SGS-THOMSON MICROELECTRONICS

APPLICATION NOTE

LPR30 LINEAR CONTROLLER

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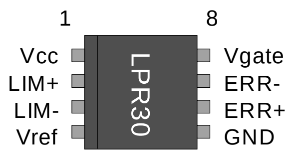
ABSTRACT

This paper proposes an integrated circuit developed for high current-low dropout linear regulators. The first section describes the internal blocks and the operating mode of the IC, while the second suggests an application example based on an existing demo-board.

Figure 1. Pin Configuration

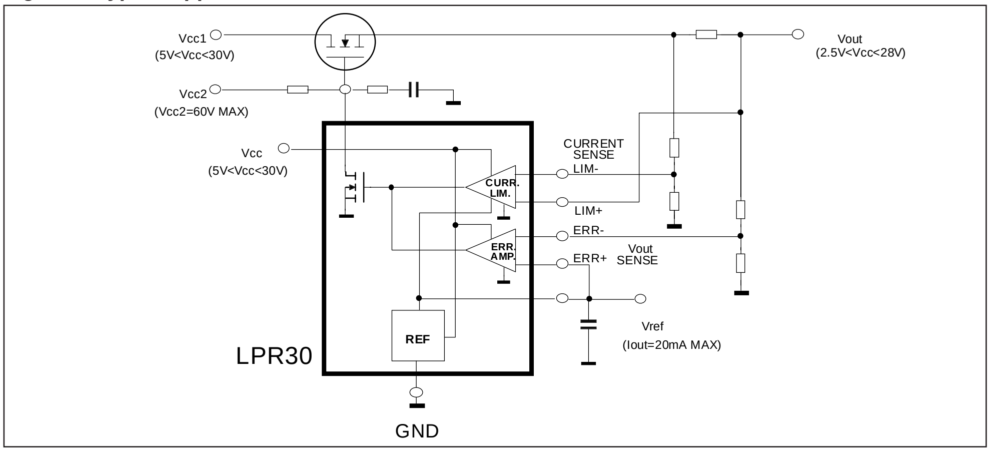


An alternative way is to use a PNP series pass transistor in order to reduce the dropout voltage, but an integrated PNP transistor is not able to sustain high current levels.

For these reasons, it is preferable to use a discrete Power MOSFET, integrating all the control functions in a single monolithic circuit. The main functions that this integrated circuit has to carry out are the output voltage control and the output current limitation. A band-gap high-stability V_{REF} and a Power MOSFET driver are also integrated.

The V_{REF} output is externally connected to the error amplifier which allows a V_{OUT} lower than V_{REF}.

Figure 2. Typical application



1. INTRODUCTION

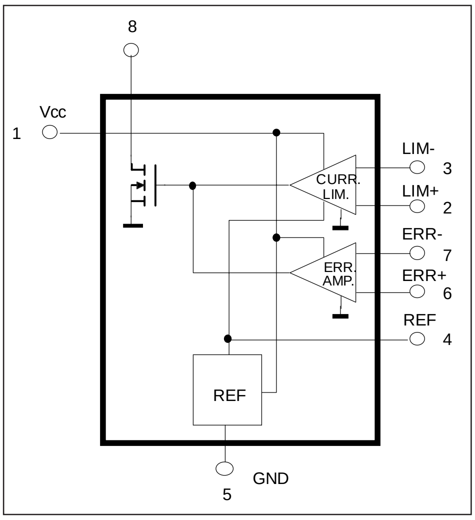
Linear regulators usually use NPN bipolar transistors for regulation of the output voltage.

To minimize the drive current, a Darlington NPN is used. Moreover, this solution involves a high dropout voltage due to the high V_{cesat} of the Darlington transistor.

2. CURRENT LIMIT BLOCK

The current limit comparator clamps the output current at a level that imposes 50mV at its' inputs. This low offset voltage allows a reduction in the drop voltage in the current sense resistor and a reduction of the thermal effect on the resistor. The intervention of the current sense comparator blocks the function of the voltage control. A foldback limitation is easily implemented by connecting two resistors at pin 3 of the IC.

Figure 3. LPR30 block diagram



3. ERROR AMPLIFIER BLOCK

The Error Amplifier Block is actuated with an operational amplifier that compares the output voltage with a reference voltage and suitably drives the external Power MOSFET if a difference exists at its inputs.

4. VOLTAGE REFERENCE BLOCK

Uses a band - gap circuit in order to improve the temperature stability.The value is set to

2.5V +/- 1 % (at 25°C).

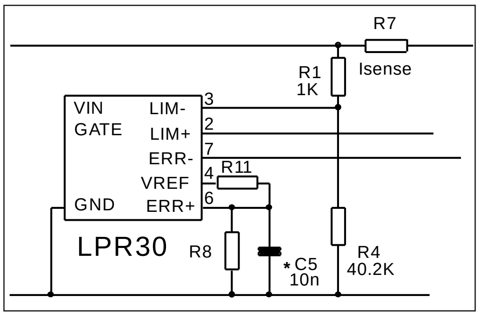
5. DRIVER BLOCK

Uses an N-channel open-drain D-MOS with R_{DSon}=3Ohm (at 25°C) and BV_{DS}= 60V.

6. OPERATING MODE

If high output current and low dropout voltage are required, it is necessary to use a low R_{DSon} external Power MOSFET (such as STD 80N03L-06).

Figure 4.



The drop voltage is $V_d = R_{DSon} * I_{OUT}$

If current limitation is used, we also have to consider the drop voltage across the sense resistor, and so the minimum V_{IN} voltage is :

$V_{IN}min = (R_{DSon} + R_{sense}) * I_{OUT} + V_{OUT}$

Considering the ripple effects, the previous V_{IN} min should be considered as the minimum peak of the input voltage.

If a high dropout voltage is required by design, it is possible to use a higher R_{DSon} external Power MOSFET, decreasing the overall cost. In this case the maximum

R_{DSon} is given by:

$R_{DSon}\ max = (V_{IN}\ min - V_{OUT} - R_{sense} * I_{OUT})/I_{OUT}$

If high dropout voltage is used, we have to consider the power dissipated on an external Power MOSFET, especially at high load current.

We have:

$P_Dmax = (V_{IN}\ max - V_{OUT} - R_{sense} * I_{OUT}) * I_{OUT}$

With a Tjmax = 150°C, the sum of the thermal resistances is given by:

$\Sigma R\theta$ = (Tjmax-Tamb)/P_{Dmax} =
= (150-T_{amb})/P_D,
with $\Sigma R\theta = R\theta jc + R\theta cs + R\theta sa$ where:

$R\theta jc$ = thermal resistance from junction of semiconductor to case, usually stated by the manufacturer (for TO-220 is about 3.0°C/Watt).

$R\theta cs$ = thermal resistance from the semiconductor to the mounting surface (comprehensive of mounting screw torque and thermal resistance of isolator, if present).

$R\theta sa$ = thermal resistance of heat sink.

The foldback current limitation allows a limitation of the power dissipation in a short-circuit condition.

The capability of the driver to withstand voltage up to 60V allows the implement voltage regulator with output voltage higher than 50V. It is important that the wiring of the output voltage sensing resistor is done correctly for a better load regulation (use a Kelvin connection).

Figure 5.

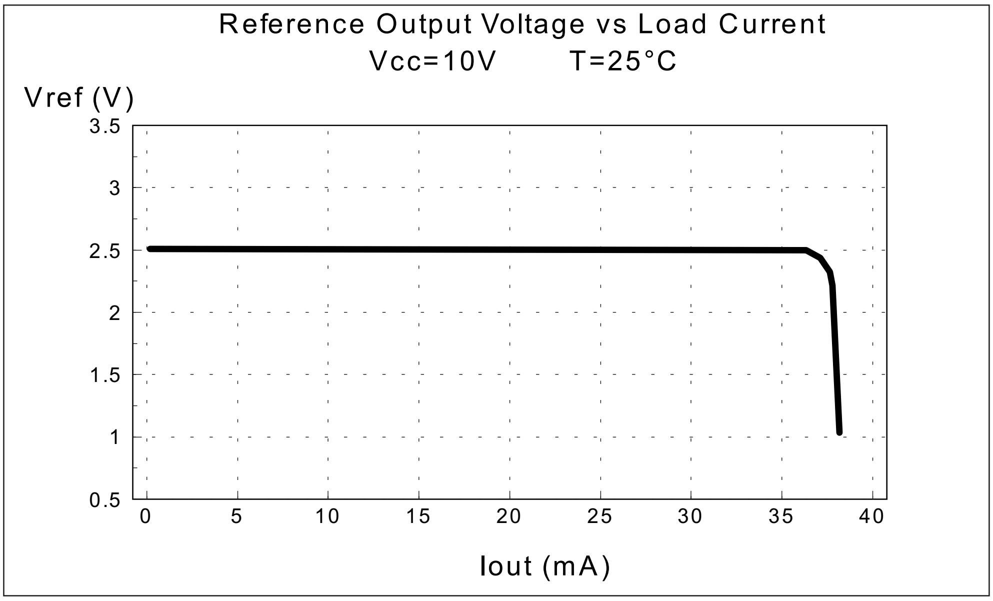
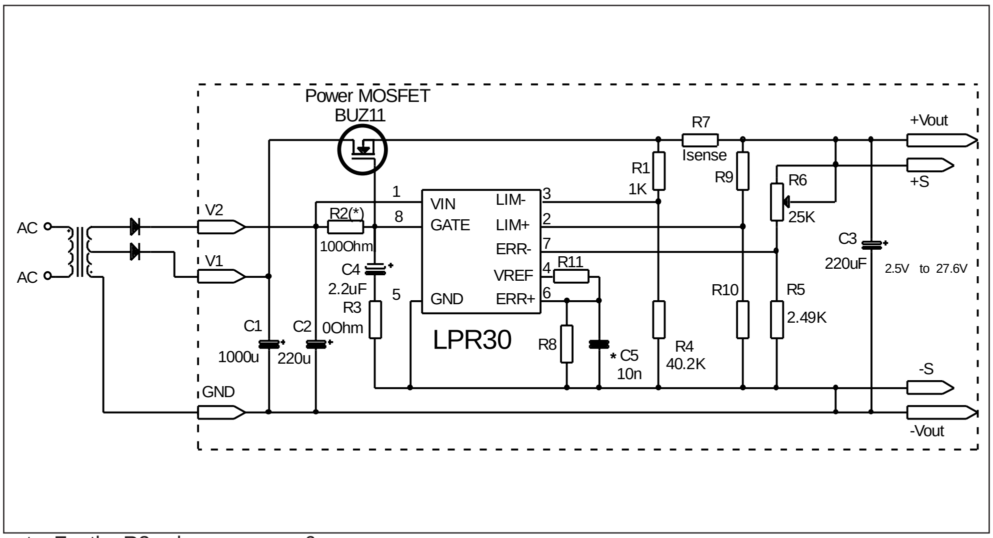


Figure 6. Schematic of variable voltage regulator



note: For the R2 value, see page 6.

The inputs of the current limiter accept signals ranging from GND to V_{cc} - 3V for the best linearity.The inputs of error amplifier accept signals ranging from 1V to V_{cc} - 1V for the best linearity. The device is not internally compensated, and so an external network must be provided (see fig. 6).

The high stability of the Vref block allows it to be connected directly to the input of the error amplifier because no oscillation occurs. The V_{REF} block can be loaded up to 30mA (guaranteed 20mA by datasheet; see fig. 5, V_{REF} voltage vs Output Current).

7. APPLICATION CIRCUIT

Fig. 6 represents the schematic of a variable voltage regulator. Fig. 7 and 8 represent respectively the component side and the solder side of the demo board LPR30, based on the schematic of fig. 6.

If a V_{OUT} > 2.5V is required, resistors R8 and R11 and capacitor C5 can be omitted and pin 4 and 6 of the IC are connected together.

Capacitor C5 can be left only for noise reduction improvement. In order to allow the complete Power MOSFET driving, V2 must be greater than $V_{OUT}+V_{GSsat}$.

If V1 is foreseen as greater than $V_{OUT}+V_{GSsat}$, it is possible to use a single supply, connecting V1 and V2 together.

The use of logic level Power MOSFET (such us STB80N03L-06) allows a lowering of the V2 voltage.

V_{IN} (of LPR30) must be less than 30V. If the V_{OUT} is foreseen as less than 30V, R9 and R10 can be omitted and pin 2 of IC can be connected directly to the R7 resistor (V_{OUT} side).

The power dissipated at point A is:

$$P_{DA} = (V_{IN} - V_{OUT} - R_{sense} * I_{max}) * I_{max}$$

While the power dissipated at point B is

$$P_{DB} = (V_{IN} - R_{sense} * I_{sc}) * I_{sc} \cong V_{IN} * I_{sc}$$

In the operating mode it is good choice to impose

$P_{DB} \leqslant P_{DA}$ to avoid a larger heatsink dimensioning in short circuit condition.

If we let $P_{DA} = P_{DB}$, we obtain:

$$I_{sc} = (V_{IN} - V_{OUT} - R_{sense} * I_{max}) * I_{max}/V_{IN}$$

Figure 7. Component side of LPR30 demo board

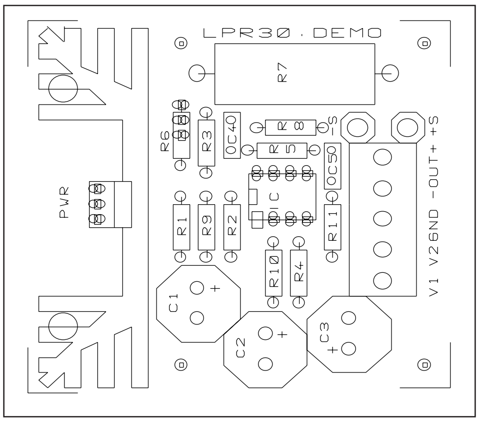


Figure 8. Solder side of LPR30 demo board

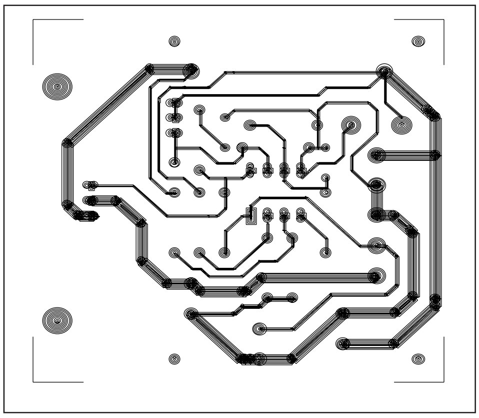
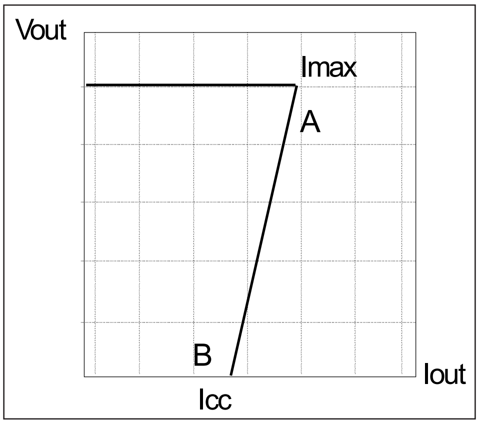


Figure 9. Foldback Limitation Characteristic



In some applications it is not possible to impose $P_{DB} \leqslant P_{DA}$ because a high ratio I_{max}/I_{sc} implies an higher drop on the R_{sense}. In fact :

$$R_{sense} * I_{sc} = 50 * 10^{-3} * \frac{R1 + R4}{R4} > 50mV$$

$R_{sense} > 50mV / I_{sc}$ and then

$$R_{sense} * I_{max} = V_{sense} > 50mV * (I_{max} / I_{sc})$$

So the starting point to determine all the components to be used is to impose the dissipation in short circuit condition :

$$P_{D\text{-}B} = (V_{IN} - R_{sense} * I_{sc}) * I_{sc} \cong V_{IN} * I_{sc}$$

$$> V_{IN} * 50mV * I_{max}/V_{sense}$$

and then

1) $V_{sense} > 50mV * [(V_{IN} * I_{max}) / P_{D\text{-}B}]$

2) $R_{sense} = V_{sense} / I_{max}$

3) $R_{ONmax} \leqslant [(V_{drop} - V_{sense}) / I_{max}]$ and so the PowerMOSFET.

4) Now we can calculate the R1 and R4 resistors.

$$(R1/R4) = \frac{V_{OUT} + V_{sense}}{V_{OUT} + 50mV} - 1$$

and so imposing the R1 we can determine the R4.

5) $I_{sc} = (50mV / R_{sense}) * [(R1+R4)/ R4]$

6) To determine the R9 and R10 at point A we have:

R10/(R9+R10)=

$$((V_{OUT} + R_{sense} * I_{max}) *$$

$$* R4/(R1 + R4) - 50 * 10^{-3})/V_{OUT} \cong$$

$$\cong (V_{OUT} * R4/(R1 + R4) - 50 * 10^{-3})/V_{OUT} \cong$$

$$\cong R4/(R1 + R4).$$

It follows: R9/R10 = R1/R4 and imposing R9 we can easily determine R10: R10 = (R9 * R4)/R1

If V_{OUT} is greater than 30V, the R9/R10 ratio is imposed by the necessity to limit at maximum 30V at pin 2 of the IC.

Figure 10.

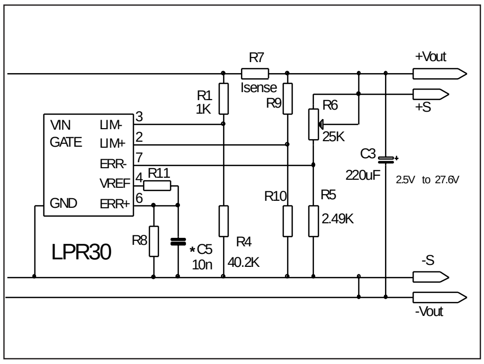
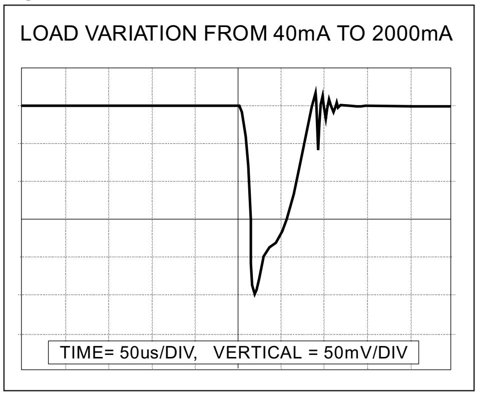


Figure 11.



Resistors R8-R11 and R6-R5 must be chosen to give the same voltage at pins 6-7 of the IC. So we have: $2.5 * R8/(R8+R11) = V_{OUT} * R5/(R5+R6)$.

With R11= 0Ohm the above expression gives:

$$V_{OUT} = 2.5 * (R5 + R6)/R6$$

Fig. 12 and 13 reports the behaviour of Current limiting for I_{OUT} = 1.5A and for Output shorted respectively.

8. HOW TO INCREASE THE RESPONSE SPEED

The response of the IC is very fast, but the total response is limited by the compensation network R2, R3 and C4, that limits the voltage rise-time at the gate of the external Power MOSFET. Better stability performances are given with R3 = 0Ohm and C4=2.2uF electrolitic capacitor. With imposed C4, the response time is determined from the R2 value.

Figure 12.

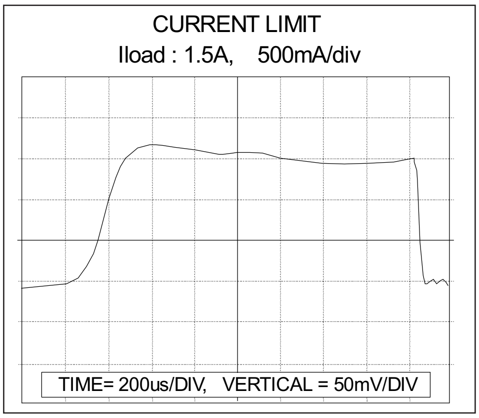


Figure 13.

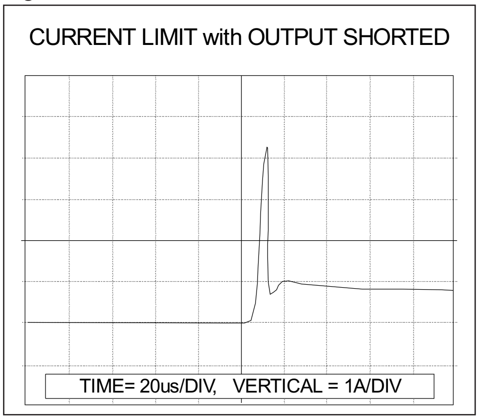
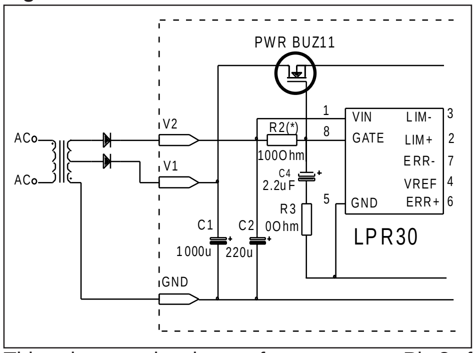


Figure 15.



This value must be chosen for a current on Pin 8 of the LPR30 not higher than 100mA.

With V2 = 12V , we suggest an R2 value of 100 Ohm. In this case, in a static condition, I_{R2} = VR2/R2 =~ (V2-V_{GS}-V_{OUT})/R2. The I_{R2} reaches the maximum value in a short circuit condition, when V_{OUT} = 0V and V_{GS} is minimum (near the threshold).

With the indicated values and V_{OUT} = 5V, I_{R2} is 20mA in normal conditions and becomes 100mA in short circuit conditions.

Maximum Power dissipated on R2 is

$P_{R2} = R2 * (I_{R2MAX})^2 = 1W$ with indicated values.

If V2 is higher than 12V, the power dissipated on R2 could be high. In this case the use of a small NPN transistor would solve the problem (see figure13).

This transistor (BC337) will work only during the transition of the load, reducing the total reaction speed, but in a static situation it will be off opening the connection to Ground, so the resistor R5 will not dissipate any power.

Figure 14.

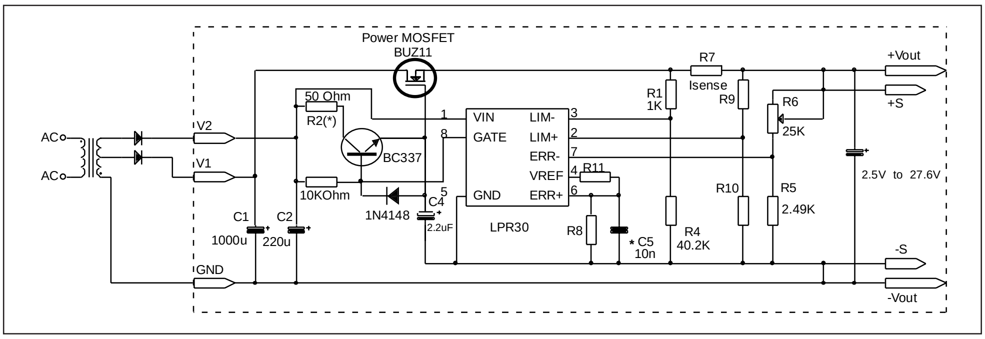
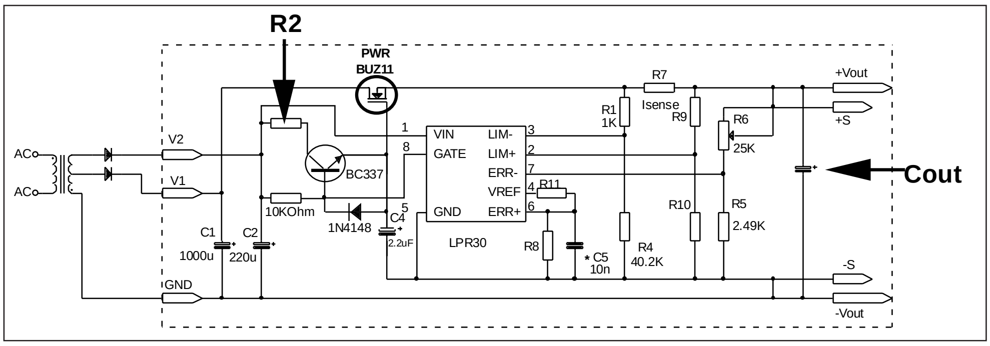


Figure 16. Schematic of variable voltage regulator



For this reason it is possible to reduce the Resistor value from 100Ohm to 50Ohm again improving the total response speed without sacrificing any power. The following diagrams show the different behaviour of the demo board configured to supply a $V_{OUT} = 5V$ with a max supply current up to $I_{OUT} = 7A$.

Taking the above schematic into consideration, here below are two diagrams showing the Load Regulation when the load passes from 0A to 4A in only one step; the good performance of the second case is obtained with a capacitor on the output of 1000uF.

Figure 17.

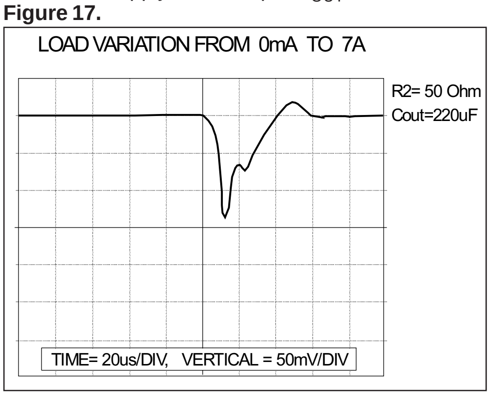


Figure 19.

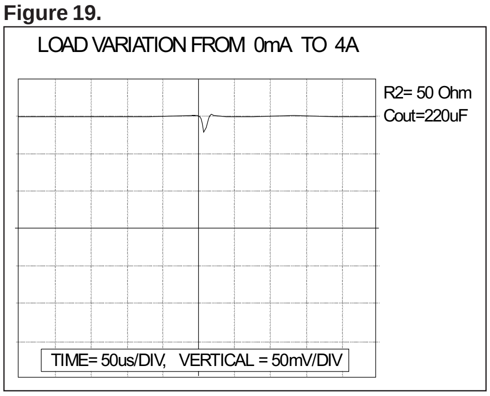


Figure 18.

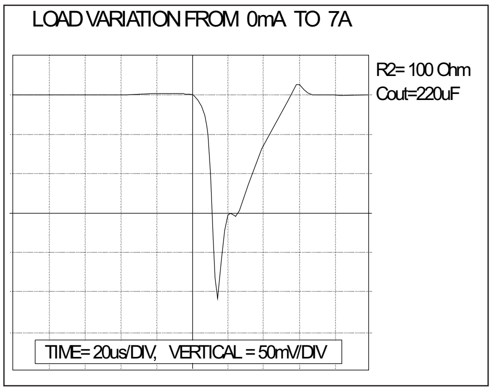


Figure 20.

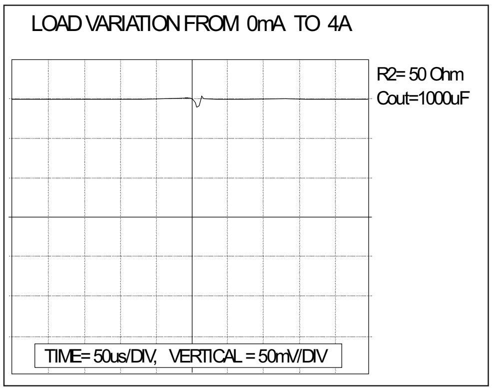
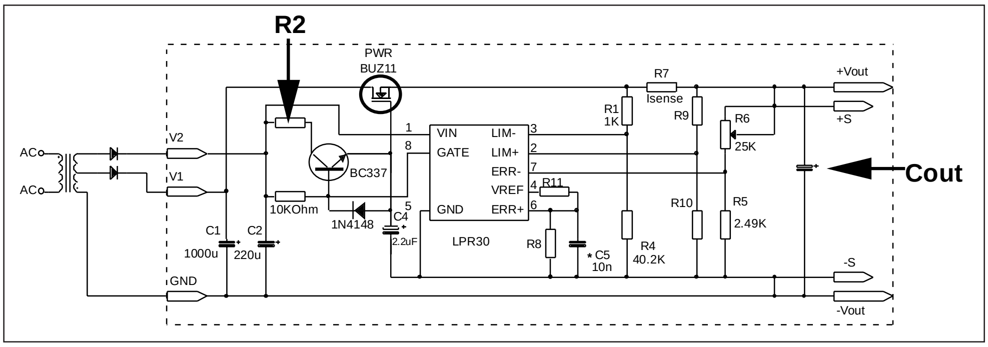


Figure 21. Schematic of variable voltage regulator



The following waveforms were made considering a change from 0A to max load of 5A and 6A respectively.

The two waveforms below pass from 0.2A to the max load of 7A. Generally, if you start from a small load > 0A to a max load, the transient is always faster than if you start from 0A.

Figure 22.

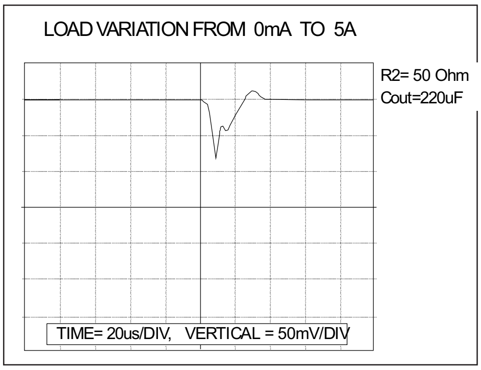


Figure 24.

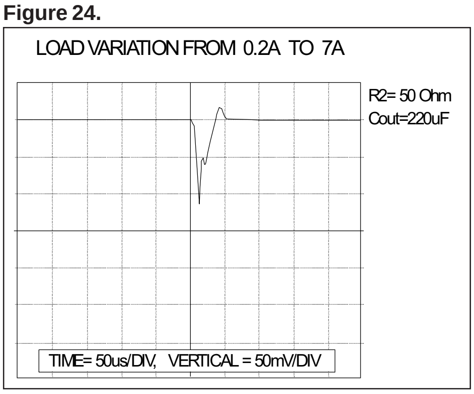


Figure 23.

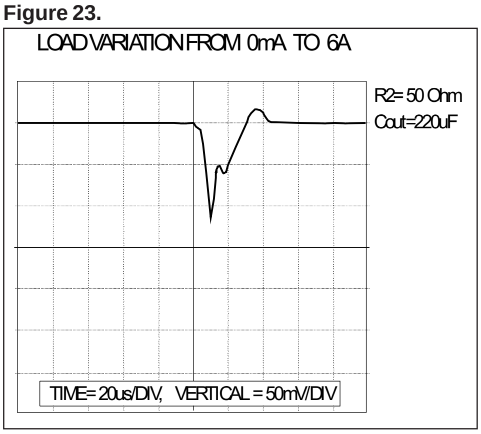
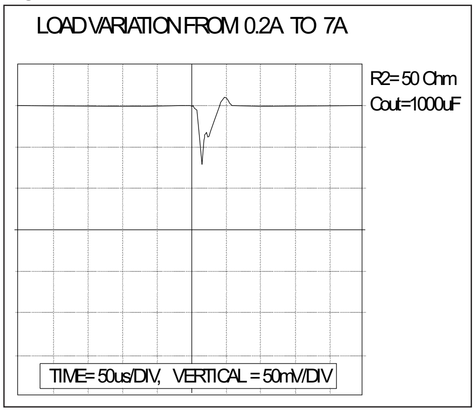


Figure 25.



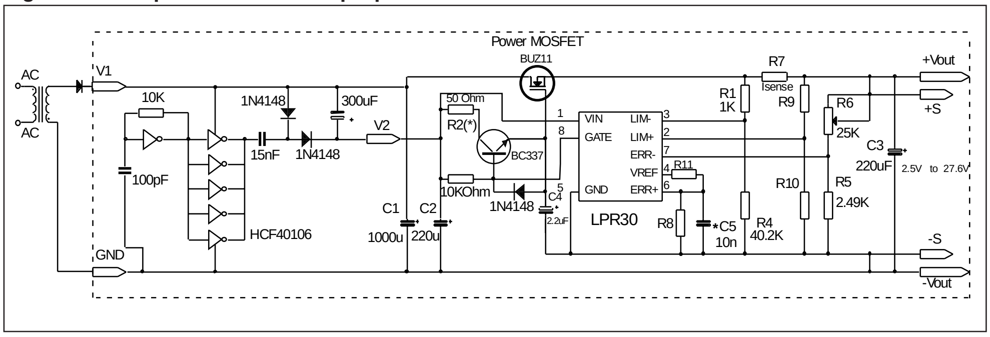
9. USE OF A SINGLE SUPPLY

Numerous applications require a single supply (e.g. Automotive). In this case it is necessary to generate the V2 voltage greater than that of V1 one.

A very simple way to obtain it is by using a charge pump, built around the single logic CMOS device HCF 40106; in this case the Max value of V1 < 18V is due to the fact that the max Vcc of the logic CMOS4000B is just 18V.

Figure 26 gives the complete schematic of the proposed circuit. The charge pump does not allow great output current, and it could be very useful to use a transistor buffer for R2 (as was proposed in figure 15) .

Figure 26. Complete schematic of proposed circuit



LPR30 APPLICATION EXAMPLES

The following practical examples are given to show how to choose the various component values in particular applications using the LPR30.

1) EXAMPLE N° 1

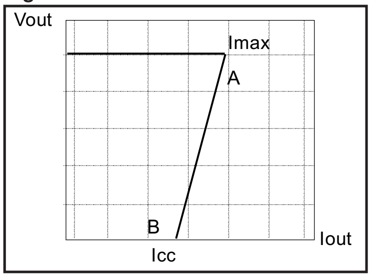
$V_{IN} = 5V$ $V_{OUT} = 3.3V$ $I_{LOAD} = 5A$

1) If we choose $I_{MAX} \cong 1.2\ I_{LOAD}$

we obtain $I_{MAX} = 6A$

2) We can now determine the power dissipated at point A (see figure 1 below);

Figure 1. Foldback limitation characteristic



then

$P_{DA} = (V_{IN} - V_{OUT} - R_{SENSE} * I_{MAX}) * I_{MAX}$

$P_{DA} \cong (V_{IN} - V_{OUT}) * I_{MAX} = (5 - 3.3) * 6 = 10.2W$

3) Setting $P_{DA} = P_{DB}$, we can choose an

$I_{SC} = P_{DB} / V_{IN} = P_{DA} / V_{IN} = 10.2 / 5 = 2.04A$

4) So, if we consider the current limit comparator clamps the output current at a level that imposes 50 mV at its inputs, we could calculate the Resistance R_{SENSE} in the following way :

$R_{SENSE} = (50 * 10^{-3}) / I_{SENSE} = (50 * 10^{-3}) / 2 =$

$= 0.025Ohm = 25mOhm$

5) We can now determine that $V_{SENSE} =$

$I_{MAX} * R_{SENSE} = 6 * 25 * 10^{-3} = 0.15V = 150mV$

6) To determine the partitor resistors R_1 and R_4 we consider the following ratio (see page 3 for more details):

$$(R1/R4) = \frac{V_{OUT} + V_{SENSE}}{V_{OUT} + 50mV} - 1$$

Then

$R1 / R4 = [(V_{OUT} + V_{SENSE}) / (V_{OUT} + 50mV)] - 1 =$

$= [(3.3 + 0.15) / (3.3 + 0.05)] - 1 =$

$= (3.45 / 3.35) - 1$

$= 0.0298$

Setting R1 = 1KOhm we obtain

R4 = 1 / 0.0298 $\cong$ 33KOhm

How to choose the values of R1 and R4:

a) Too low a value for R1 and R4 implies an excessive dissipation of current.

b) Too high a value implies a high impedance at the input of the current limit comparator

(pin 3 of LPR30)

It is a good choice to impose R1 in the range from 500Ohm to 2.5KOhm

When $V_{OUT} \leqslant 30V$ it is possible to omit the two resistors R9 and R10. Therefore, R9 = 0 (short circuit) and R10 is not connected (open circuit).

If V_{OUT} **>** 2.5V**,** we are permitted to omit even the R11, R8 and C5. We then have to connect pin 4 and pin 6 of the LPR30 (R11 = 0, short circuit).

7) To determine the partitor resistor R5 and R6**,** we must consider that :

$V_{OUT} = V_{REF} * [(R5 + R6) / R6]$

(see page 3) and consequently:

$R5 / R6 = (V_{OUT} / 2.5) - 1 = (3.3 / 2.5) - 1 =$

$= 0.32V.$

Then $R6 = R5 / 0.32$

Choosing the appropriate commercial values, we obtain :

R5 = 1.5KOhm and R6 = R5 / 0.32 = 4.7KOhm.

How to choose the values of R5 and R6:

a) Too low a value of R5 and R6 implies an excessive dissipation of current.

b) Too high a value implies an high impedance at the input of the Error Amplifier (pin 7 of LPR30)

It is a good choice to impose R5 in the range from 500Ohm to 2.5KOhm.

8) At this point we can determine the maximum value of the external Power MOSFET's resistance

($R_{DSON\ MAX}$) to utilise. The calculation is developed in the following way:

$R_{DSON\ MAX} \leqslant (V_{IN} - V_{OUT} - V_{SENSE}) / I_{MAX} =$

$= (5 - 3.3 - 0.15) / 6 \cong 260mOhm$

9) Concerning the Power Mosfet HEAT SINK, if we consider Tjmax = 150°C , the total thermal resistance is given by:

$\Sigma SR\theta_q = (Tjmax - Tjamb) / P_D = (150° - 40°) / 10.2 = 10.7°C/W$

Supposing that Rqjc is about 3.0°C/W and Rcs =1°C / W, we obtain

$\Sigma SR\theta_{qSa} = \Sigma SR\theta_q - R\theta_{qjc} - R\theta_{qcs} = 10.7 - 3 - 1 = = 6.7C°/W.$

$R\theta_{qjc}$ = thermal resistance from the junction of the semiconductor to the case, usually stated by the manufacturer (for the TO-220 CASE it is about 3.0°C/ Watt).

$R\theta_{qcs}$= thermal resistance from the semiconductor to the mounting surface (comprehensive of screw torque and thermal resistance of isolator, if present)

$R\theta_{qsa}$ **=** thermal resistance of the heat sink.

2) EXAMPLE N°2

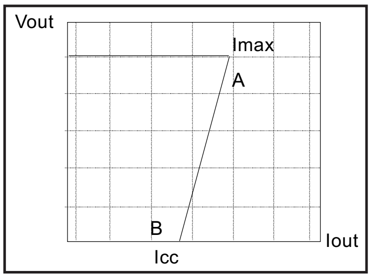
V_{IN} variable from 3.2V to 3.4V, V_{OUT} =

= 2.7V I_{LOAD} = 5A

1) Supposing that

$I_{MAX} \cong 1.2\ I_{LOAD}$, we obtain I_{MAX} = 6A.

Figure 2. Foldback limitation characteristic



In this case the regulator must work with a very low drop, and for this reason it is necessary to minimise the V_{SENSE}.

It is possible to accept a P_{DB} = 8W (depending on the heat sink that has been used).

2) Determine the V_{SENSE}.

$V_{SENSE} > 50 * 10^{-3} * [(V_{IN\ (MAX)} * I_{MAX}) / P_{DB}]$

[see page 3, point 1] it follows

$V_{SENSE} > 50 * 10^{-3} * [(3.4 * 6)] / 8] =$

$= 127.\ 5 * 10^{-3}$

then V_{SENSE} > 128mV

3) Now we consider the relationship existing among the different parameters.

$50mV / V_{SENSE} = I_{SC} / I_{MAX}$

4) We can then calculate $R_{SENSE} = V_{SENSE} / I_{MAX}$

$= (150 * 10^{-3}) / 6 = 25mOhm$

[see page 3, point 2] then R_{SENSE} = 25Ohm

5) To determine the two resistors R1 and R4,we proceed as in previous example.

$R1 / R4 = [(V_{OUT} + V_{SENSE}) / (V_{OUT} + 50mV)] - 1 =$

$= [(2.7 + 0.15) / (2.7 + 0.05)] - 1 =$

$= (3.45 / 3.35) - 1 = 0.0363$

Imposing R1 = 1KOhm we obtain

$R4 = 1 / 0.0363 \cong 27KOhm$

6)The R_{DSON} max of the Power MOSFET is given by:

$R_{DSON} \max = (V_{MIN} - V_{OUT} - V_{SENSE}) / I_{MAX} =$

$= (3.2 - 2.7 - 0.15) / 6 =$

$= 58mOhm$

7) Of course, in the case that $V_{OUT} \leqslant 30V$, it is possible to omit the two resistors R9 and R10. We will then consider that R9 = 0 (short circuit) and that R10 is not connected (open circuit).

Given that the $V_{OUT} > 2.5V$, we can even omit the R11, R8 and C5.

We then have to connect pin 4 and pin 6 of the LPR30 (R11 = 0, short circuit).

3) EXAMPLE N°3

V_{IN} variable from 50V to 60V, V_{OUT} = 1V to 50V (adjustable)

This is a typical example of a Power Supply for a laboratory.

If the V_{OUT} min = 1V, it is necessary to impose 1V on the pin 6 of the LPR30.

So $[R8 / (R8 + R11)] * V_{REF} = 1V$ then

$R8 * V_{REF} = R8 + R11$

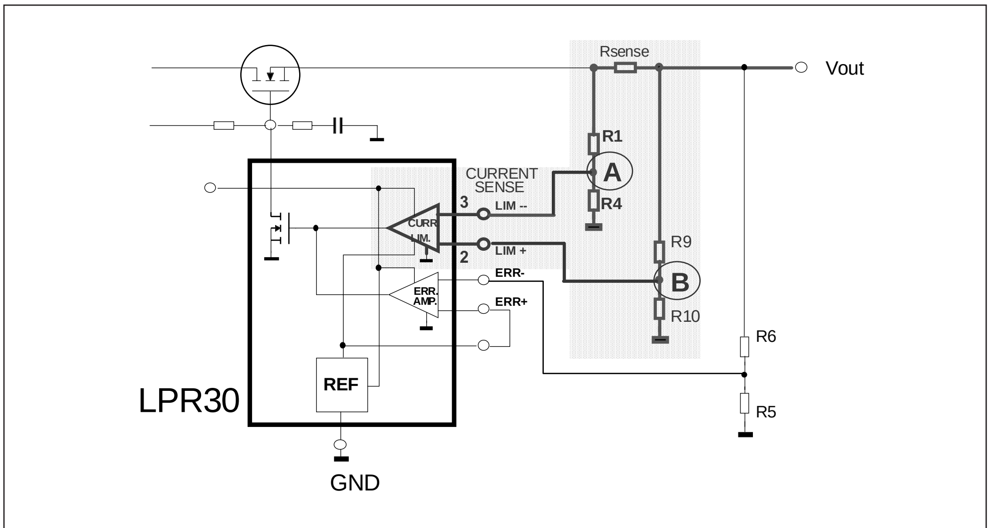
and then

$R11 / R8 = V_{REF} - 1 = 2.5 - 1 = 1.5 V$

Imposing R8=1KOhm , it follows that R11 = 1.5KOhm

If we impose V_{SENSE} = 150mV, it follows that

Figure 3.



$I_{SC} = (50mV / V_{SENSE}) * I_{MAX} =$

$= (50 * 10^{-3}) / (128 * 10^{-3}) * 6 =$

$= 2.34A$

1) In this case the V_{OUT} is greater than 30V, so we must use the two resistors R9 and R10 to prevent the destruction of the IC.

Considering that the voltage at pin 2 of LPR 30 must be lower than 30V (remember that even $V2 \leqslant 30V$) and the MAX $V_{OUT} = 50V$, then we will have :

$50 * [(R10 / (R9+ R10)] \leqslant 30V$ then

$(50/30) \leqslant (R9 / R10) + 1$ then

$R9 / R10 \geqslant (50/30) - 1 = 0.67$

This ratio has a value of 0.67 and consequently

$R9 \geqslant 0.67 R10$

2) We must make the same consideration that we made for point 1) even for the ratio R1 / R4 (see page 4); then we will have R1 / R4 = R9 / R10 and consequently even $R1 \geqslant 0.67 R4$

Now taking the following circuit into consideration :

$V_A = (V_{OUT} + V_{SENSE}) * [R4 / (R1 + R4)] =$

$V_{OUT} * [R4 / (R1 + R4)] + V_{SENSE} * [R4 /(R1 + R4)]$

$V_B= V_{OUT} * [R10 / (R9 + R10)] =$

$= V_{OUT} * [R4 / (R1 + R4)]$

remembering that the ratio R1 / R4 = R9 / R10
it follows that:

$(R1/ R4) + 1 = (R9/R10) + 1$ then

$R4 / (R1 + R4) = R10 / (R9 + R10)$ then

$V_{AB} = 50mV = V_{OUT} * [R4 / (R1 + R4)] +$

$V_{SENSE} * [R4 /(R1 + R_4)] - V_{OUT} * [R4 / (R1 + R4)]$

to conclude $50mV = V_{SENSE} * [R4 /(R1 + R4)]$ and then

$R1 / R4 = (V_{SENSE} / 50mV) -1$

using the previous equations, it follows that :

$(V_{SENSE} / 50mV) - 1 \geqslant 0.67$ then

$V_{SENSE} \geqslant (0.67 + 1) * 0.05$ so

$V_{SENSE} \geqslant 83.5mV$

We now make the same suppositions that we have made in the previous examples.

If we consider the relationship existing among the following parameters:

$50mV / V_{SENSE} = I_{SC} / I_{MAX}$ then

$I_{MAX} / I_{SC} \geqslant 83.5 / 50 = 1.67.$

It is now possible to assign $I_{MAX} = 2 I_{SC}$ and it follows that:

$V_{SENSE} = (I_{MAX} / I_{SC}) * 50mV = 100mV$

3) The ratio R1 / R4 =

$= (V_{SENSE} / 50mV) -1 =$

$= (100mV / 50mV) -1 =$

$= 1$

In this way we obtain R1 = R4, and remembering the existing ratio between R1 / R4 and R9 / R10 it is possible to conclude that R1 = R4 = R9 = R10.

We could choose R1 = 3.3KOhm (1/2W) and the same for R4, R9, R10.

4) Of course the choice of R_{SENSE} choice depends on I_{MAX}. In fact, if $I_{MAX} = 1A$

$R_{SENSE} = V_{SENSE} / I_{MAX} = 100mV / 1A =$

$= 100$ mOhm

5) Setting the two conditions:

a) when R6 min = 0Ohm we have V_{OUT} min = 1V

and

b) when R6 is at maximum value (R6 max) the V_{OUT} max = 50V we will have

$$V_{OUT} * [R5 / (R5 + R6\ MAX)] =$$

$$V_{PIN6} = 1V$$

due to the fact that the voltage available on pin 6 of the LPR30 is always 1V.

Considering the previous relationship existing between the two resistors, it follows that:

R6 MAX = 49 R5

Considering the previous relationship existing between the two resistors, it follows that:

R6 MAX = 49 R5

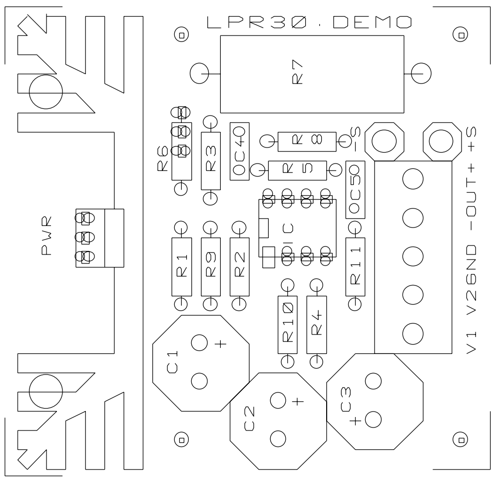
So setting R5 = 1KOhm the value of R6 MAX will be 49KOhm, in which case we can utilise a commercial trimmer resistor of 50KOhm such as R6.

CONCLUSION

This paper gives practical information to help numerous applications using this Linear Voltage Regulator, especially in fields such as high V_{OUT} values or high current/low dropout - where conventional regulators cannot be used.

The use of the existing LPR30 DEMO-BOARD allows the development of the final product.

Figure 4. LPR30 Demo Board



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