8 PIN PWM SWITCHER CONTROLLER IC

PRELIMINARY DATASHEET

FEATURES

- **8 pin SOIC Switching Controller with HICCUP Current Limiting Reduces Diode Power Dissipation to Less than 1% of Normal Operation**
- **Soft Start Capacitor allows for smooth Output Voltage ramp up**
- **On board MOSFET driver**
- **Fastest transient response of any controller method. (0 to 100% Duty Cycle in 100 nS)**
- **1% internal voltage reference**
- **Internal Under Voltage Lockout protects MOSFET during start-up**

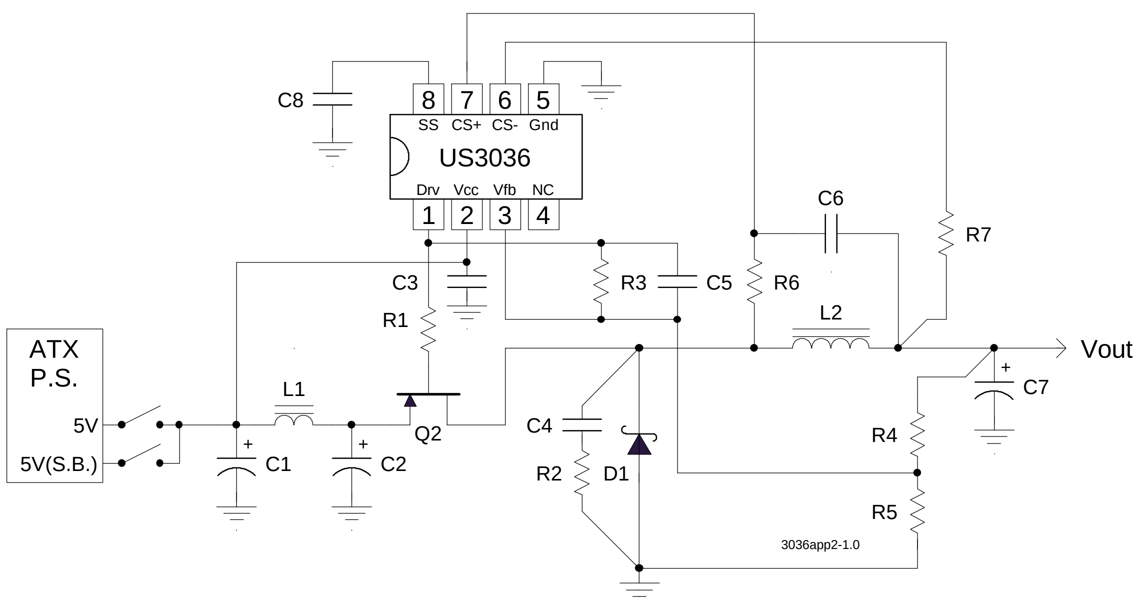
APPLICATIONS

- Single input Switching Regulators such as Simple 5V to 2.5V switcher for RDRAM regulator

DESCRIPTION

The US3036 IC **provides an 8 pin low cost switching controller with true short circuit protection all in a compact 8 pin surface mount package,** providing a **low cost switching solution** for applications that require a simple switching regulator from the 5V input where there is no other supply available. One type of such application is generating 2.5V standby from the dual 5V(5V and 5V standby) for the next generation processors. The IC starts below 4.5V supply and drives an external Pch MOSFET or and external low cost PNP as the switching element. The IC also includes an error comparator for fast transient response, a precise voltage reference for setting the output voltage as well as a direct drive of the MOSFET for the minimum part count.

TYPICAL APPLICATION



Typical application of US3036

PACKAGE ORDER INFORMATION

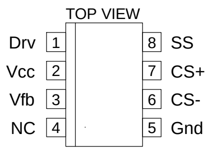
TA (°C)	8 PIN PLASTIC SOIC (S)
0 TO 70	US3036CS

ABSOLUTE MAXIMUM RATINGS

V_{CC} Supply Voltage 20V
F.B Pin Voltage... -0.3V to 5V
Storage Temperature Range .... -65 TO 150°C
Operating Junction Temperature .... 0 TO 150°C

PACKAGE INFORMATION

8 PIN PLASTIC SOIC (S)



θ_{JA}=160°C/W

ELECTRICAL SPECIFICATIONS

Unless otherwise specified the following specification applies over V_{CC} =5V, and T_A =0 to 70°C. Low duty cycle pulse testing are used which keeps junction and case temperatures equal to the ambient temperature.

PARAMETER	SYM	TEST CONDITION	MIN	TYP	MAX	UNITS
F.B Voltage Initial Accuracy	V_{FB}	T_J =25°C	1.237	1.250	1.262	V
F.B Voltage Total Variation			1.225	1.250	1.275	V
F.B Voltage Line Regulation				0.2		%
F.B Input Bias Current	I_{FB}	V_{FB} =1.25V	-1		+1	uA
Min On Time		V_{FB} is sq wave with 300 ns on time and 2 uS off time		800		nS
Min Off Time		V_{FB} is sq wave with 300 ns off time and 2 uS on time		800		nS
Supply Current	I_{CCSW}	V_{FB} =1.5V		10		mA
Maximum Duty Cycle	D_{MAX}	V_{FB} =1.5V			100	%
Minimum Duty Cycle	D_{MIN}	V_{FB} =1V	0			%
Gate Drive Rise/Fall Time	V_{GATE}	Load=1000pF		70		nS
C.L Threshold Current	I_{CL}	C.S+ , C.S- from 1.3V to 3.7V		20		uA
C.S Comp Common Mode		V_{CS+} = V_{CS-}	0		4.5	V
Soft Start Current				10		uA
UVLO Threshold	V_{UVLO}		4.25	4.4	4.55	V

Rev. 1.1
12/4/98

PIN DESCRIPTIONS

PIN #	PIN SYMBOL	PIN DESCRIPTION
3	V_{FB}	A resistor divider from this pin to the output of the switching regulator and ground sets the Core supply voltage.
6	C.S-	This pin is connected to the minus side of the external current sense resistor. An internal current source together with an external resistor in series with this pin programs the current limit threshold voltage. This voltage divided by the external current sense resistor sets the current limit threshold.
7	C.S+	This pin is connected to the plus side of the external current sense resistor. A resistor in series with this pin and a capacitor connected between this pin and pin 6 provides a high frequency filtering for the noise spikes of turn on and turn off switching.
5	Gnd	This pin is connected to the IC substrate and must be connected to the lowest potential in the system.
1	Drv	The PWM output of the switching controller. This pin is a totem pole drive that is connected to the gate of the power MOSFET. A resistor may be placed from this pin to the gate in order to reduce switching noise.
2	V_{CC}	This pin supplies the voltage to the PWM drive and hysterises circuitry and it is connected to the same supply as the input supply to the switching regulator . A 1 uF, high
8	S.S	frequency capacitor must be connected from this pin to ground to provide the peak current for charging and discharging of the MOSFET. This pin provides the soft start for the regulator during power up. It also sets a long off time when the converter goes into current limiting, providing low duty cycle for the catch diode allowing it to survive during short circuit.
4	N.C	No connect.

BLOCK DIAGRAM

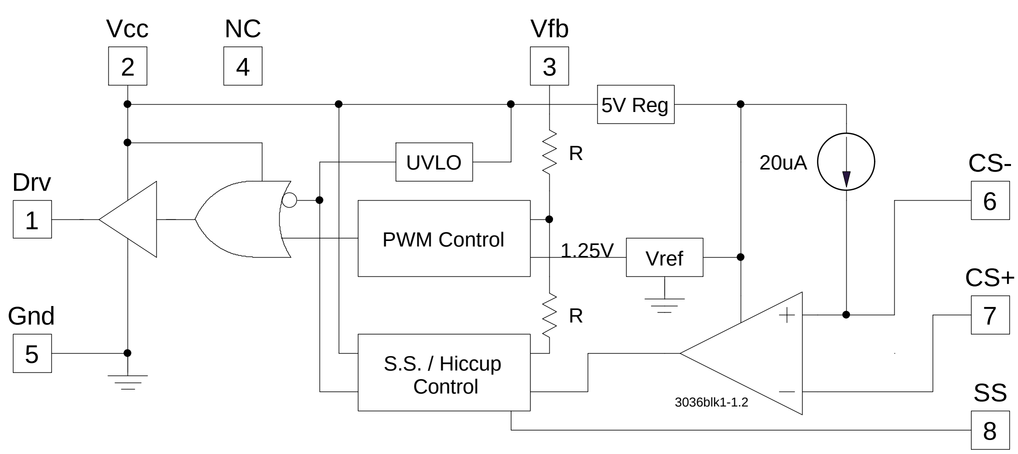


Figure 1 - Simplified block diagram of the US3036

TYPICAL APPLICATION

5V to 2.5V for RDRAM Supply

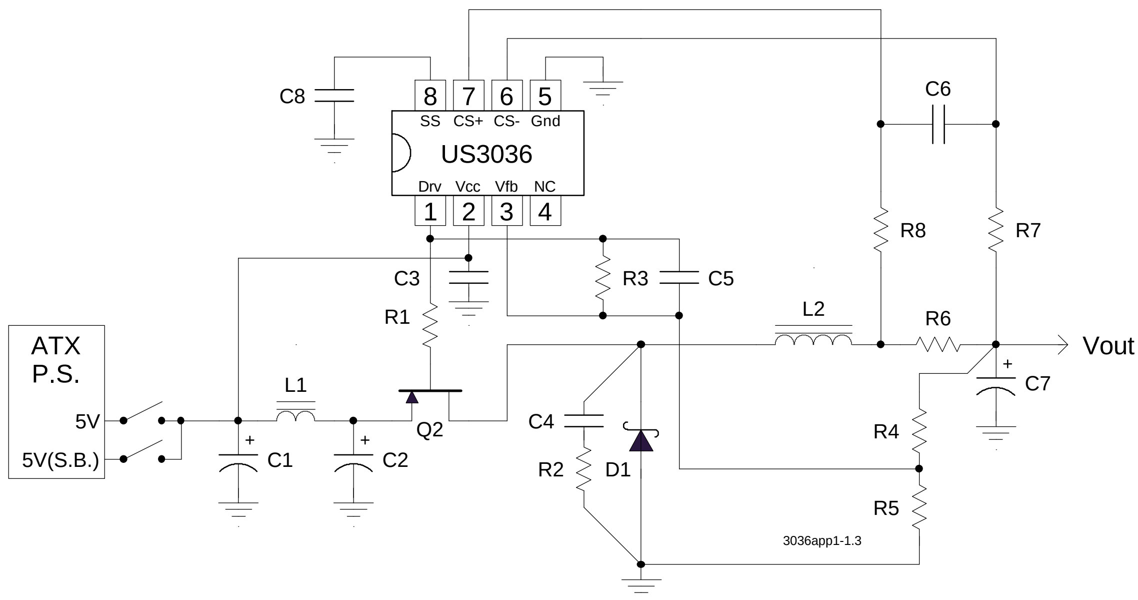


Figure 2- The circuit in figure 2 is the application of the US3036 providing a low cost solution for a 2.5V/2A supply from the 5V dual supply. This circuit uses current sense resistor to set the current limiting.

Ref Desig	Description	Qty	Part #	Manufacturer
U1	LDO/Switcher IC	1	US3036CS (8 pin SOIC)	Unisem
Q2	MOSFET P Ch	1	IRF7204 (8 pin SOIC) or IRF7406 for 4A SI9435DY (8 pin SOIC) or SI4431 for 4A	IR Temic
D1	Schottky Diode	1	SK33DICT (SMC)	Lite on
L2	Inductor	1	Core:T44-52,L=6 uH Turns: 15T, 20 AWG	Micro Metal (core)
L1	Inductor	1	L=1 uH	
R1	Resistor	1	10 ohm,5%, SMT 1206 size	
R2	Resistor	1	10 ohm, 5%, SMT 1206 size	
R3	Resistor	1	200 kohm,1%, SMT 0805 size	
R4	Resistor	1	1 kohm,1%, SMT 0805 size	
R5	Resistor	1	1 kohm,1%, SMT 0805 size	
R6	Resistor	1	5 miliohm,5%, 2W	Ohmite
R7,8	Resistor	2	3.57 kohm,1%, SMT 0805 size	
C1	Capacitor	1	470uF,10V, Elect	Sanyo
C2	Capacitor	1	10CV1000DX, 1000uF,10V, Elect ,ESR=0.07 Ohm	Sanyo
C3	Capacitor	1	1 uF,Ceramic, SMT 0805 size	
C4	Capacitor	1	470 pF,Ceramic, SMT 0805 size	Sanyo
C5	Capacitor	1	10 pF,Ceramic, SMT 0805 size	Sanyo
C6	Capacitor	1	4700pF	
C7	Capacitor	1	10CV1000DX, 1000uF,10V, Elect ,ESR=0.07 Ohm	Sanyo
C8	Capacitor	1	0.15 uF	

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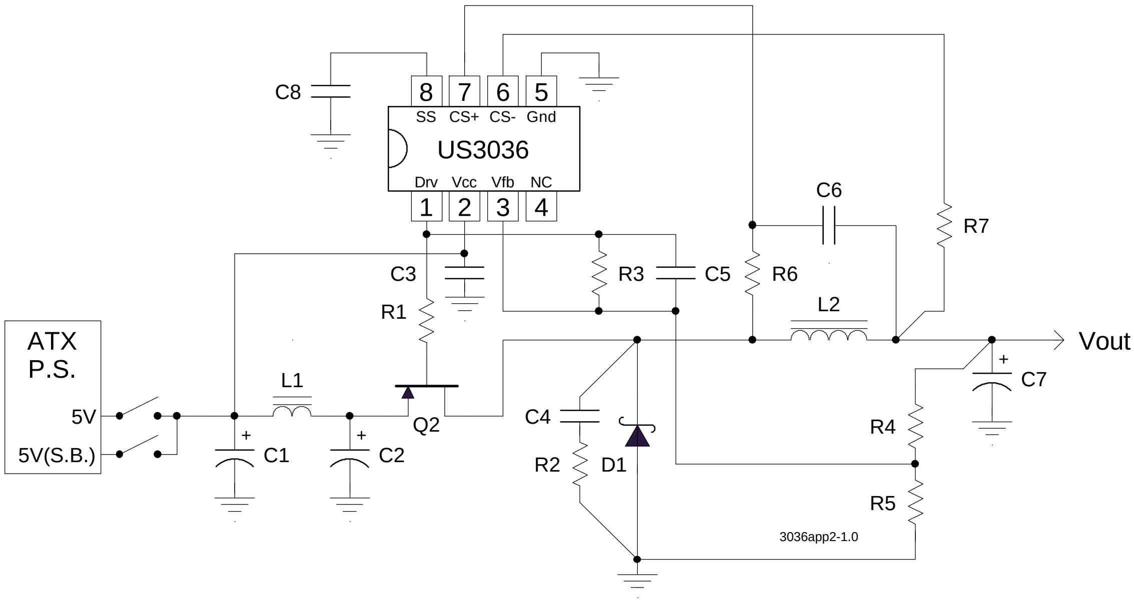

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R4	Resistor	1	1 kohm,1%, SMT 0805 size	
R5	Resistor	1	1 kohm,1%, SMT 0805 size	
R6	Resistor	1	1 kohm,5%	
R7	Resistor	1	3.57 kohm,1%, SMT 0805 size	
C1	Capacitor	1	470uF,10V, Elect	Sanyo
C2	Capacitor	1	10CV1000DX, 1000uF,10V, Elect ,ESR=0.07 Ohm	Sanyo
C3	Capacitor	1	1 uF,Ceramic, SMT 0805 size	
C4	Capacitor	1	470 pF,Ceramic, SMT 0805 size	Sanyo
C5	Capacitor	1	10 pF,Ceramic, SMT 0805 size	Sanyo
C6	Capacitor	1	0.1uF	
C7	Capacitor	1	10CV1000DX, 1000uF,10V, Elect ,ESR=0.07 Ohm	Sanyo
C8	Capacitor	1	0.15 uF	

APPLICATION INFORMATION

Introduction

The US3036 device is an application specific product designed to provide an on board switching supply for the new generation of microprocessors requiring separate Core and I/O supplies where the load current demand from the I/O supply requires this regulator to also be a switching regulator such as the motherboard applications with AGP slot or the Pentium II with on board 5V to 3.3V converter. The US3036 provides an easy and low cost switching regulator solution for Vcore and 3.3V supplies with true short circuit protection.

Switching Controller Operation

The operation of the switching controller is as follows : after the power is applied, the output drive pin, "Drv" goes low turning the P MOS to 100% duty cycle and the the current in the inductor charges the output capacitor causing the output voltage to increase. When output reaches a pre-programmed set point the feedback pin "Vfb" exceeds 1.25V causing the output drive to switch low and the "Vhyst" pin to switch high which jumps the feedback pin higher than 1.25V resulting in a fixed output ripple which is given by the following equation :

dVo=(Rt/Rh)x(Vcc -1)

Where:

Rt=Resistor connected from Vout to the Vfb pin of US3036

Rh=Resistor connected from Vfb pin to Vhyst pin.

For example, if Rt=1k and Rh=200k, then the output ripple is :

dVo=(1/200)x4=20 mV

The advantage of fixed output ripple method is that when the output voltage changes from 2V to 3.5V, the ripple voltage remains the same which is important in meeting the Intel maximum tolerance specification.

Soft Start

The soft start capacitor must be selected such that during the start up when the output capacitors are charging up, the peak inductor current does not reach the current limit treshold. A minimum of 0.1uF capacitor insures this for most applications. During start up the soft start capacitor is charged up to approximately 6V keeping the output shutdown before an internal 10uA current source start discharging the soft start capacitor which slowly ramps up the inverting input of the PWM comparator, Vfb. This insures the output to ramp up at the same rate as the soft start cap thereby limiting the input current. For example, with 0.1uF and the 10uA internal current source the ramp up rate is $(\Delta V/\Delta t)=I/Css = 10/0.1=100V/Sec$ or 0.1V/mSec. Assuming that the output capacitance is 6000uF, the peak input current will be:

$Iin(pk)=Css*(\Delta V/\Delta t)=6000uF*(0.1V/mSec)=0.6A$

The soft start capacitor also provides a delay in the turn on of the output which is given by:

$Td=C_{SS}*K$

Where K=30 ms/uF

For example for C_{SS}=0.1uF,

Td=0.1* 30=3 ms

Switcher Current Limit Protection

The US3034 uses an external current sensing resistor and compares the voltage drop across it to a programmed voltage which is set externally via a resistor (R_{CL}) placed between the "CS-" terminal of the IC and Vout. Once the voltage across the sense resistor exceeds the threshold, the soft start capacitor pulls up to 12V, pulling up the inverting pin of the error comparator higher than non inverting which causes the external MOSFET to shut off. At this point the C.S comparator changes its state and pulls the soft start capacitor to Vcc which is 12V and shutting the PWM drive. After the output drive is turned off, an internal 10uA current source slowly discharge the soft start capacitor to approximately 5.7V, before the output starts to turn back on causing a long delay before the MOSFET turns back on. This delay causes the catch diode to cool off between the current limit cycles allowing the converter to survive a short circuit condition. An example is given below as how to select the current limiting components. Assuming the desired current limit point is set to be 20A and the current sense resistor $R_S=5m\Omega$, then the current limit programming resistor, R_{CL} is calculated as :

$Vcs=I_{CL}*Rs=20*0.005=0.1V$

$R_{CL}=Vcs/I_b=(0.1V)/(20uA)=5k\Omega$

Where: I_b=20uA is the internal current source of the US3034

The peak power dissipated in the C.S. resistor is :

$Ppk=(I_{CL}\text{^}2)*Rs=20\text{^}2*0.005=2W$

However, the average power dissipated is much lower than 2W due to the long off time caused by the hiccup circuit of 3034. The average power is in fact the short circuit period divided by the short circuit period plus the off time or "hiccup" period. For example, if the short circuit lasts for T_{SC}=100uSec before the 3034 enters hiccup, the average power is calculated as :

$Pave=Ppk*D_{SC}$

Where:

$D_{SC}=T_{SC}/T_{HCP}$

$T_{HCP}=C_{SS}*M$

Where M=630 ms/uF & C_{SS}, is the soft start capacitor

For example for C_{SS}=0.1uF & T_{SC}=100uSec=0.1mS

T_{HCP}=0.1* 630=63 ms

Pave=2*(0.1/63)=3.2 mW

Without "hiccup" technique, the power dissipation of the resistor is 2W.

Switcher Output Voltage Setting

The output voltage can be set using the following equations.
Assuming , Vo=3.38V and the selected output ripple is ≈ 1.3%(44mV) of the output voltage, a set of equations are derived that selects the resistor divider and the hysterises resistor.
Assuming, Rt=1kΩ , 1%
Rh=(11*Rt)/ΔVo
Where:
Rt=Top resistor of the resistor divider
Rh=Hysterises resistor connected between pins 3 and 4 of the US3034
ΔVo=Selected output ripple (typically 1% to 2% of output voltage)
Assuming, ΔVo=44mV
Rh=(11*1000)/0.044=250 kΩ
Select Rh=249 kΩ , 1%
The bottom resistor of the divider is then calculated using the following equations:
Rb=Rt/X
Where:
Rb=Bottom resistor of the divider
X=[(Vo + (ΔVo/2))/Vref] - 1
Vref=1.25 V typ.
X=[(3.38+ (0.044/2))/1.25] - 1 = 1.72
Rb=1000/1.72=580 Ω
Select Rb=576 Ω , 1%

Frequency Calculation

The US3034 frequency of operation is calculated using the following formula:
Fs=[(Vo*(1-D)*ESR)]/(L*ΔVo) (MHz)
Where:
Vo=Output voltage (V)
D=Duty cycle
ESR=Output capacitor ESR (V)
L=Output inductance (uH)
ΔVo=Output ripple voltage (V)
For our example:
D≈(Vo + Vf)/Vin
Where, Vf=Forward voltage drop of the Schotky diode
D=(3.38 + 0.5)/5=0.78
The ESR=18mΩ for 2 of the Sanyo 1500uF, 6MV1500GX caps. If L=3.5uH then, Fs is calculated as follows:
Fs=[(3.38*(1-0.78)*0.018)]/(3.5*0.044)= 0.087 Mhz = 87 kHz