High Efficiency LCD Monitor Power Design Using AIC1578

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DESCRIPTION

The AIC1578 is a high performance step-down DC/DC converter, designed to drive an external P-channel MOSFET to generate programmable output voltages. Two main schematics of Pulse-Skipping and Pulse-Frequency Modulation are employed to maintain low quiescent current and high conversion efficiency under wide ranges of input voltage and loading condition. A current sense comparator with both inverting and non-inverting input uncommitted is included to provide the crucial function of either current limit protection or constant output current control. When the AIC1578 is used in a high-side current source step-down constant current source, the efficiency is typically greater than 90%. Duty cycle can be adjusted to greater than 90% by connecting a resistor from DUTY pin to VIN. Switching frequency being in around 90KHZ to 280KHZ range small size switching components are ideal for portable equipment.

In order to maintain good conversion efficiency form light loads to full loads, the AIC1578 uses the intermittent switch control method of PFM (Pulse-Frequency Modulation) rather than the conventional PWM control method, Fig1. shows its basic structure.

When the feedback voltage is greater than the reference voltage (1.22V),the Err Amp. output is Low, and DRI (Pin6) is Hi Level, turn off outside drive device(P MOSFET), Whereas when the feedback voltage is lower than the reference voltage, the Err Amp is Hi, and DRI(Pin6) is Low Level, turn off outside drive device. The kind of control method works similar to PWM at full load, with a stable switch waveform, Whereas when at light load it uses intermittent switching to efficiently sustain output loading requirements.

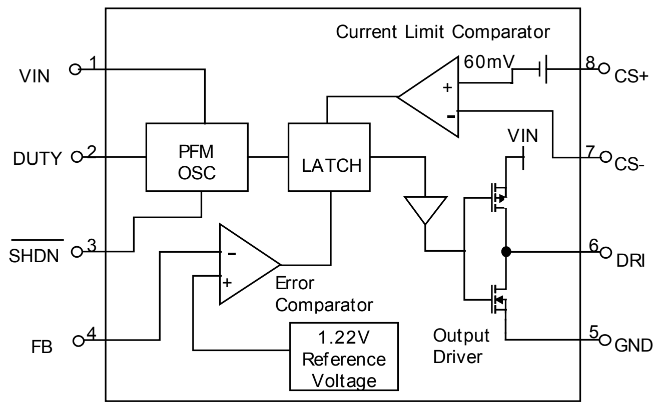


Fig1. AIC1578 Function Block

In addition, the AIC1578 converter has the following feature:

1. It can operate under an input voltage of 4V to 20V.
2. Output voltage can be adjusted externally.
3. It has a PFM design and automatically adjusted switching frequency and duty cycle, which makes it possible to obtain highly efficient conversion over a wide input and output voltage range.
4. It has a shutdown mode control
5. It works in the high frequency range of 90KHZ to 280KHZ,and only requires small size inductors.
6. It has complementary push-pull output,and can drive external P-channel MOSFET or PNP transistor.
7. Low cost.

Buck Switching Regulator Topology

Basic operation:

Fig. 2 shows the basic structure of an Buck DC/DC converter (switching regulator).

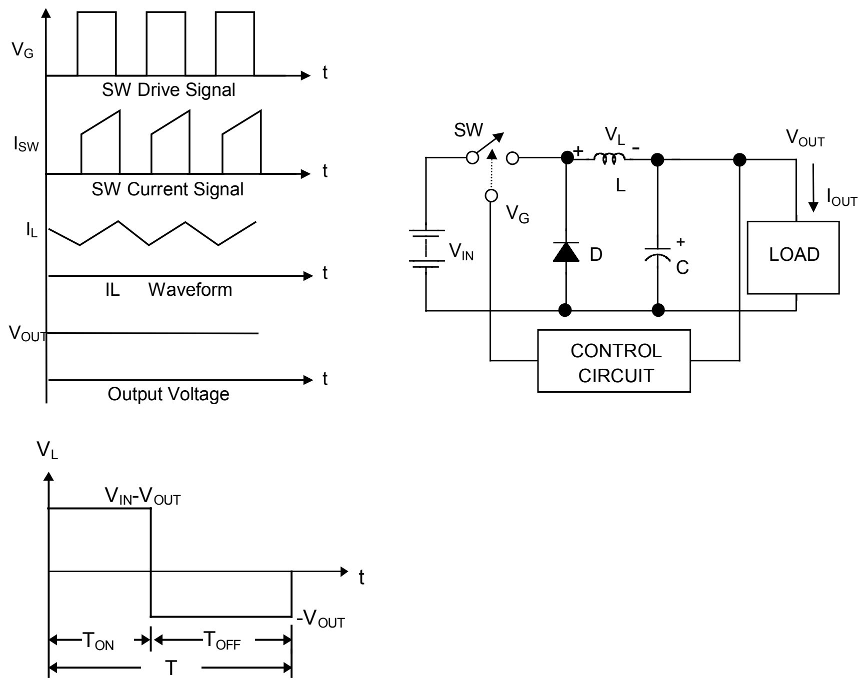


Fig2. Typical Buck Converter Topology

The basic operation principle is to use feedback to control the ON-and-OFF of the power switch to obtain the specified output voltage, for low power applications, conventional PWM control schemes are not ideal, because of, first, the low conversion efficiency due to high switching losses as compared to low output power, and second, the fact that the PWM controller requires a minimum load to maintain its stability. The most efficient and reliable control method is then to use a Pulse-Skipping-Modulation switching control with the control waveforms shown in Fig. 3. This switching control method can put the DC/DC converter into quasi-sleeping mode under no load or light load condition, which reduces switching losses while maintaining high conversion efficiency and good stability.

In order to choose the appropriate switching converter for an electronic product, therefore, 4 key factors need to be considered:

(1) The current capacity and regulation of the output current should meet what the product demands.

(2) High conversion efficiency.

(3) Low power consumption.

(4) Small size and light weight.

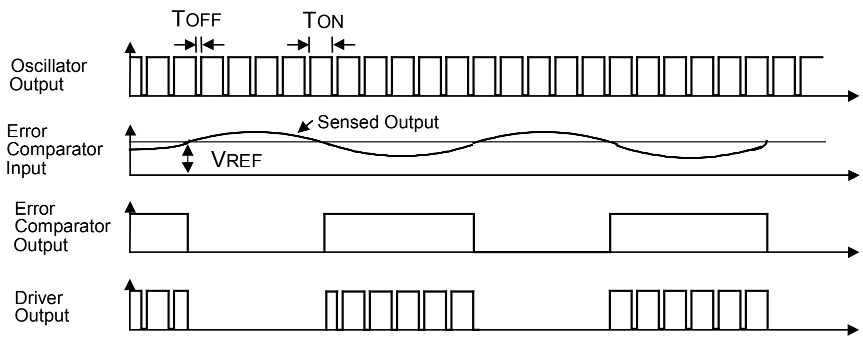


Fig 3. PSM Time Sequence Waveform

TYPICAL APPLICATION

The circuit shown in Fig.4 is an output power for LCD MONITOR , when V_{IN} is 10V ~ 14V ,a high efficiency of 86% can be obtained at full load.

(1) Power Specification :

Item	Symbol	Min.	Typ.	Max.	Unit
Input Voltage	V_{IN}	10		14	V
Output Voltage	V_{OUT}	4.75	5	5.25	V
Output Current	I_{OUT}	0.2A		3A	A
Output Ripple Voltage	V_{RIPPLE}		100		mV

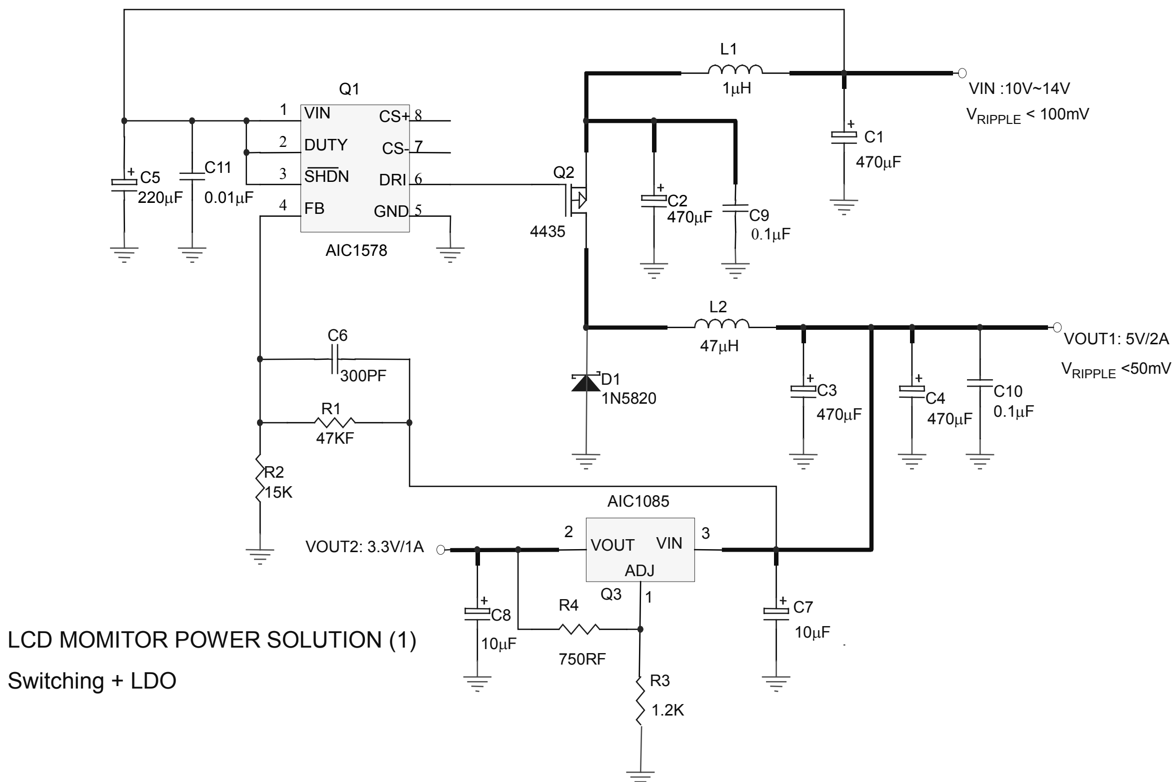


Fig4. AIC1578 for LCD MONITOR Power solution

Fig5. Frequency & Duty Cycle vs V_{IN}

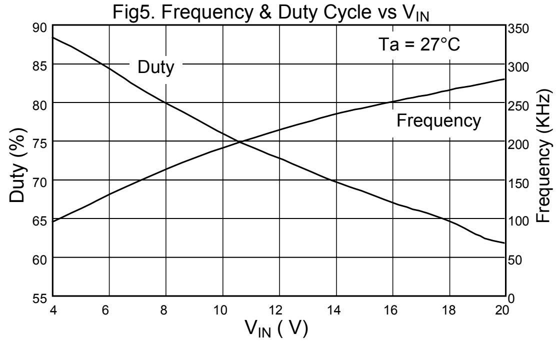
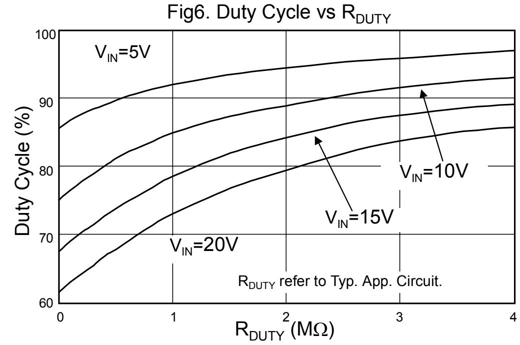


Fig6. Duty Cycle vs R_{DUTY}



(ii) Design note and Component selection:

Design note

1. DC-DC Converter efficiency

   Efficiency

$$= \frac{P_{OUT}}{P_{IN}} = \frac{I_{OUT} \times V_{OUT}}{I_{IN} \times V_{IN}} = \frac{I_{OUT} \times V_{OUT}}{I_{OUT} \times V_{OUT} + P_{LOSS}}$$

2. Set feedback component (R1,R2)
   following the Datasheet equation :

   V_{OUT}=1.22 (1+$\frac{R1}{R2}$)$\Rightarrow$ R1= 47KF , R2 = 15KF.

   (R1+R2) must be bigger than 50KR,for high efficiency request.
   C6 is noise filter depend on device's switching frequency.

3. Set Duty range :(if MOSFET CEM4435 : R_{DS-ON} =20 mR ,1N5820 :V_F=0.475V)

   $$D\ min = \frac{5 + 0.475}{14 - 0.04 + 0.475} = 37.9\%$$

   $$D\ max = \frac{5 + 0.475}{8 - 0.04 + 0.475} = 65\%$$

   Duty range is : 35.5% ~ 65%

   See Fig 5 ,When V_{IN} = 10V ~ 14V ,F_{SW} range is 180KHZ ~ 230KHZ and Duty range is 74% ~ 78%. So, Duty pin can directly connect to VIN pin .If you need larger Duty cycle than typical applications ,can reference Fig6 add R_{DUTY} to adjust it .

4. Set output inductor

   $$L = \frac{(V_{DC} - V_0)}{dI} = \frac{(V_{DC} - V_O)T_{ON}}{0.2I_{ON}}$$

Component selection :

(1) Sitching MOSFET Selection

The power dissipation of MOSFET is divide into two parts :Conduction losses and Switching losses.
Conduction losses :On-state losses are related to the load current and MOSFET R_{DS-ON} .

$$P_C = I^2_{out} R_{DS-ON} D$$

Switching losses: These losses are encountered during the MOSFET on and off states. They depend on the nature of the load as well ws the switching speed of the MOSFET.

$$P_S = f_S \left[\int_0^{ts1} V_{DS} I_D dt + \int_0^{ts2} V_{DS} I_D dt \right]$$

$$\fallingdotseq \frac{V_{DS} I_D (ts1 + ts2) fs}{6}$$

f_s : switching frequency
ts1 : turn-on time
ts2 : turn-off time
V_{DS} :supply voltage
I_D : drain current

Select MOSFET key factors:

1. Low R_{DS-ON}
2. Low C_{ISS}
3. Short Reverse recovery time

(2) SCHOTTKY BARRIER RECTIFIER SELECTION :

Conduction losses:Diode losses due to recovery time and conduction are strongly related to circuit topology and load impedance.

$P_{CR} = V_F\ I_{OUT}\ (1-D)$
V_F:Forward Conduction Voltage

Select SCHOTTKY Key factors :

1. Low forward conduction voltage(V_F)
2. Low ESR
3. Short Reverse recovery time
4. large Reverse Breakdown Voltage
5. I_D-PEAK > I_L-PEAK

(3) PWM Output Capacitors Selection

The bulk filter capacitor values are generally determined by the ESR(effective series resistance) and ESL (effective series inductance) parameters rather than actual capacitance. High frequency decoupling capacitors

Should be placed as close to the power pins of the load as physically possible. Be careful not to add inductance in the circuit board wiring that could cancel the usefulness of these low inductance component, use only specialized low-ESR capacitors intended for switching regulator applications for the bulk capacitors. The bulk capacitor's ESR determines the output ripple voltage and the initial voltage drop after a high slew-rate transient. An aluminum electrolytic capacitor's ESR value is related to the case size with lower ESR available in larger case sizes.

(4) PWM Output Inductor Selection

The output inductor is selected to meet the output voltage ripple requirements and sets the converter's response time to a load transient. The inductor value determines the converter's ripple current and the ripple voltage is a function of the ripple current. The ripple voltage and current are approximate by the following equation :

$$\Delta I = \frac{V_{IN} - V_{OUT}}{F_S L_O} \times \frac{V_{OUT}}{V_{IN}}, \quad \Delta V_{OUT} = \Delta I \times ESR$$

Increasing the value of inductance reduces the ripple current and converter's response time to a load transient.

1. Efficiency Test:

Input Voltage	Input Current	Output Voltage	Output Current	Output Load	Efficiency
10V	290 mA	5.06V	503mA	500mA	87.8 %
10V	570 mA	5.06V	1003 mA	1A	89.0 %
10V	1149 mA	5.05V	2001 mA	2A	87.9 %
10V	1754 mA	5.05V	3001 mA	3A	86.4 %
12V	252 mA	5.06V	503mA	500mA	84.2 %
12V	489 mA	5.06V	1003 mA	1A	86.5 %
12V	979 mA	5.05V	2001 mA	2A	86.1 %
12V	1491 mA	5.06V	3001 mA	3A	84.9 %
14V	217 mA	5.09V	503mA	500mA	84.3 %
14V	419 mA	5.09V	1003 mA	1A	87.0 %
14V	836 mA	5.08V	2001 mA	2A	86.9%
14V	1271 mA	5.07V	3001 mA	3A	85.5 %

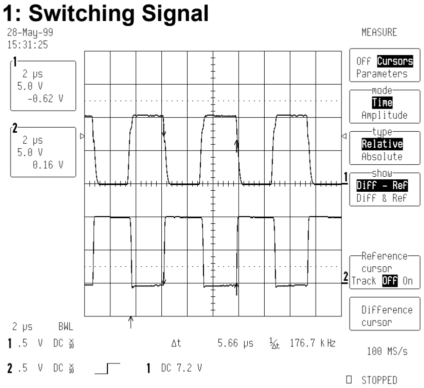
2.Temperature Test

LOAD / V_{IN}	LOAD = 1A				LOAD = 2A				LOAD = 3A			
	1578	MOS	L1	L2	1578	MOS	L1	L2	1578	MOS	L1	L2
8V	34.1	35.5	32.8	35.9	38.1	42.2	35.1	44.1	40.2	51.3	37.3	61.1
10V	36.7	37.9	34.5	36.4	41.5	48.8	35.6	49.9	45.5	53.3	38.9	66.5
12V	39.3	38.3	34.5	36.6	43.7	51.2	36.1	50.7	49.7	65.8	37.4	70.7
14V	40.8	40.2	34.8	37.5	44.3	56.6	38.7	62.1	50.3	66.4	39.2	74.6
15V	42.4	40.6	35.1	39.3	45.5	58.9	39.5	69.4	53.9	67.2	44.3	80.1

Unit: °C

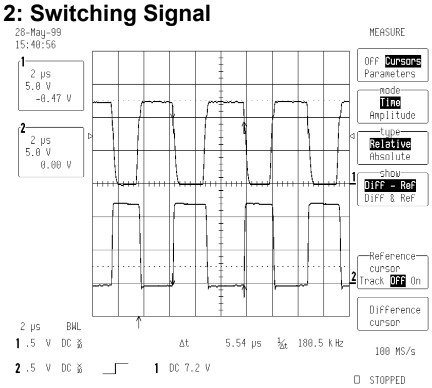
3.TEST WAVEFORM:

FIG 1: Switching Signal



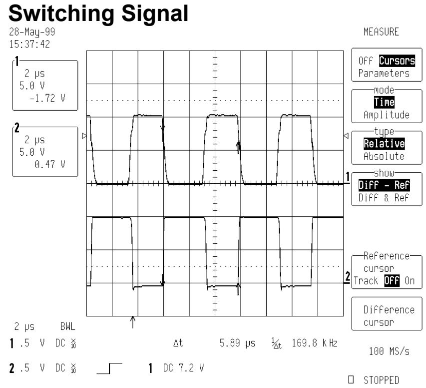
CH1: VG-GND (5V / DIV)
CH2: VS-GND (5V / DIV)
Status: V_{IN}= $10V_{DC}$
V_{OUT}= $5.06V_{DC}$
Output Load = 1A

FIG 2: Switching Signal



CH1: VG-GND (5V / DIV)
CH2: VS-GND (5V / DIV)
Status: VIN= $12V_{DC}$
V_{OUT}= $5.05V_{DC}$
Output Load = 2A

FIG3: Switching Signal



CH1: VG-GND (5V / DIV)

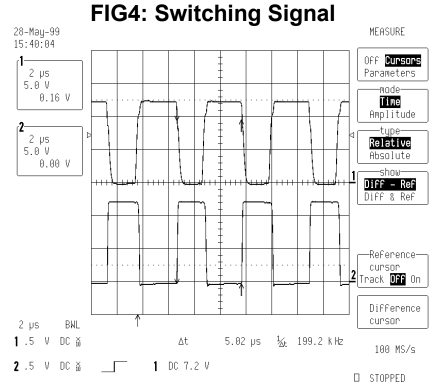
CH2: VS-GND (5V / DIV)

STATUS: V_{IN}= 10Vdc

V_{OUT}= 5.05Vdc

Output Load = 3A

FIG4: Switching Signal



CH1: VG-GND (5V / div)

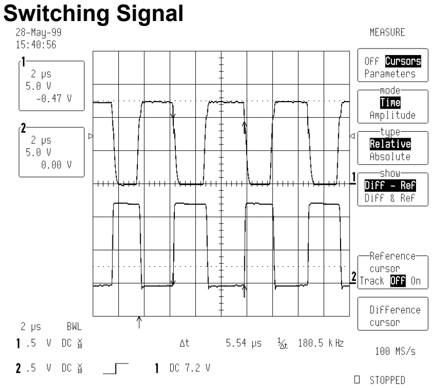
CH2: VS-GND (5V / div)

STATUS: V_{IN}= 10Vdc

V_{OUT}= 5.05Vdc

Output Load = 2A

FIG5: Switching Signal



CH1: VG-GND (5V / DIV)

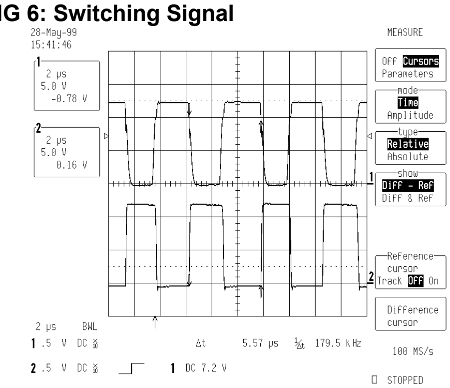
CH2: VS-GND (5V / DIV)

Status: V_{IN}= 12V_{DC}

V_{OUT}= 5.05Vdc

Output Load = 2A

FIG 6: Switching Signal



CH1: VG-GND (5V / DIV)

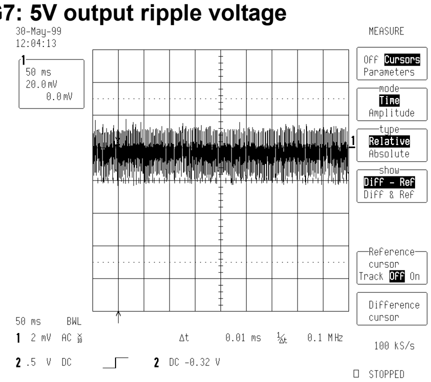
CH2: VS-GND (5V / DIV)

Status: V_{IN}= 12V_{DC}

V_{OUT}= 5.06Vdc

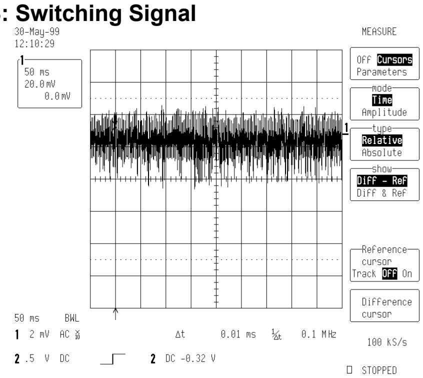
Output Load = 3A

FIG7: 5V output ripple voltage



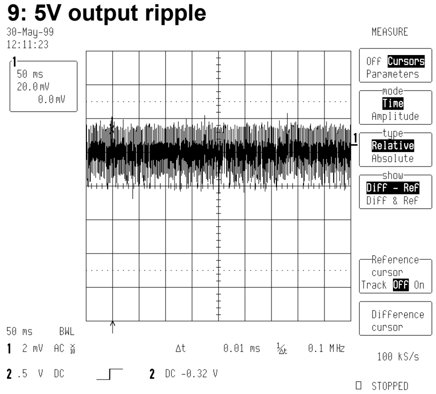
CH1: 5V Output (Ripple Voltage)
Status: Input Voltage: 10V
Output Load: 1A

FIG 8: Switching Signal



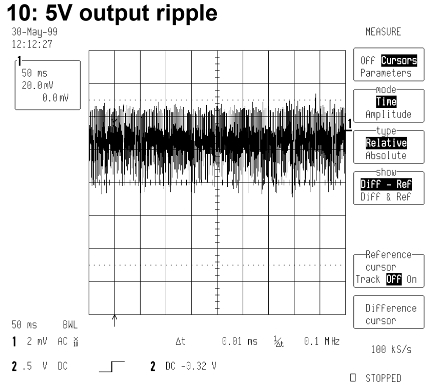
CH1: 5V Output (Ripple Voltage)
Status: Input Voltage: 10V
Output Load: 3A

FIG 9: 5V output ripple



CH1: 5V Output (Ripple Voltage)
Status: Input Voltage: 12V
Output Load: 1A

FIG 10: 5V output ripple



CH1: 5V Output (Ripple Voltage)
Status: Input Voltage: 12V
Output Load: 3A

4. LCD MONITOR BOM LIST

Reference	Part Number	QTY	PKG	Manufacturer	Remark
Q1	AIC1578CS	1	SO-8	AIC	
Q2	CEM4435	1	SO-8	CET	N-MOSFET
Q3	AIC1085CM	1	TO-263	AIC	
L1	1μH / 2A	1	SMD	H&D / Cailcraft	
L2	47μH / 3A	1	SMD	H&D / Cailcraft	
D1	1N5820	1	DIP		Schottky
C1,C2,C3,C4	470μF / 16V	4	DIP		
C5	220 μF / 16V	1	DIP		
C6	330 PF	1	SMD		
C7,C8	10 μF / 16V	2	DIP		
C9,10	0.1μF	2	SMD		
C11	0.01μF	1	SMD		
R1	47KΩ/ 1%	1	SMD		
R2	15KΩ/ 1%	1	SMD		
R3	12KΩ/ 1%	1	SMD		
R4	750Ω/ 1%	1	SMD		