	TYP	MAX	UNIT
Feedback Voltage	V_{IN1}	Level to produce V_{EO}=1.265V	1.247	1.265	1.283	V
Input Bias Current	I_{B1}	V_{IN1}=1.265V		0	40	nA
Feedback-Voltage Line Regulation	V_{RI}	Level to produce V_{EO}=1.265V $2.6V < V_{DD} < 5.5V$		0.05	0.15	% /V
Transconductance	g_m	ΔI=5μA	70	105	240	μA /V
Voltage Gain	A_V			1,500		V /V
Fault Detect Trigger Voltage			0.98	1.02	1.06	V

Oscillator

PARAMETER	SYMBOL	TEST CONDITION	MIN	TYP	MAX	UNIT
Oscillation Frequency	f_{OSC}	FREQ=GND	500	600	700	kHz
		FREQ= V_{DD}	900	1250	1500	kHz
Maximum Duty Cycle	D_{MAX}	FREQ=GND	79	85	92	%
		FREQ= V_{DD}		85		%

Electrical Characteristics, V_{DD}= 3V, FREQ=GND, V_{DD1}= 10V

N-CHANNEL SWITCH

PARAMETER	SYMBOL	TEST CONDITION	MIN	TYP	MAX	UNIT
Current Limit	I_{LIM}	V_{IN1}=1.1V,	1.1	1.6	2.1	A
On-Resistance	R_{ON}	I_{SW}=1.2A		0.28	0.50	Ω
Leakage Current	I_{SWOFF}	V_{SW}=12V		0.01	20.00	μA

Soft Start & Fault Detect Time

PARAMETER	SYMBOL	TEST CONDITION	MIN	TYP	MAX	UNIT
Soft Start Time	t_{SS}			14		ms
During Fault Protect Trigger Time	t_{FS}			55		ms

Control Inputs Characteristics

PARAMETER	SYMBOL	TEST CONDITION	MIN	TYP	MAX	UNIT
Input Low Voltage	V_{IL}				0.3 V_{DD}	V
Input High Voltage	V_{IH}		0.7 V_{DD}			V
Hysteresis	V_{HYS}			0.1 V_{DD}		V
FREQ Pull Down Current	I_{PL}		3.5	5.0	6.5	μA
SHDN Pull Up Current	I_{PH}			0.001	1.000	μA

Electrical Characteristics, V_{DD}= 3V, FREQ=GND, V_{DD1}= 10V

V_{COM} and Gamma Buffer Performance

PARAMETER	SYMBOL	TEST CONDITION	MIN	TYP	MAX	UNIT
Power Supply Rejection Ratio	PSRR	V_{DD1} from 6.5V to 13.5V	-	80	-	dB
Supply Current	I_{VDD}		-	1.5	-	mA

V_{COM} and Gamma Buffer Input Characteristics

PARAMETER	SYMBOL	TEST CONDITION	MIN	TYP	MAX	UNIT
Input Offset Voltage	V_{OS}	V_{CIN+} or $V_{GI1\sim4}$ =5V	-	2	12	mV
Input Bias Current	I_{B2}	V_{CIN+} or $V_{GI1\sim4}$ =5V	-	2	50	nA

V_{COM} and Gamma Buffer AC Characteristics

PARAMETER	SYMBOL	TEST CONDITION	MIN	TYP	MAX	UNIT
Slew Rate [Note 1]	SR	V_{CIN+} or $V_{GI1\sim4}$ = 2V to 8V, 20% to 80%	-	12	-	V/µs
Settling Time	t_S	V_{CIN+} or $V_{GI1\sim4}$ = 4.5V to 5.5V 0.1% V_{CIN+} or $V_{GI1\sim4}$ = 5.5V to 4.5V 0.1%	-	5	-	µs

Note 1: Slew rate is measured on rising and falling edges.

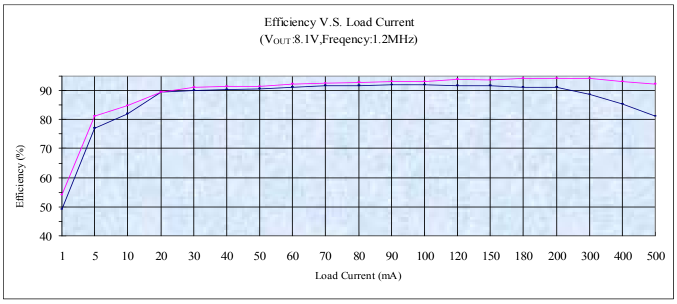
Electrical Characteristics, V_{DD}= 3V, FREQ=GND, V_{DD1}= 10V

V_{COM} and Gamma Buffer Output Characteristics

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output Swing Low	V_{OL2}	I_{COUT} =5mA (V_{COM} Buffer) V_{CIN+} =0V	-	0.08	0.15	V
		$I_{GO1\sim4}$ =10mA (Gamma Buffer) $V_{GI1\sim4}$ =1V	-	1.02	1.05	
Output Swing High	V_{OH2}	I_{COUT} =−5mA (V_{COM} Buffer) V_{CIN+} =10V	9.85	9.92	-	V
		$I_{GO1\sim4}$ =−10mA (Gamma Buffer) $V_{GI1\sim4}$ =9V	8.95	8.98	-	
Output Swing (Gamma Buffer)	V_{OL3}	$I_{GO1\sim4}$ =10mA, $V_{GI1\sim4}$ =5V	-	5.02	5.04	V
	V_{OH3}	$I_{GO1\sim4}$ =−10mA, $V_{GI1\sim4}$ =5V	4.96	4.98	-	
Output Swing (V_{COM})	V_{OL3}	I_{COUT} =50mA, V_{CIN+} =5V	-	5.03	5.05	V
	V_{OH3}	I_{COUT} =−50mA, V_{CIN+} =5V	4.95	4.97	-	
Short Circuit Current	I_{SHORT}	(Gamma Buffer)	-	±70	-	mA
		(V_{COM} Buffer)	-	±180	-	mA

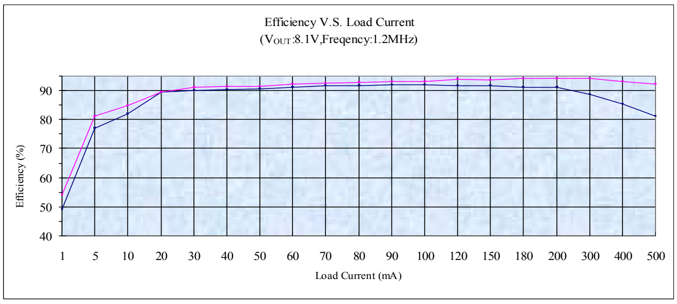
Efficiency vs. Load Current
(f_{OSC} =1.2MHz V_{OUT} =8.1V)

L:10μH



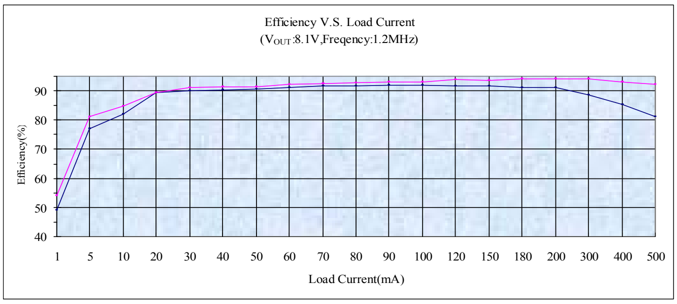
Efficiency vs. Load Current
(f_{OSC} =600kHz V_{OUT} =8.1V)

L:10μH



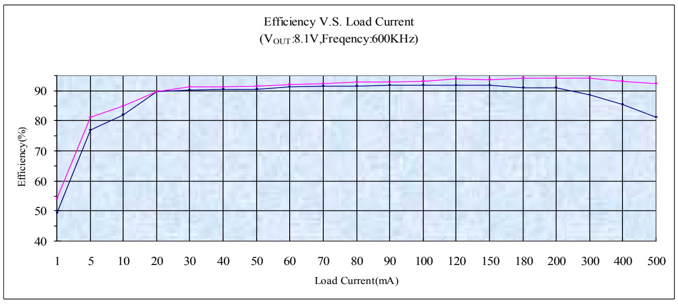
Efficiency vs. Load Current
(f_{OSC} =1.2MHz V_{OUT} =8.1V)

L:4.7μH

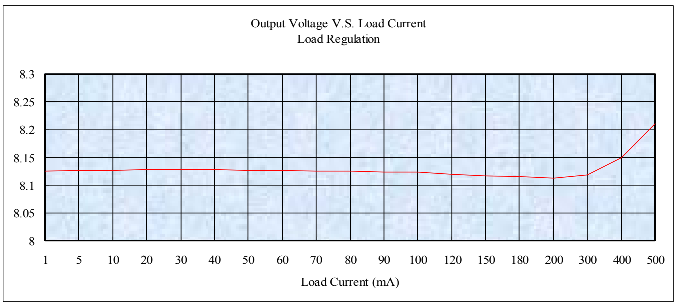


Efficiency vs. Load Current
(f_{OSC} =600kHz V_{OUT} =8.1V)

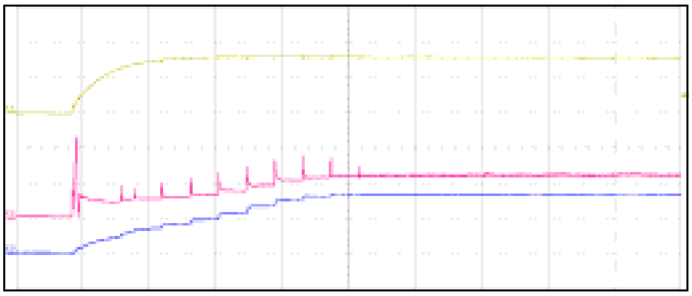
L:4.7μH



Load Regulation



Internal Soft Start



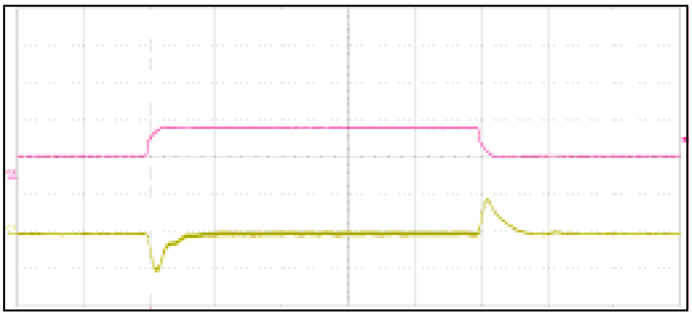
CH1: V_{IN} , 2V/div, DC

T = 2ms/div

CH2: I_L , 500mA/div, DC

CH3: V , 5V/div, DC

Load Transient Response



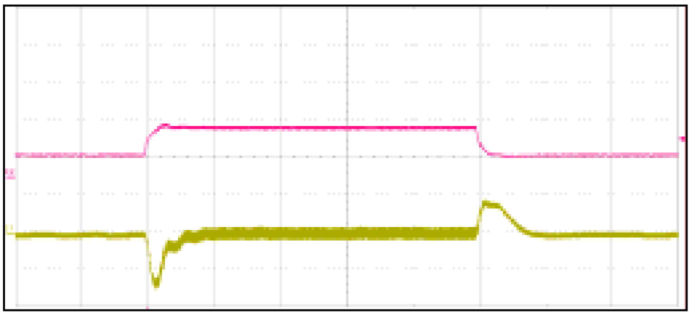
T = 100µs/div

V_O = 8.1V, V_{IN} = 3.3V, f_{OSC} =1.2MHz

CH1: Load, 100mA to 250mA

CH2: V_O, 20

Load Transient Response



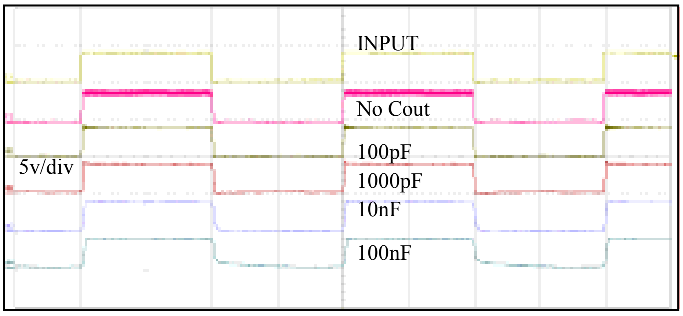
T = 100µs/div

V_O = 8.1V, V_{IN} = 3.3V, f_{OSC} =600kHz

CH1: Load, 100mA to 250mA

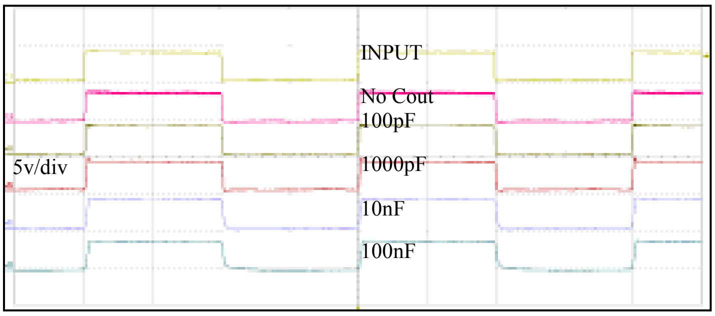
CH2: V_O, 200mV/div, AC

V_{GAMMA} Signal Response



10 µ s/div

V_{COM} Signal Response



10 µ s/div

Operation Information:

Setting the Output Voltage:

Output voltage is set by using a feedback pin and a resistor divider; equation is as follows:

$V_{P1}=1.265\ (1+R1/R2)$

Soft-Start:

The soft-start function is embedded with a typical setting of 14ms

Operation Frequency Setting:

Pin4 (FREQ) can set PWM operation to low with f_{OSC} =600kHz, or set PWM operation to high with f_{OSC} =1.2 MHz.

Diode Selection:

Schottky diode for the boost regulator must be selected correctly depending on the output voltage and the output current. The diode must have a reverse voltage equal to or greater than the output voltage. In addition, the diode current must exceed the switch current limit as a lower forward voltage will increase efficiency.

Inductor Selection:

$I_{L(peak)} = I_{IN} + V_{IN}*D/(2*L*f_S)$

D: PWM duty

$V_O/V_{IN}=1/(1-D)$

Maximum current of the inductor must be greater than $I_{L(peak)}$

The Compensation:

Pin17 (EO) series with R_C & C_C for compensation, usually range as $1k\Omega \le R_C \le 200k\Omega$, $100pF \le C_C \le 6{,}800pF$. Standard formulas are only for reference purpose, as PCB has a lot of noise or parasitic capacitance and resistance, it often requires on board adjustment.

The key steps for step-up compensation are as follows:

Transconductance (from FB to CC), g_m (105µS)

Current-sense amplifier transresistance, R_{CS} (0.275V/A)

For continuous conduction, the right-half-plane zero frequency (f_{RHPZ}) is given by the following: $f_{RHPZ}=V_O\ (1-D)^2/(2\pi*L*I_{LOAD})$ where D=the duty cycle=1-(V_{IN}/V_O), L is the inductance value, and I_{LOAD} is the maximum output current. Typical target, crossover (f_C), is 1/6 of the RHPZ.

For example, if oscillation frequency is assumed to be f_{OSC} =500kHz, V_{IN}=2.5V, V_O=5V, and I_{OUT} =0.5A, then R_{LOAD} =10Ω. If we select L=4.7µH, then:

$f_{RHPZ}=5(2.5/5)^2/(2\pi*4.7*10^{-6}*0.5)=84.65kHz$

If f_C=14kHz, C_C would be calculated as:

$C_C=(V_{FB}/V_O)(R_{LOAD}/R_{CS})(g_m/2\pi*f_C)(1-D)/2=(1.25/5)(10/0.275)*[105\mu S/(6.28*14kHz)](1/4)=2.7nF$

Now selected R_C has fulfilled transient-droop requirements. For example, if 4% of transient droop is allowed, input to error amplifier moves

0.04*1.25V, or 50mV. Error amplifier output drives 50mV*105µs, or 6.25µA, across R_C to provide transient gain. Since the current-sense transresistance is 0.275V/A, the value of R_C that would allow the required load-step swing is as follows:

$$R_C = 0.275 I_{IND(PK)} / 6.25\mu A$$

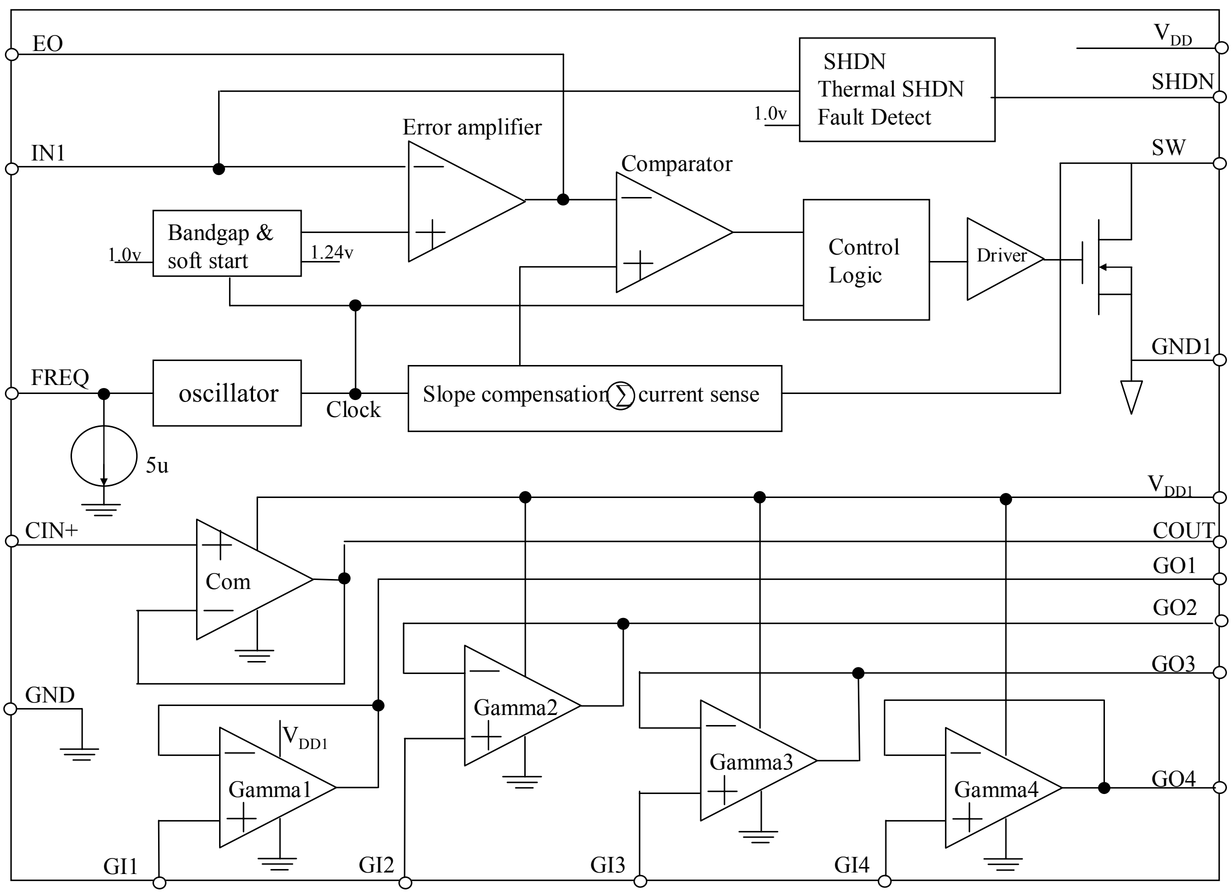
In a step-up DC-to-DC converter, if L_{IDEAL} is used, output current would relate to inductor current as:

$$I_{IND(PK)} = 1.25 I_{OUT}/(1-D) = 1.25 I_{OUT} * V_O / V_{IN}$$

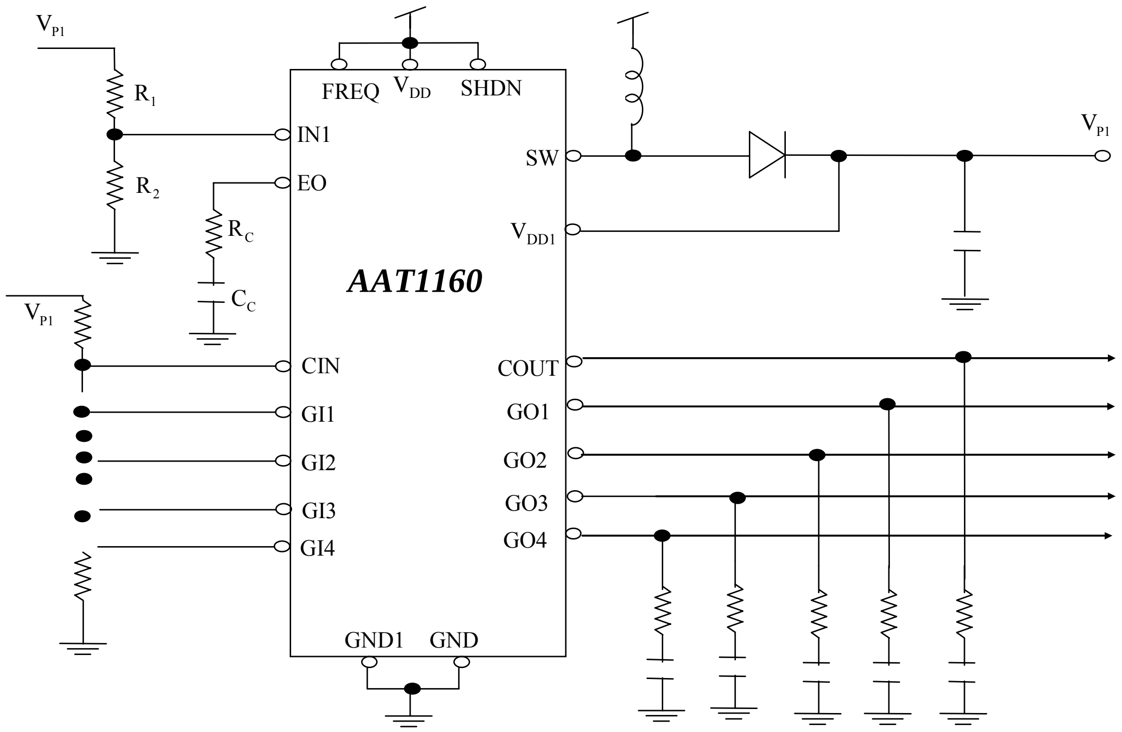
Therefore, for a 500mA output load step with V_{IN}=2.5V and V_O=5V:

$$R_C = [1.25(0.75*0.5*5)/2)]/6.25\mu A = 18.7k\Omega$$

BLOCK DIAGRAM

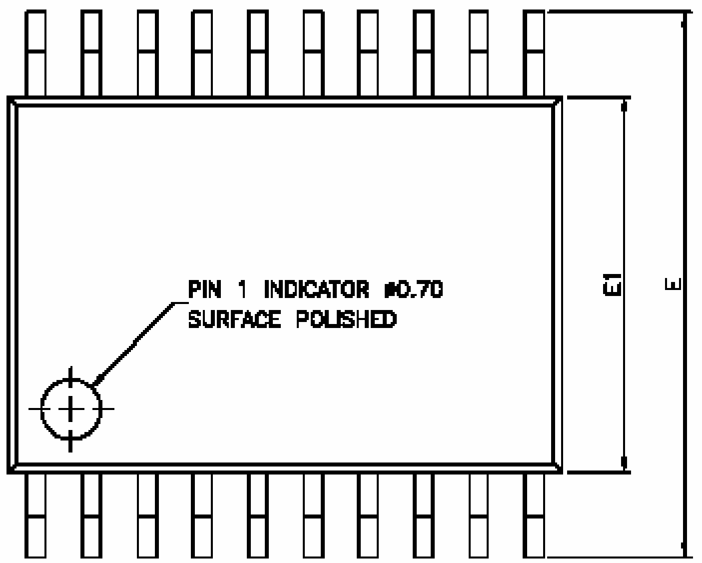


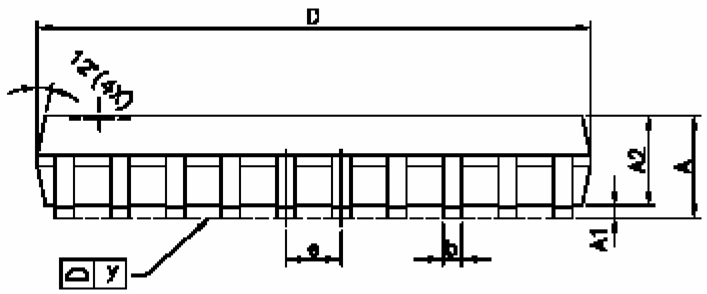
Application Circuit

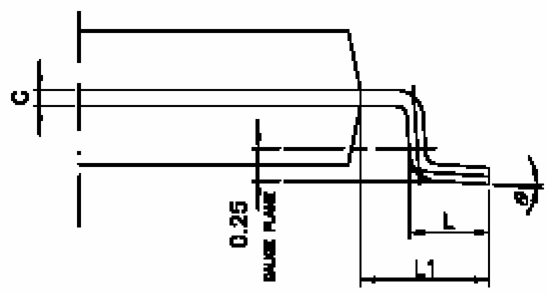


Package Dimension

20-Pin TSSOP



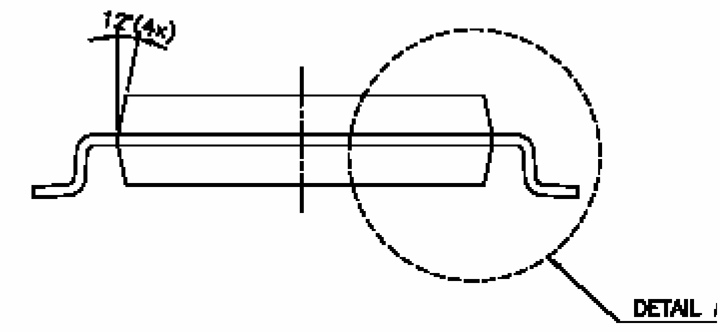




DETAIL A

Package Dimension (Cont.)

20-Pin TSSOP



SYMBOLS	DIMENSIONS IN MILLIMETERS			DIMENSIONS IN INCHES		
	MIN	NOM	MAX	MIN	NOM	MAX
A	—	—	1.20	—	—	0.047
A1	0.05	—	0.15	0.002	—	0.006
A2	0.08	1.00	1.05	0.003	0.039	0.041
b	0.19	—	0.30	0.007	—	0.012
C	0.09	—	0.20	0.0035	—	0.008
D	6.40	6.50	6.60	0.252	0.256	0.260
E	—	6.40	—	—	0.252	—
E1	4.30	4.40	4.50	0.170	0.173	0.177
e	—	0.65	—	—	0.026	—
L	0.45	0.60	0.75	0.0177	0.024	0.0295
L1	—	1.00	—	—	0.039	—
y	0°	—	8°	0°	—	8°
θ'	—	—	0.076	—	—	0.003

NOTE :

1. CONTROLLING DIMENSION : mm
2. LEAD FRAME MATERIAL : OLIN C7025/EFTEC 64T
3. DIMENSION "D" DOES NOT INCLUDE MOLD FLASH, TIE BAR BURRS AND GATE BURRS. MOLD FLASH, TIE BAR BURRS AND GATE BURRS SHALL NOT EXCEED 0.006"[0.15mm] PER END DIMENSION "E1" DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010"[0.25mm] PER SIDE.
4. DIMENSION "b" DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.003"[0.08mm] TOTAL IN EXCESS OF THE "b" DIMENSION AT MAXIMUM MATERIAL CONDITION. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OR THE FOOT. MINIMUM SPACE BETWEEN PROTRUSION AND AN ADJACENT LEAD TO BE 0.0028"[0.07mm]
5. TOLERANCE : ±0.010"[0.25mm] UNLESS OTHERWISE SPECIFIED.
6. OTHERWISE DIMENSION FOLLOW ACCEPTABLE SPEC.
7. REFERENCE DOCUMENT : JEDEC SPEC MO-153