Power Supply Design Using WEBENCH

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November 6, 2003

The Goal of WEBENCH.NATIONAL.COM

Create a highly productive design experience that saves our customers time.

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Before we created our web site, we defined our goal. In all of our development, we have kept this idea as our driving force: save our customers time.

Customers' Design Expertise and Time Goes Into the Main Board

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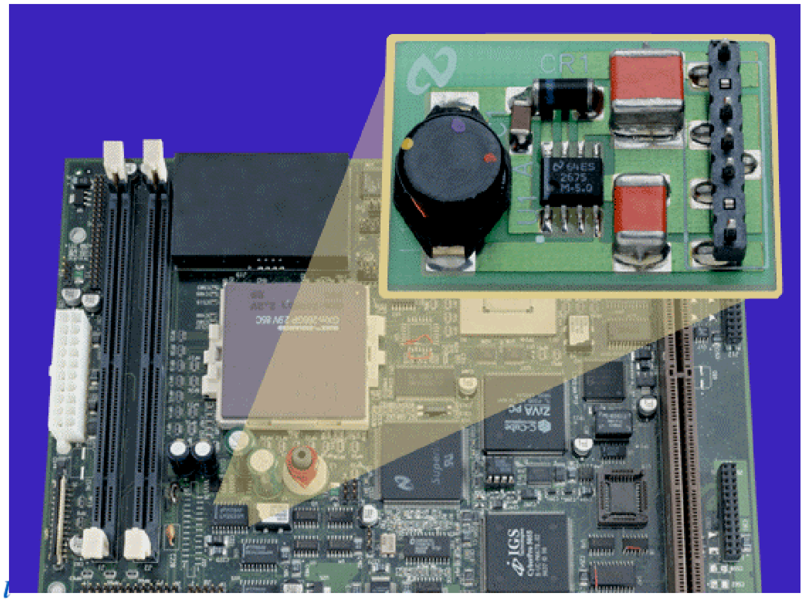
Customers put their time and effort into the main board, and typically do not want to spend a lot of time designing a proprietary power supply circuit.

Objective: Get to This as Quickly as Possible



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At POWER.NATIONAL.COM, National can provide the customer with a plug-in power supply design which is customized to the specifications of the customer's design.

WEBENCH™ Design Environment

- **On-line design and prototyping**
  - **Selection and calculation of passive components**
  - **Real time electrical simulation**
  - **WebTHERM™ board level thermal simulation**
  - **Order custom prototype power supply kits online**

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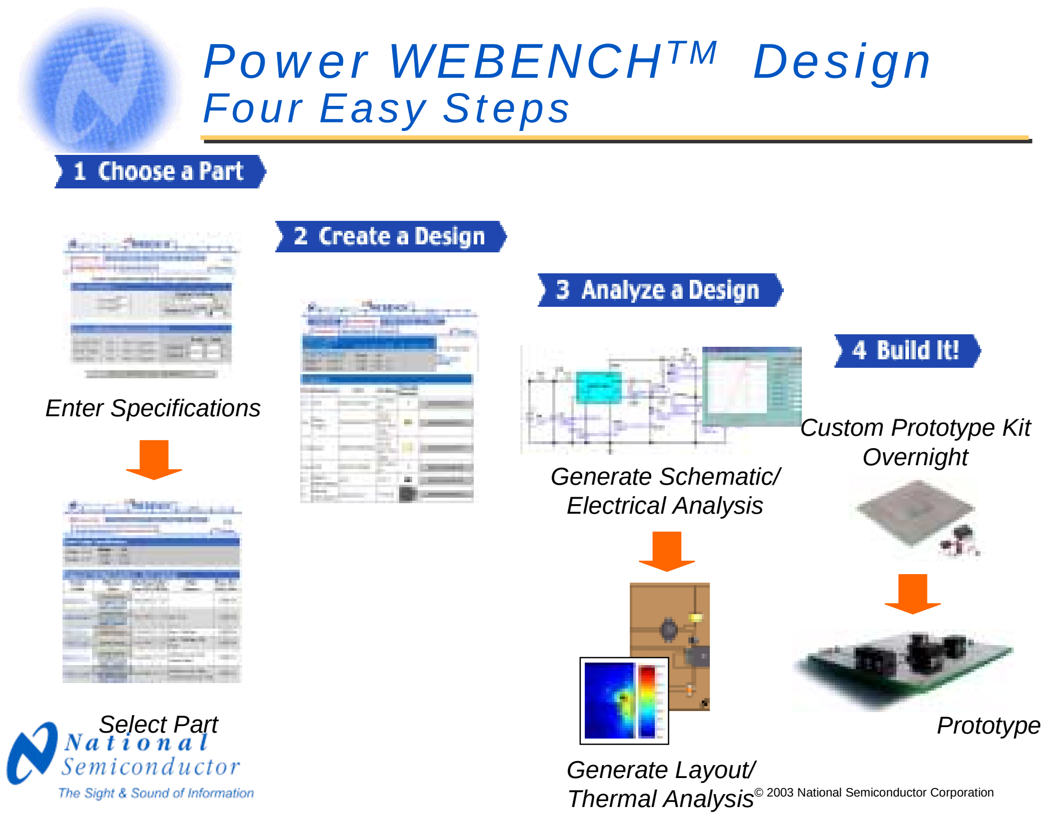
WEBENCH™ design tools are National's exciting on-line environment which saves our customers time in the design process


Power WEBENCH™ Design
Four Easy Steps
1 Choose a Part
Enter Specifications
Select Part
2 Create a Design
3 Analyze a Design
Generate Schematic/
Electrical Analysis
Generate Layout/
Thermal Analysis
4 Build It!
Custom Prototype Kit
Overnight
Prototype
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Available WEBENCH Devices: Switchers

Device	Electrical Sim	Circuit Calculator	WebTHERM	Build It
LM2670,3,7,8,9	X	X	X	X
LM2671,2,4,5	X	X		
LM2595,6,8,9	X	X	X	X
LM2694,7,(+HV)	X	X		
LM2574,5,6, (+HV)	X			
LM2651,3	X			
LM2585,6,7,8, LM2577 Boost	X	X	X	X
LM2585,6,7,8, LM2577 Flyback	X	X		
LM2621 SEPIC, Boost	X			
LM3478/88 Boost	X			
LM2645	X			
LM5007 NEW	X			
LM5000 NEW	X			

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Different devices have different features enabled in WEBENCH. One of these features is the Circuit Calculator which determines the passive components for the design. If a device does not have a circuit calculator, a reference design will be created and the user will need to adjust the component to match the specific design requirements.

Available WEBENCH devices: LDOs, Switched Capacitors

- **Low Drop-out Linear Regulators**
  - **Bipolar LDO: LP2978, LP2980, LP2981, LP2982, LP2985, LP2986, LP2987, LP2988,**
  - **Quasi-LDO: LM3480, LM3490**
- **Switched-Capacitor Converters**
  - **LM2660, LM2661, LM2662, LM2663, LM2664, LM2665, LM2681 (Doublers/Inverters)**
  - **LM3350, LM3351 (Fractional Converters 2/3 - 3/2)**

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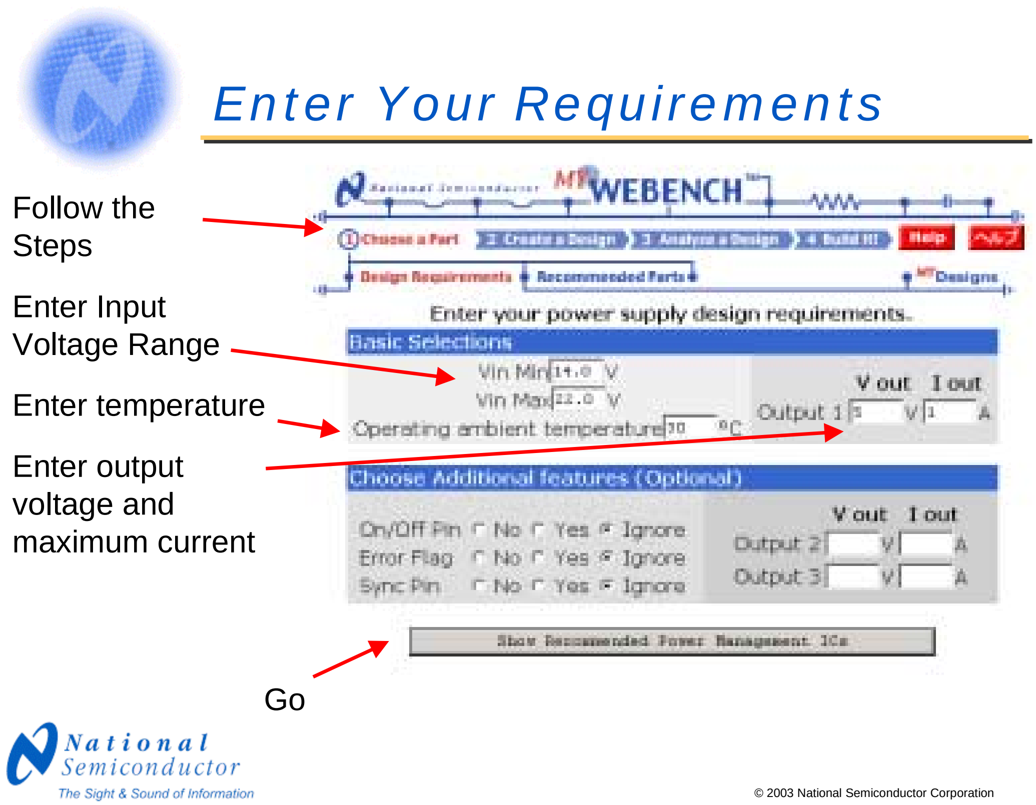
These devices are enabled for electrical simulation and they use reference designs.



Now we will create a power supply design using power WEBENCH™.

On the very top of each screen in WEBENCH is a set of 4 buttons which tell the user which step the design process is in. These steps are:

Choose a Part,

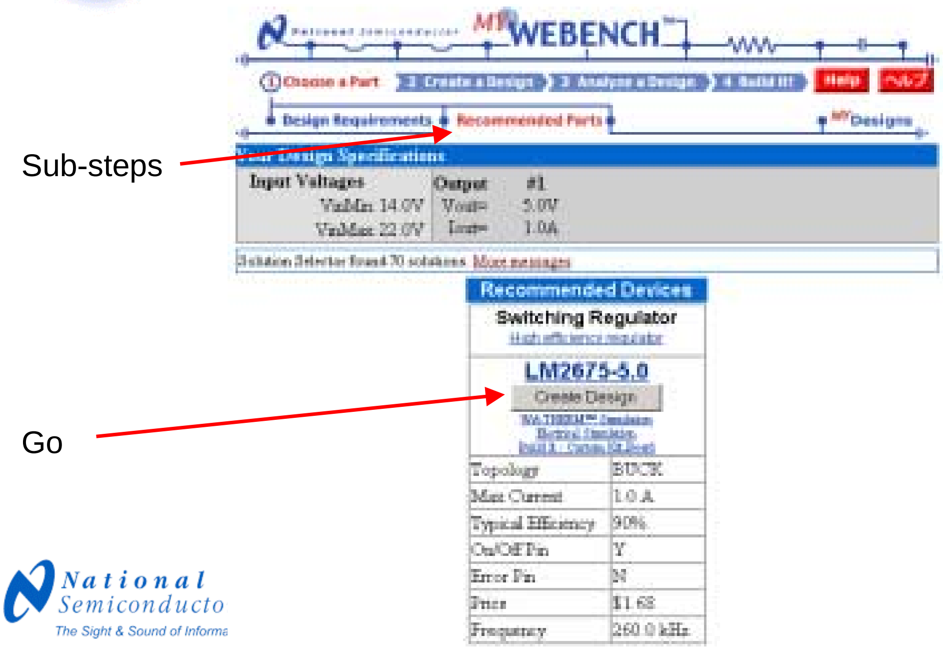
Create a Design,

Analyze a Design

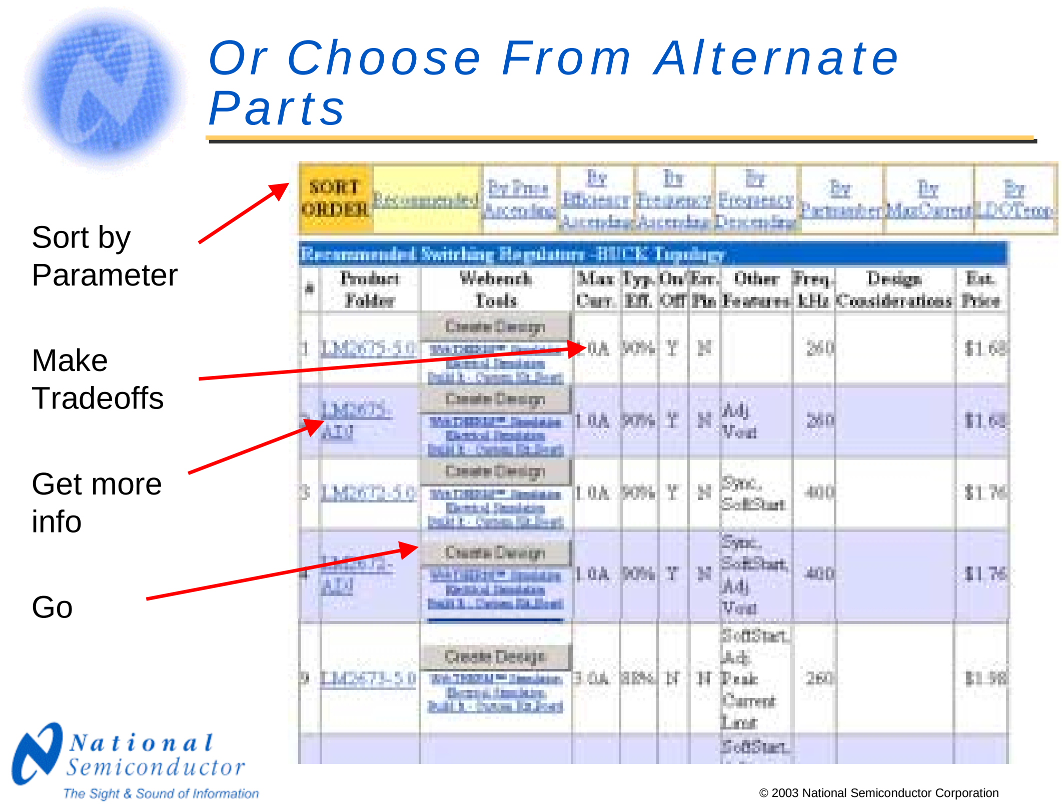
Build It.

The first step is to enter the power supply design requirements in the Choose a Part screen. Simply enter the range for the input voltage (Vin), the desired output voltage and the output current. After entering the design specifications, press the button at the bottom of the screen to “Show Recommended Power Management ICs.”

Show Recommended Parts



On the “Recommended Parts” page, the recommended devices are shown at the top of the page. This may include a switching regulator, a linear regulator/LDO and/or a switched capacitor converter. If the recommended part is enabled for WEBENCH™, there will be a “create design” button below the part number. Clicking on that button will put you into the WEBENCH™ design environment.



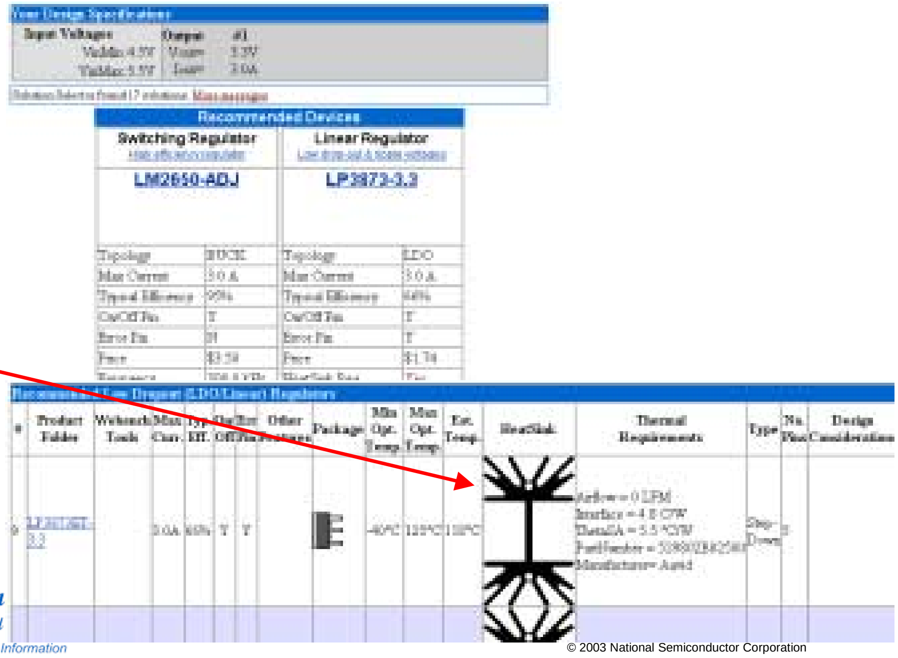
Below the recommended parts is a sortable list of alternate devices which includes all Power Management products which address your power supply requirements. A number of useful parameters are displayed including efficiency and price which help you select the best part to meet your needs. Clicking on a sort link will re order the list based on parameters such as price, efficiency or frequency. If you desire more information about a device you can go to the device Product Folder, using the link in the left column of the display. Text indicators below the Create Design buttons show whether the device is enabled for electrical simulation or WebTHERM™ simulation, meaning it can be simulated thermally. If the text indicator says “Build It Custom Kit”, a custom prototype kit is available in the “Build It” step.

If you decide to use one of the alternate selections, click on the “Create Design” button next to the part name to have WEBENCH™ create your design in your personal workspace.

WEBENCH™ 4.0 Design – Vast Solution Selector

More than 500 new parts added to Solution Selector

LDO selection includes temperature constraints and thermal requirements



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The WEBENCH™ 4.0 design environment includes an upgraded solution selector which now includes over 500 new parts. Parts are listed even if they are not included in WEBENCH in order to give the widest possible selection. The selection criteria for LDOs (low dropout regulators) includes a thermal calculator which takes into account temperature constraints. If necessary, a heat sink, thermal grease and forced airflow will be recommended.

In this case, we've entered design parameters of:

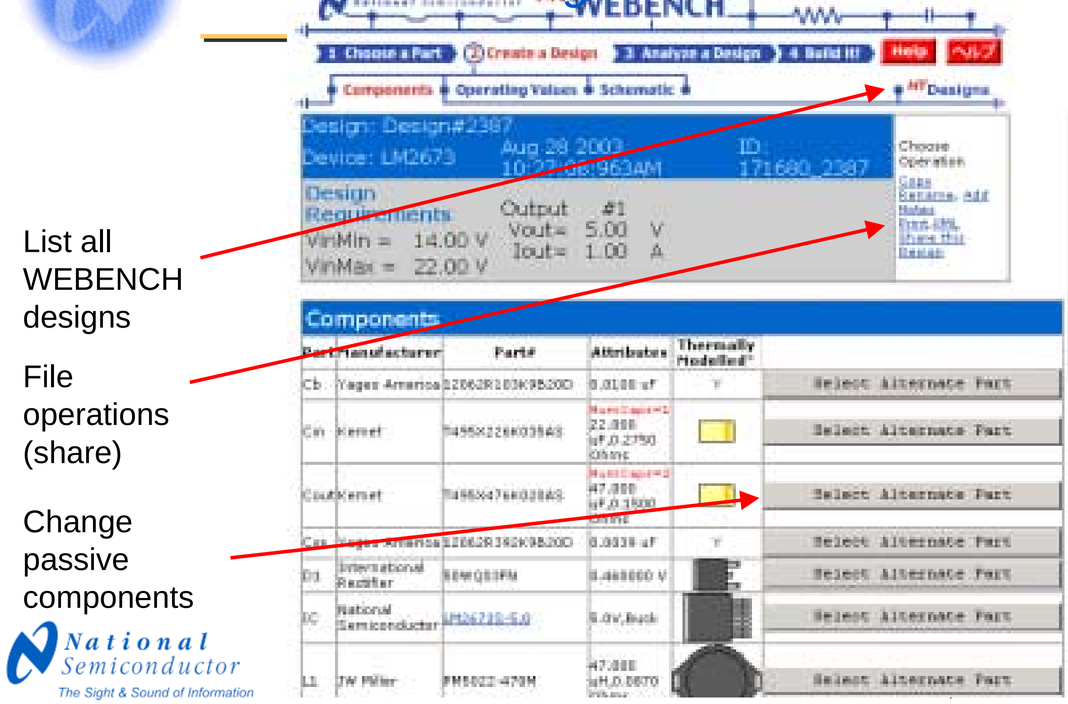
Vin: 4.5 to 5.5 Volts

Vout: 3.3V

Iout: 3.0A

The results show a switcher and an LDO in the recommended parts list. However, the difference between the two options becomes apparent when we view the LDO details and find that there is a large heat sink required to keep the temperature below 125C.

Create a Design - View BOM



This is the "View Components" screen. It summarizes the design thus far, including the power supply requirements and the IC selected. In addition, the external components needed for the total solution are listed with manufacturer, part number, and key values. A top-view scaled drawing of each thermally modeled part is also shown. Parts which are not required by WebTHERM are indicated by a Y in the "Thermally Modeled" column. The component selection, as well as the operating value calculations, are done using the same algorithms as are used in Switchers Made Simple.

From here you can work with the design file name and information, view the operating values by clicking on the "Operating Values" tab, or select alternate component values for your design by clicking on any "Select Alternate Part" button. In each "Select Alternate Part" screen, it will list parameters for suggested alternate components including electrical, size and footprint data. You can also find out if the component is available for use in a custom prototype kit and how much the component costs. To get a quick view of the custom prototype availability, click on the "Build It" button.

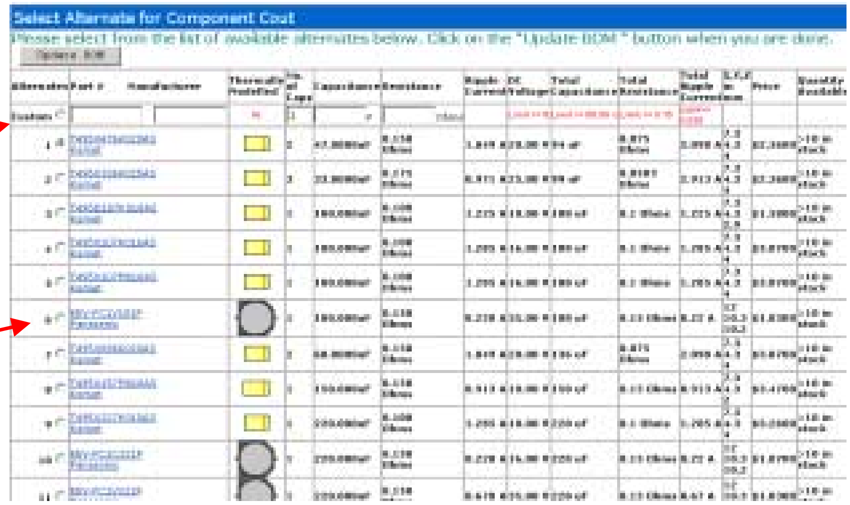
To list all of your WEBENCH designs, click on the "MyDesigns" tab

To go to the next step and simulate the design using the WEBENCH Electrical Simulator or WebTHERM™, click on the 'Analyze a Design" button.

Select Alternate Part

Enter your own custom component

Select component from a list



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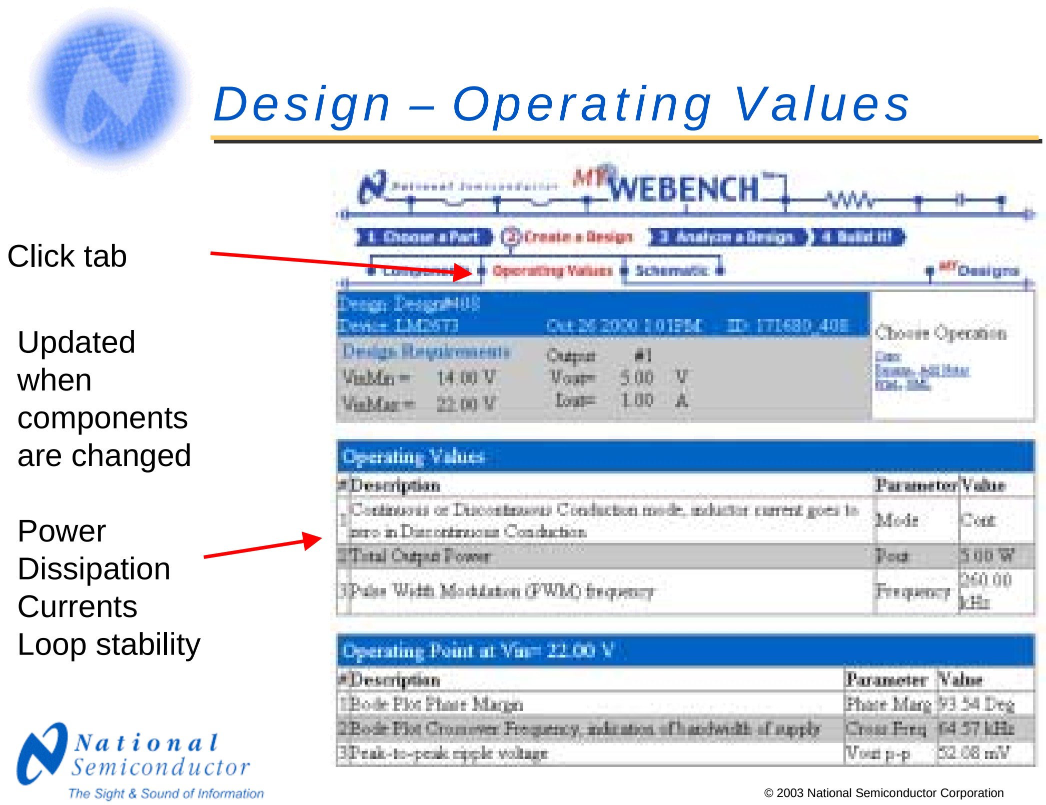
If you click on the "Choose Alternate Button" for the Cout component, the suggested alternative capacitors are listed, all appropriate for this power supply design. The limits for the capacitor parameters are listed in red at the top of the table. If another capacitor is desired that is not listed, it can be entered as custom (Be sure to click on the custom button if you want to enter custom values). Notice the ability to select multiple capacitors in parallel to reduce the equivalent series resistance and increase the capacitance.



Clicking on the Operating Values tab brings up a page which gives the result of calculations for the power supply design. These calculations were used in the selection of the design components, and are reported here to give an estimate of the circuit performance. In this example, the operating values provided are:

Bode Plot Phase Margin, Bode Plot Crossover Frequency

Steady State Efficiency, Continuous or Discontinuous Conduction mode

Total Output Power

IC Power Dissipation, Diode Power Dissipation

Input Capacitor Power Dissipation, Inductor Power Dissipation

Average input current, Input Capacitor RMS ripple current

IC Junction Temperature, IC Junction to Ambient Thermal Resistance

Vout p-p, Inductor ripple current, Output Capacitor RMS ripple current

Peak Current in IC for Steady-State Operating Point, IC Maximum rated peak current

Steady-State PWM Duty Cycle, Pulse Width Modulation (PWM) frequency

These calculations use the Switchers Made Simple™ algorithms and may differ somewhat from the electrical simulation results.

“View Components” will take you back to the previous page showing the components used in the design. If you change component values, the Operating Values will be updated.

For further investigation of the design, you can analyze it using the online WEBENCH Electrical Simulator and WebTHERM™ simulation tools.

What's Behind the WEBENCH Electrical Simulator?

- Large server farm runs the simulation software
- Small Flash application runs on user's browser
  - Handles mouse movements and button clicks in real time
- Low bandwidth requirement
- Uses industry standard SPICE for simulation

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The WEBENCH Electrical Simulator was developed by National to allow users to quickly characterize their power supply circuits based on their own design specifications. Because the WEBENCH Electrical Simulator resides on a fast, high-powered server, the user does not need to have any special software loaded on his/her PC to be able to use it except for the commonly installed Macromedia Flash. The models and simulation engine software on the server are always up to date, so the user gets the most current information.

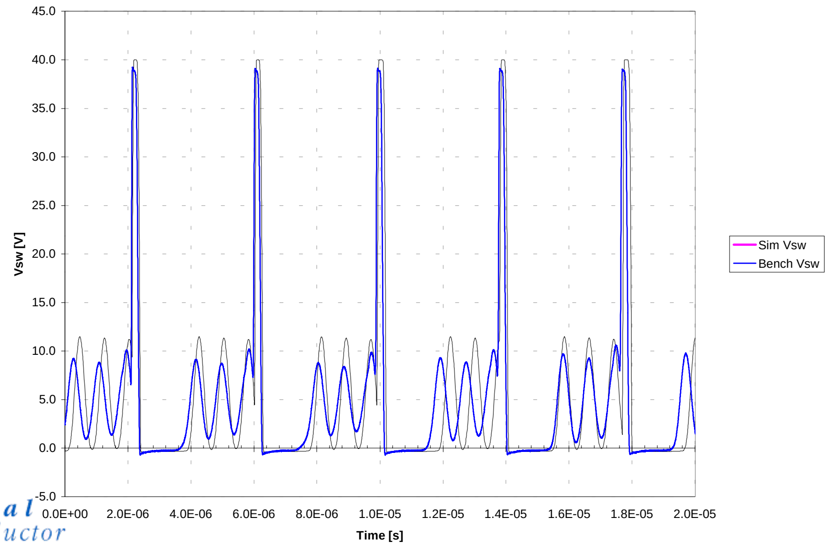
Some older devices are supported by WebSIM which is another electrical simulator developed by Transim™ Corporation.

WEBENCH™ 4.0 Design – Accuracy

Plot of Bench data and Simulation Data

Showing Accurate Depiction of Discontinuous Mode

Switch Voltage



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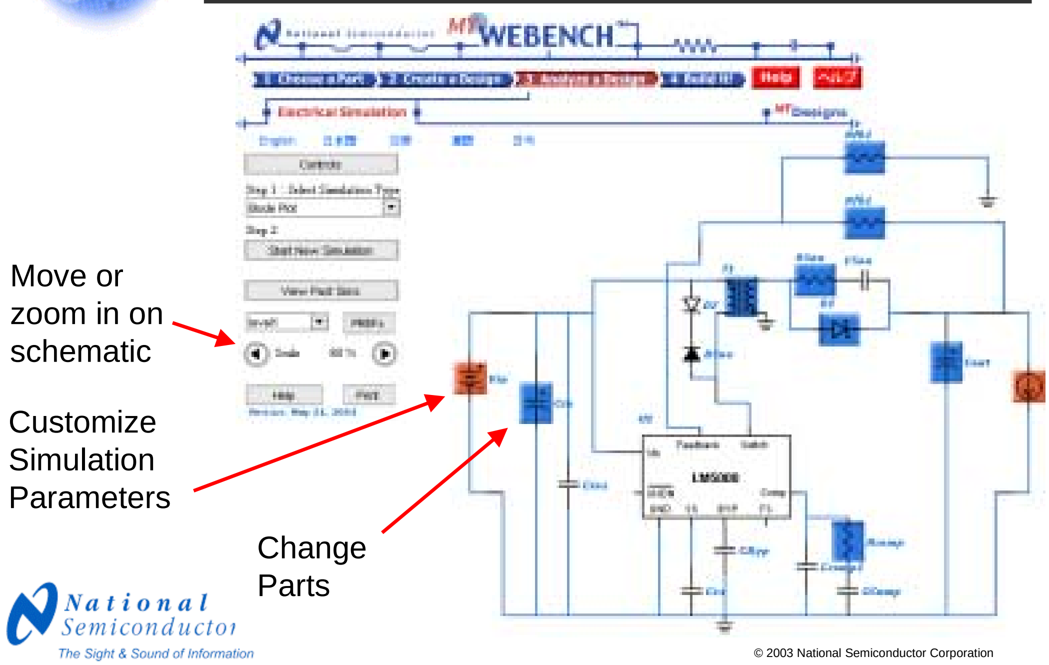
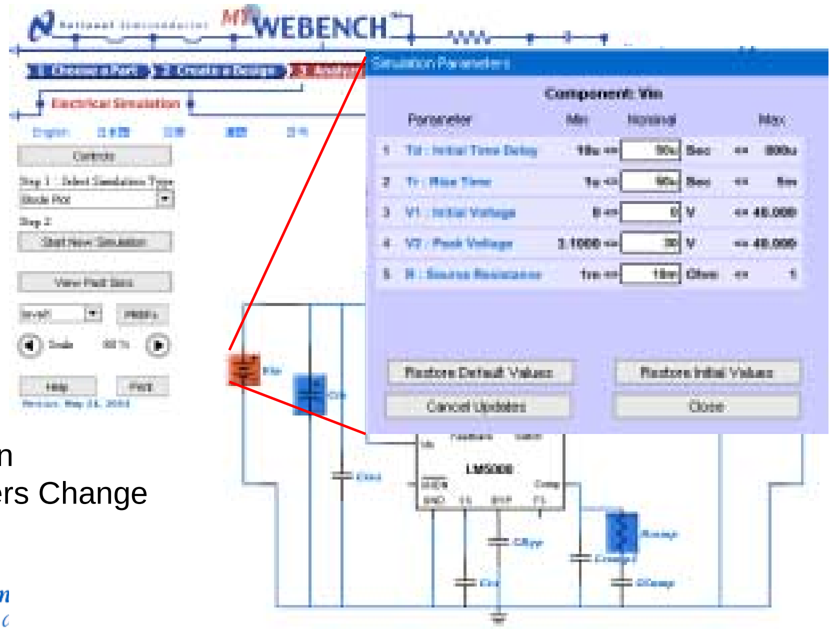
WEBENCH™ 4.0 has improved accuracy in electrical simulation. The use of Spice for the simulation engine has enabled this to happen. More accurate models for the output capacitor and diode have also been implemented along with the new Spice IC models. Extensive correlations with bench data have been performed in order to fine-tune the models and assure accuracy. Here we see a correlation between bench data and simulation data for the switch voltage for a design which is in discontinuous mode.

WEBENCH™ Electrical Simulator



Once in the "Analyze a Design" step, you may begin by using the WEBENCH Electrical Simulator, to do electrical simulations for your design. The schematic is generated by a Macromedia Flash application that runs on the client browser. This allows the user to interact with the schematic in real time. The user can select between 5 languages: English, Japanese, Chinese (simplified), Chinese (traditional) and Korean. User changeable components used in the schematic are highlighted with blue boxes, simulation parameters are highlighted with red boxes and probe points are highlighted with yellow boxes. You can also move the schematic by clicking and dragging on the schematic area with your mouse or you can zoom in or out by using the scale control in the control panel.

WEBENCH™ Electrical Simulator



Simulation Parameters Change Dialog

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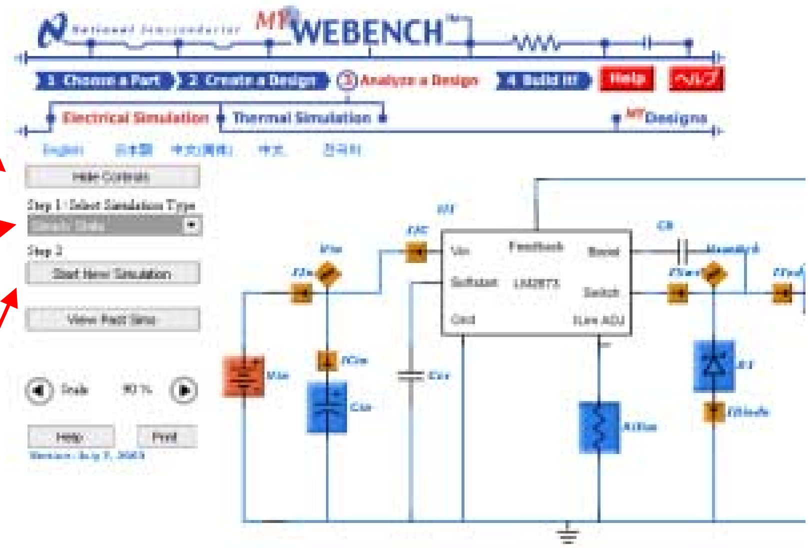
If you click on a simulation parameter or a component, you will see a dialog which allows you to change the relevant parameters or part.

WEBENCH Schematic

Controls for simulations

Tests available:
-Bode plot
-Steady state
-Input transient
-Output load transient
-Startup



Start Simulation

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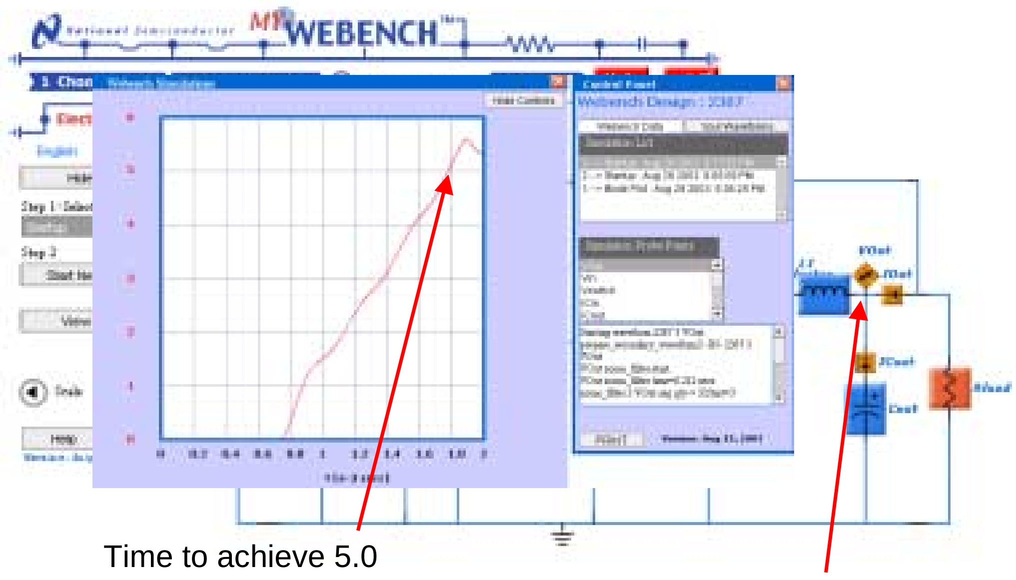
Set up simulations by using the controls on the left side of the screen . The user can hide the controls by pressing the "Hide Controls" button in order to get more room to view the schematic. To run a simulation, click on the "Start New Simulation" button. Depending on the complexity of the simulation, results will be available typically in 15 to 90 seconds. After the simulation is complete, the waveform viewer allows the user to view current and voltage waveforms as shown by the probe symbols on the schematic. Several types of simulations may be run including start-up, input line transient, output load transient and steady state. A Bode plot, useful for confirming system stability can also be obtained. The schematic will change as different simulation types are selected to reflect the text setup. For example, for a load transient test, the Iout output element will be a piece wise linear current source. To view past sims, click on the "View Past Sims" button.

View Waveforms



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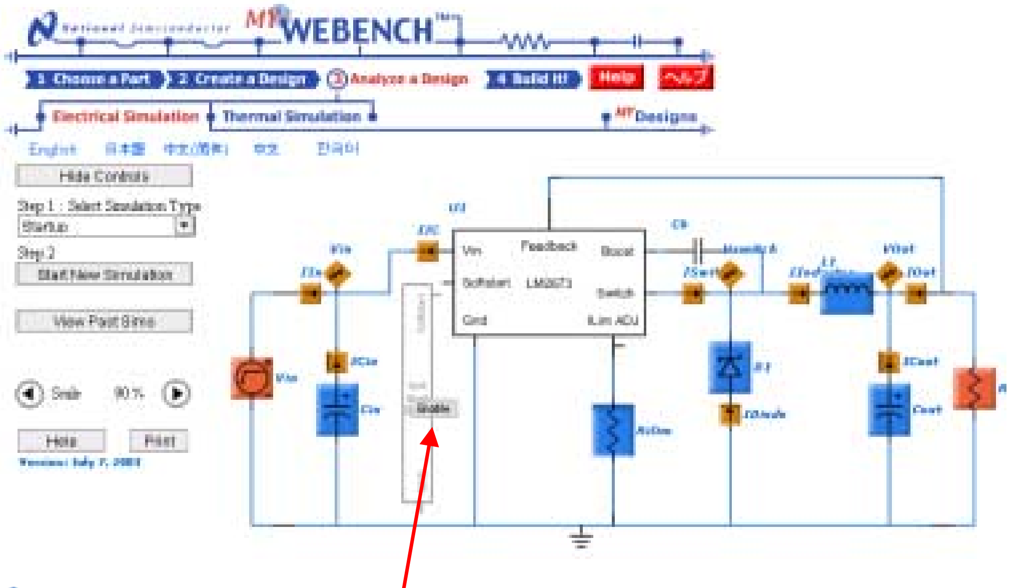
We will run a start-up test on this circuit to check the start-up time and determine if our soft start capacitor (Css) is correct for our design. For the start-up parameters we specify the input voltage going from 0 to 18V with a 50 microsecond rise time. When the simulation is complete, the waveform viewer will appear.

For the Startup test, as well as the transient and steady-state responses, two type of probes are available. The current probe allows the user to view the current through a component, and the voltage probe allows a look at the voltage with respect to ground. When we click on the Vout probe, we see the output waveform. Using the M1 measurement cursor, we see that it takes about 1.75 milliseconds to initially achieve 5 volts.

Changing Components



Click on a part to view, change or disable it (if applicable)

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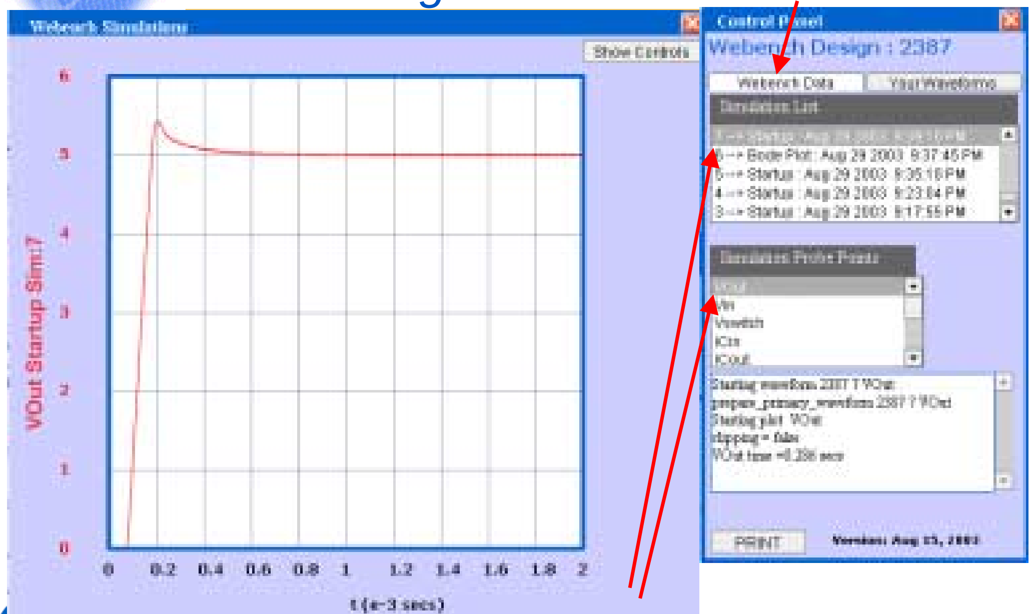
We now remove the soft start capacitor (Css) by hovering the mouse over it and clicking on the disable button. Then we run another simulation.

Vout Waveform After Removing Css

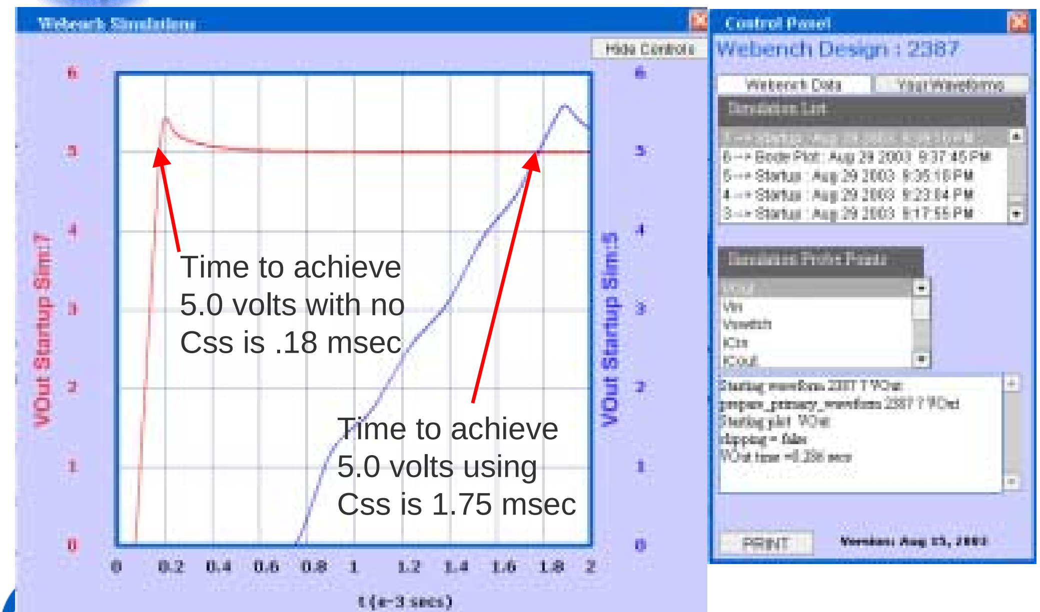
Select Waveform Control Tab



View multiple simulations and waveforms

The WEBENCH waveform viewer allows the user to simultaneously view multiple waveforms from different simulations. Click on the “Show Controls” button to view the waveform controls. Then click on the first simulation in the “Simulation List” box and the plot for Vout appears superimposed on our most recent simulation. We see that the time to reach 5 volts has decreased from 1.75 milliseconds to .18 milliseconds after the softstart cap is removed.

Vout Waveform After Removing Css



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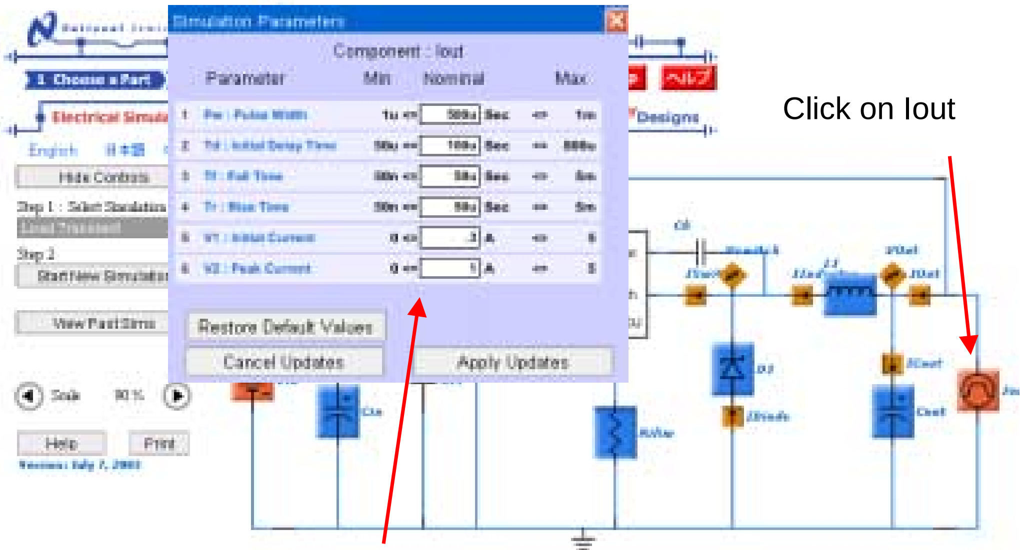
Load Transient Test



Click on Iout

Transient starts at .3A, rises to 1A for a duration of .5msec

To run the Load Transient Response test, it is useful to check the load transient settings and adjust them, if necessary. The settings include the initial delay time, the starting current level, the maximum current level, rise time of the pulse, the duration (pulse width), and the fall time. Here we have adjusted the load transient to step from 300mA to 1A, with a duration of 500usec. The rise and fall times are unchanged at 50us.

Waveform viewer

Select a waveform

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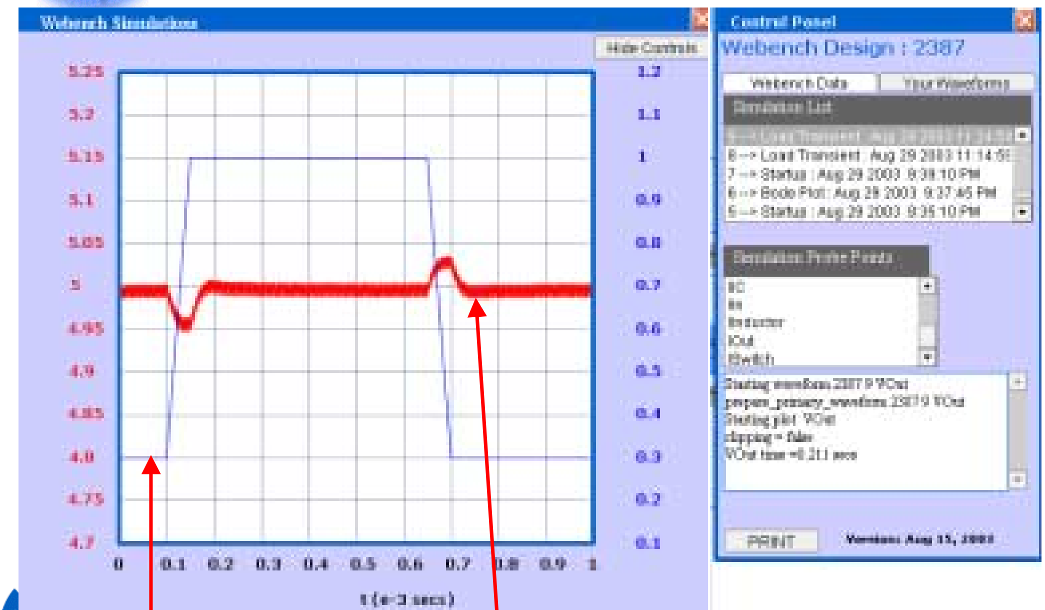
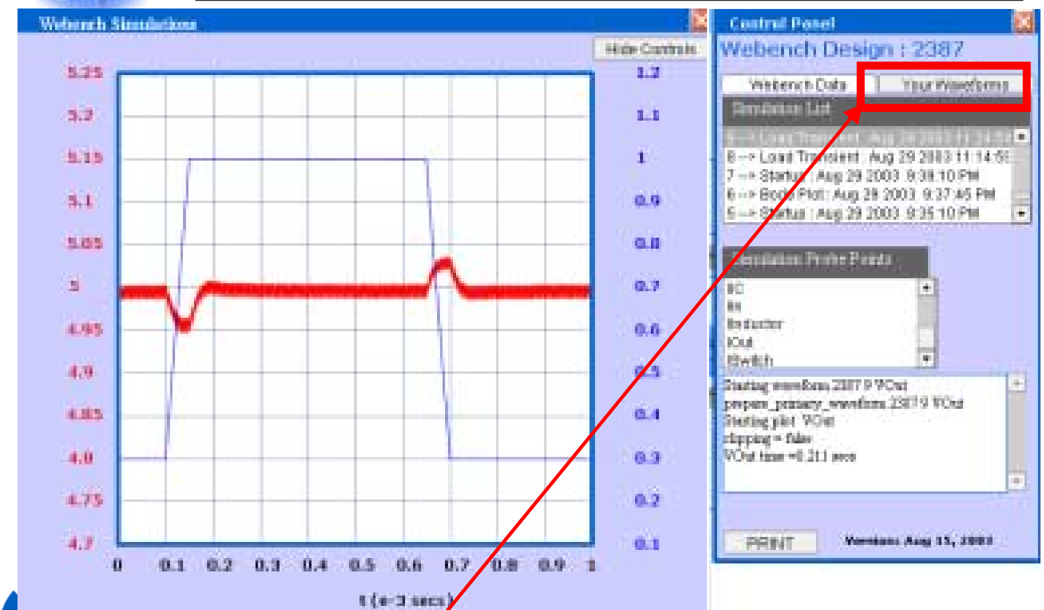
After running the simulation, the waveform viewer appears and shows the Vout waveform. Click on the show controls button to show the control panel. Then click on the WEBENCH Data tab and lastly click on the Iout waveform to show the load transient pulse.

Waveform viewer



Now you can see both the load transient pulse in blue and the corresponding Vout waveform in red. You can see that there is an undershoot of about 50mV when the load current is rising and an overshoot of about the same amount when the load current is falling. Overall, the output waveform is well behaved without excessive ringing.

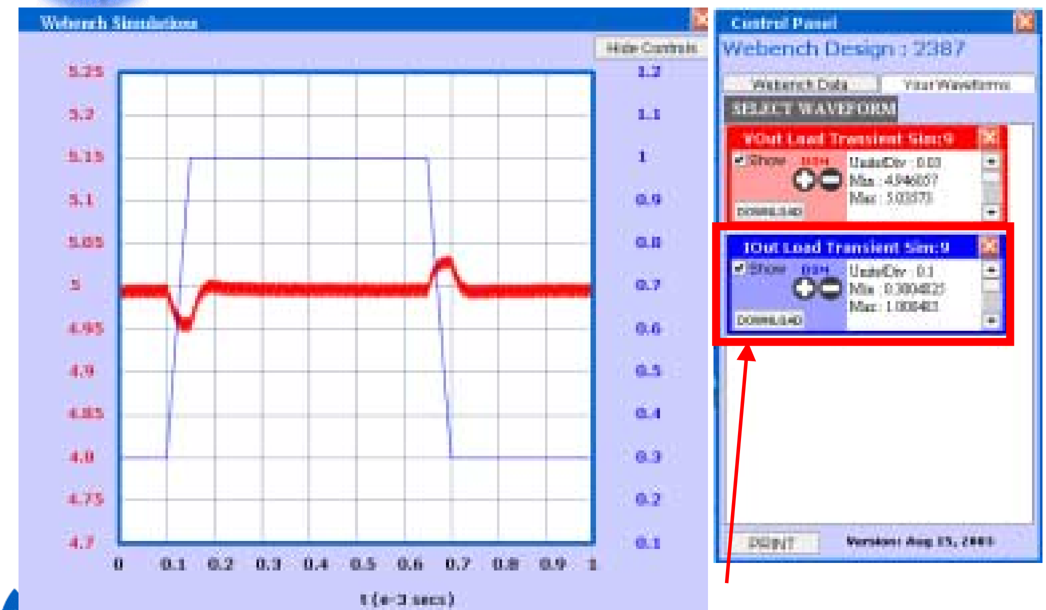
Waveform viewer



Waveform controls

Next click on the Your Waveforms tab to get more information about each waveform.

Waveform viewer



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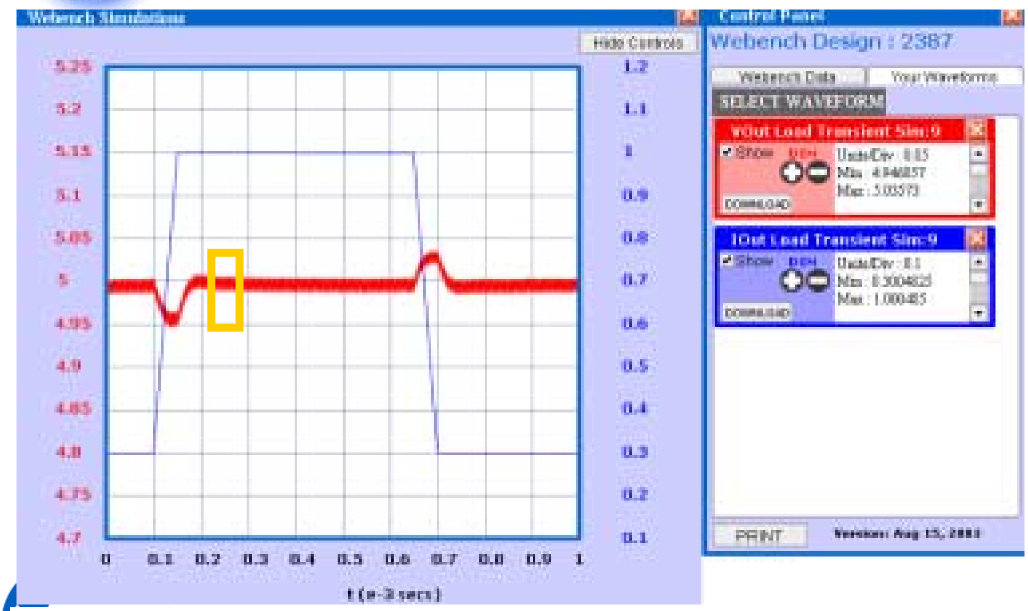
Hide, dim, download or delete

This area shows statistics for each waveform along with controls to hide, dim or delete the waveform on the display. You can also download the raw waveform data if you would like to view it offline in a spreadsheet or other viewing tool

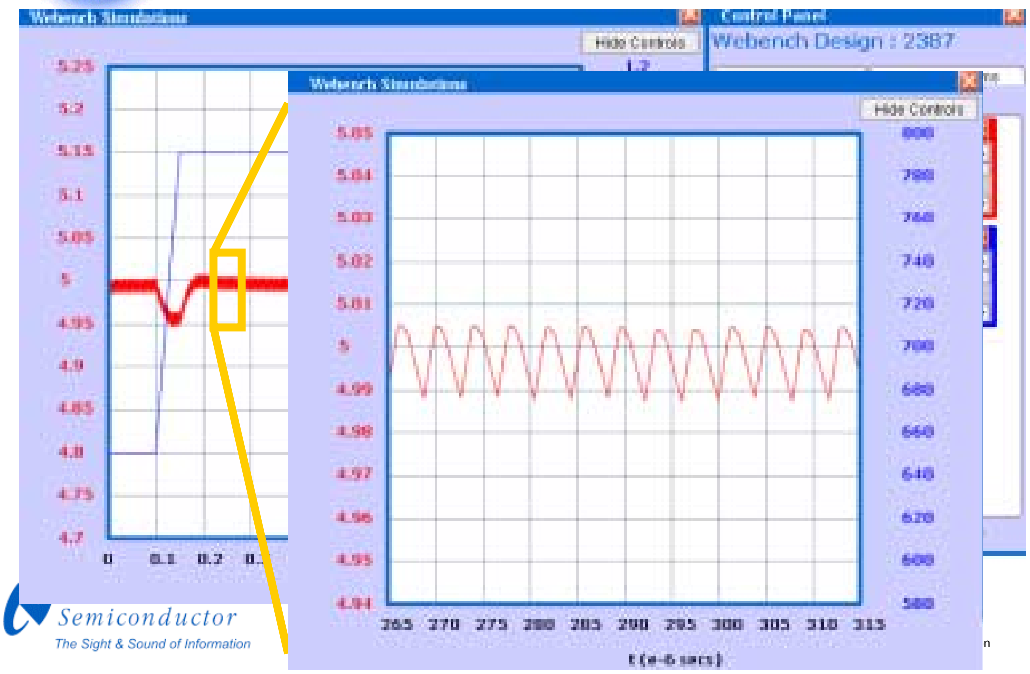
Output Ripple Voltage



Click and drag to zoom

We can zoom in on a section of the waveform by clicking and dragging with the mouse. If there is a lot of data, the zoom operation can take a few seconds.

Output Ripple Voltage



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In the zoomed-in view, we can estimate the peak-to-peak output voltage ripple at full load, to be a little less than 15 mV.

WEBENCH Bode Plots

- The Bode Plot shows the phase and gain on the same graph plotted vs frequency
- The phase should be at least 25 degrees above -180, and preferably 45 degrees above -180
- The phase margin is the difference between the phase and –180 degrees measured at the point where the gain = 0 dB (crossover frequency)
- We are not worried about the phase when the gain goes below zero
- If the phase gets close to -180 at frequencies below crossover and it comes back up, that is conditional stability which is acceptable as long as the phase is good at the crossover frequency

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The Bode plot is an important tool to examine the stability of a design. Bode plots are easy to get using The WEBENCH Electrical Simulator. Simply run a Bode Plot simulation, and the waveform viewer will appear with the results.

Bode Plot Basics

The crossover frequency is the point at which the gain crosses 0dB

The phase margin is the difference between the phase at the crossover frequency and –180 degrees

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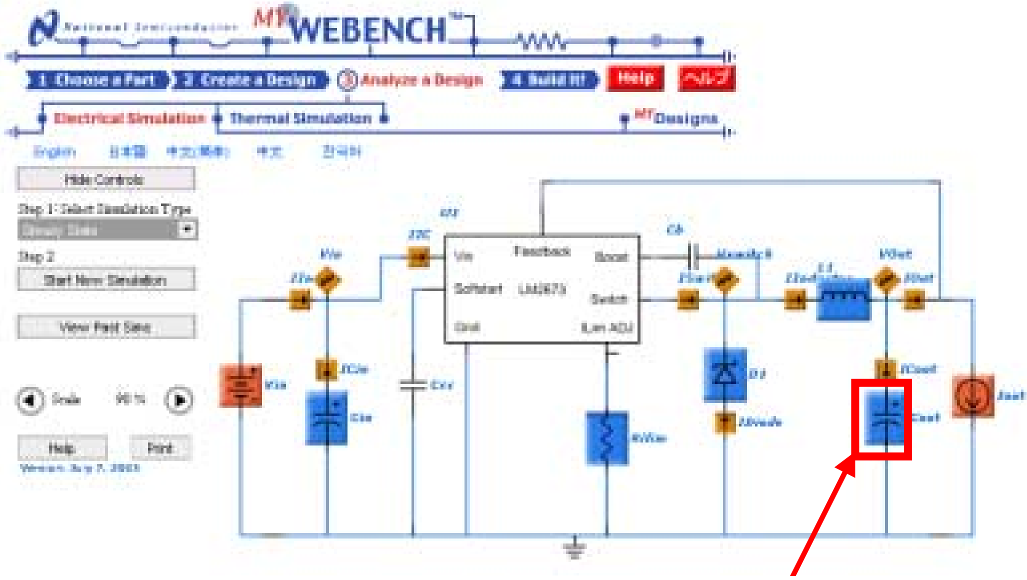
The crossover frequency is the frequency at which the gain drops below 0dB. To measure the phase margin, we get the phase at the crossover frequency and subtract –180 degrees. In this example, the crossover frequency is 15kHz. At that frequency the phase is –104 degrees so the phase margin is –104 – (-180) = 76 degrees which is plenty.

Try Different Components



Try 2 different output capacitors: one with 43mOhm ESR and the other with 100mOhm ESR

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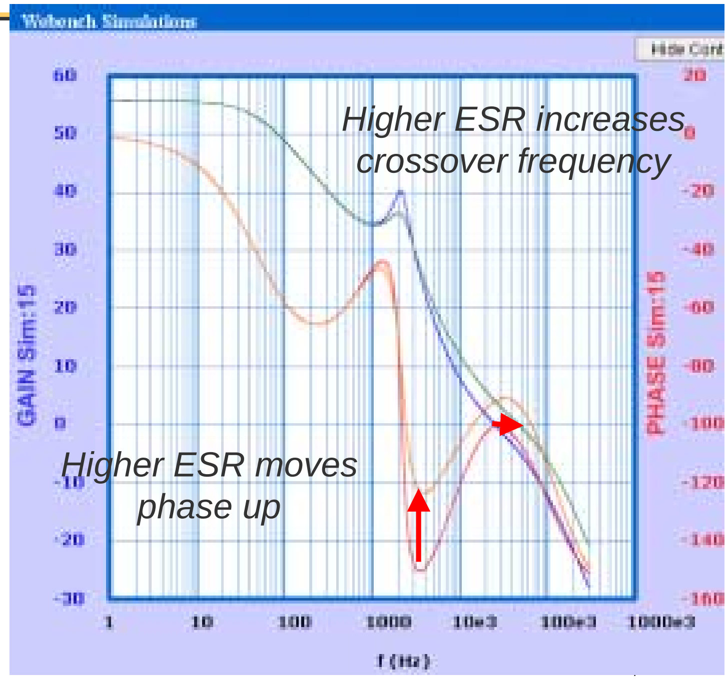
We will investigate the effect of output capacitor ESR on the circuit using the WEBENCH Electrical Simulator. First we try a bode plot simulation using an output capacitor with 43mOhm ESR. Next, we change the capacitor to one which has 100mOhm ESR and run another Bode Plot simulation.

Effect of Cout ESR on Stability

- **Raising Cout ESR helps phase margin for this design**



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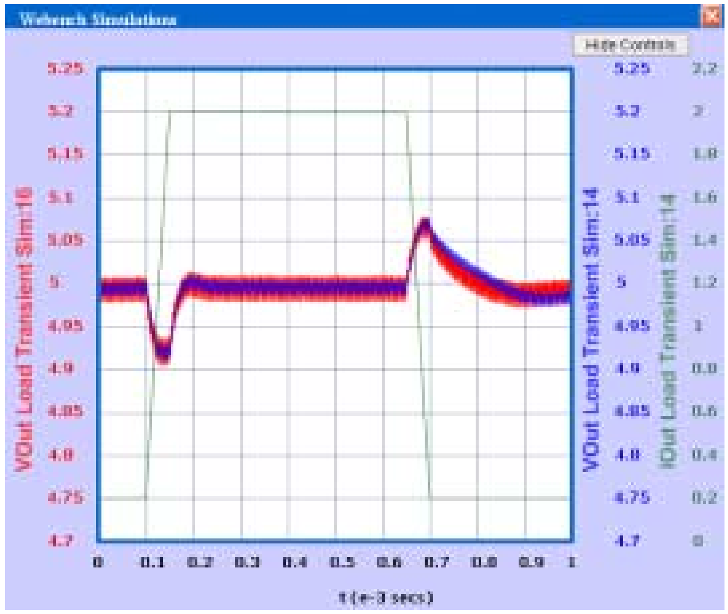
This is a WEBENCH Bode Plot showing different output capacitor ESRs for a design using an LM2676 switching regulator. The phase is plotted in blue and and the gain in red. All the runs show a dip in the phase at about 3300Hz – 4000Hz. This is called conditional stability. The phase increases at higher frequencies and then drops again above the crossover frequency. We see from the plot that we can improve the conditional stability issue by raising the ESR of the output capacitor. This also increases the crossover frequency and bandwidth.

Effect of Cout ESR on Load Transient

- Raising Cout ESR did not materially affect the transient response



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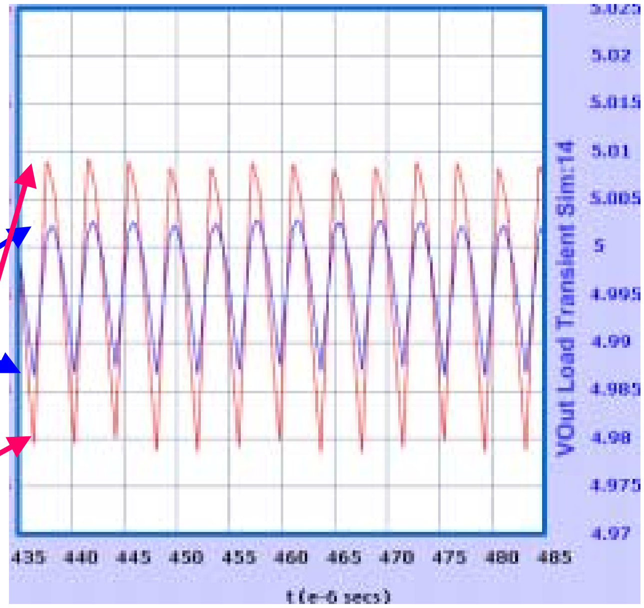
We now examine the effect of raising the Cout ESR on the output voltage during a load transient test where the current goes from .2A up to 2A and back. There is little effect on the overshoot and there is a minor effect on the settling time during the downward current pulse.

Effect of Cout ESR on Vout Ripple

- **Raising Cout ESR hurts the output voltage ripple**

Steady state Vout ripple at high current: for 43mOhm = 15mV

Steady state Vout ripple at high current : for 100mOhm = 30mV



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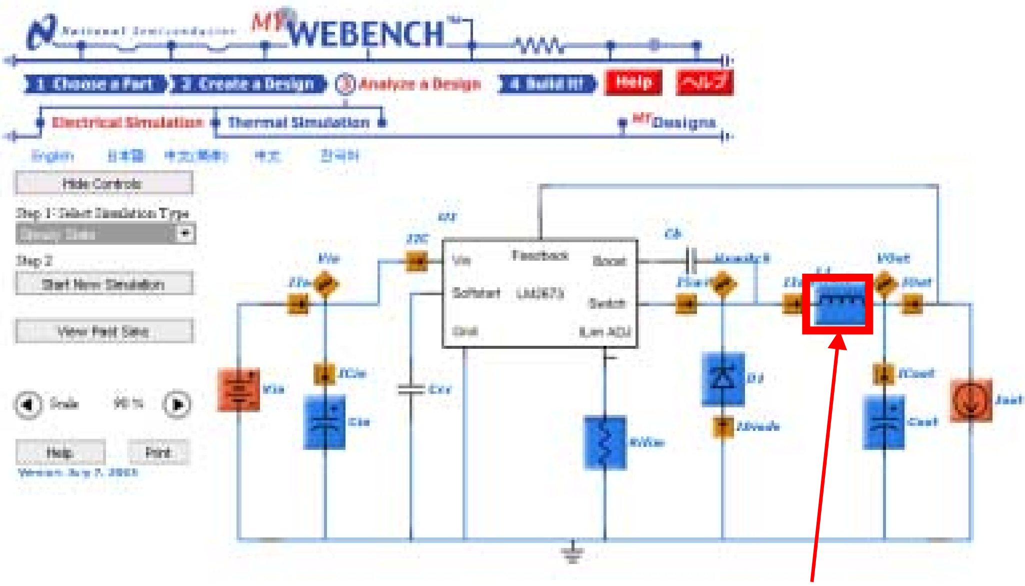
The other effect of changing the output capacitor ESR is that the output voltage ripple increases as the output capacitor ESR goes up. The output voltage ripple can be estimated as:

Vout Ripple = Inductor Ripple Current * Cout ESR

We can use the WEBENCH™ electrical simulator to examine the output voltage waveform after the Cout ESR is adjusted to make sure that the voltage ripple is within your spec. Here we see that for the 43mOhm Cout ESR, the Vout ripple is about 14 mV and for 100mOhm it is about 30mV.

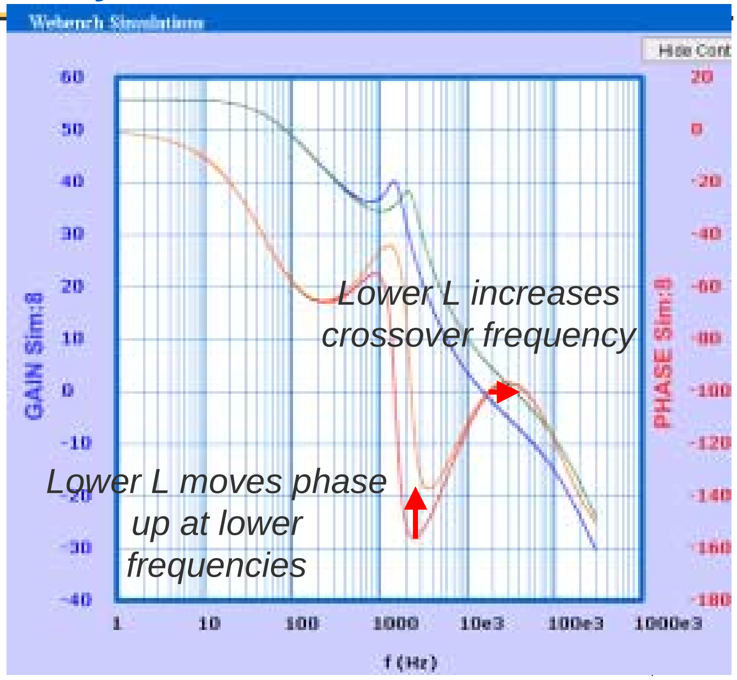
Try Different Inductors



We will investigate the effect of inductance on our design using the WEBENCH Electrical Simulator. Again we run two bode plot simulations: one using a 33uH inductor and another using a 68uH inductor.

Effect of Inductance on Stability

- **Lowering inductance helps phase margin for this design**



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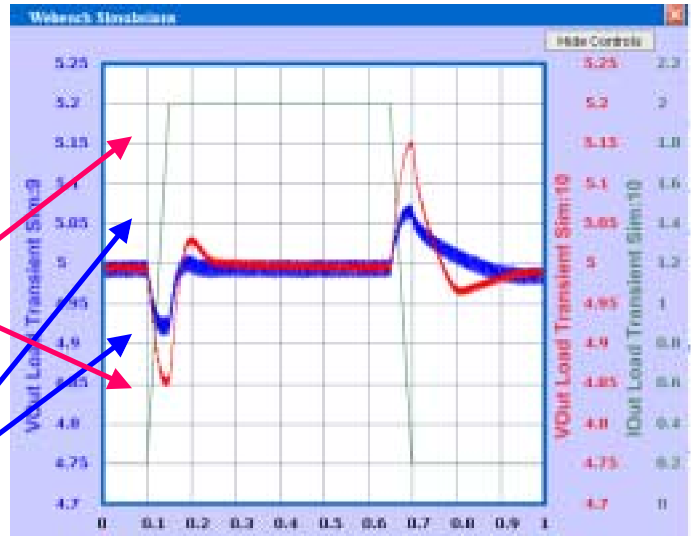
This is a plot of several WEBENCH bode plots for different inductances for an LM2676 design. The gain is plotted in blue (68uH) and green (33uH) and the phase in red (68uH) and orange (33uH). All the runs show a dip in the phase at about 1600 - 3300Hz. The phase can be raised at the lower frequencies by decreasing the inductance. However, this may cause a problem with the peak switch current and Vout ripple. We will first explore the effect on load transient for the 2 inductances.

Effect of Inductance on Load Transient

- **Lowering inductance improves transient response (within limits)**

Load transient Vout overshoot:
for 68uH = 300mV

Load transient Vout overshoot:
for 33uH = 150mV



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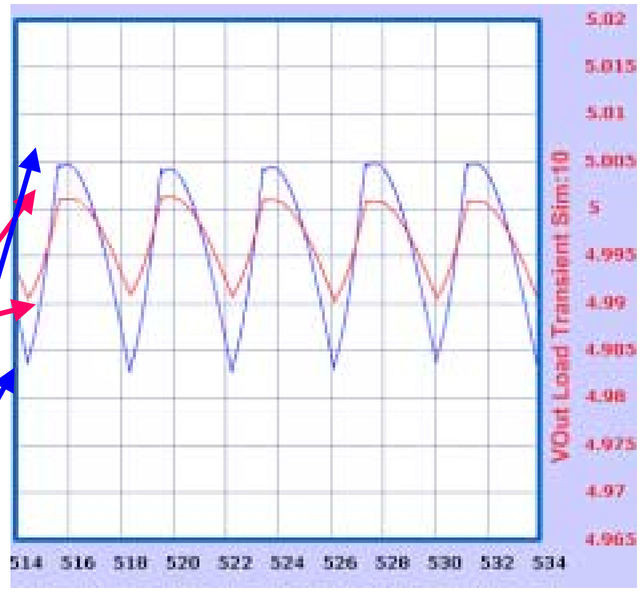
The Vout load transient response is plotted for the two inductances. The blue plot is for 33uH and the red plot is for 68uH. For this design, the 33uH L value, which corresponds to higher phase margin on the Bode Plot, results in less excursion during the load transitions. But you can also see that the steady state Vout ripple is less for the 68uH case.

Effect of Inductance on Vout Ripple

- **Lowering inductance increases the output voltage ripple**

Steady state Vout ripple at high current: for 68uH = 10mV

Steady state Vout ripple at high current : for 33uH = 21mV



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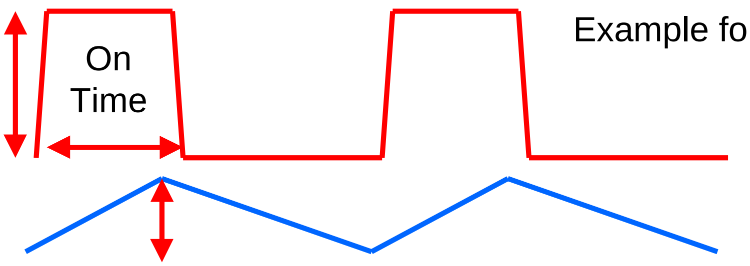
We now zoom in on the load transient plot in the portion where the pulse current is high at 2A. We can thus better see the steady state Vout ripple voltage for the two inductances. It is observed that the 33uH L value results in a steady state Vout ripple which is about 2 times higher that of the the 68uH case.

Now Does the Inductor Affect Peak Current?

- **Basic inductor Equation: V = L di/dt**
- **di = (1/L) * voltage applied across inductor * time voltage is on = ILpp**
- **On time = duty cycle * 1/frequency**
  - **Higher switching frequency = less on time**
- **Ipeak = ILavg + ½ ILpp**



The peak inductor current (and peak switch current) is a function of the average output current and the inductor ripple current. The peak inductor current is:

ILaverage + 1/2 ILpp (the inductor ripple current) The average inductor current is:

For Buck: ILaverage = Iout

For Boost: ILaverage = Iout/(1-DC) where DC = duty cycle

DC = (Vout-Vin+Vdiode+ILavg*DCR)/(Vout - Vswitch + Vdiode)

Higher DCR means higher duty cycle and higher average inductor current

The inductor ripple current is determined by the basic inductor equation:

V = L dI/dt

di = V/L dt

Peak to peak inductor current (inductor ripple current) = Voltage applied across the inductor/L * time during which voltage is applied to the inductor.

When the switch is closed we have:

For Buck: ILpp = (Vin - Vswitchingloss - ILavg*DCR - Vout)/L * Ton

For Boost: ILpp = (Vin - Vswitchingloss - ILavg*DCR)/L * Ton

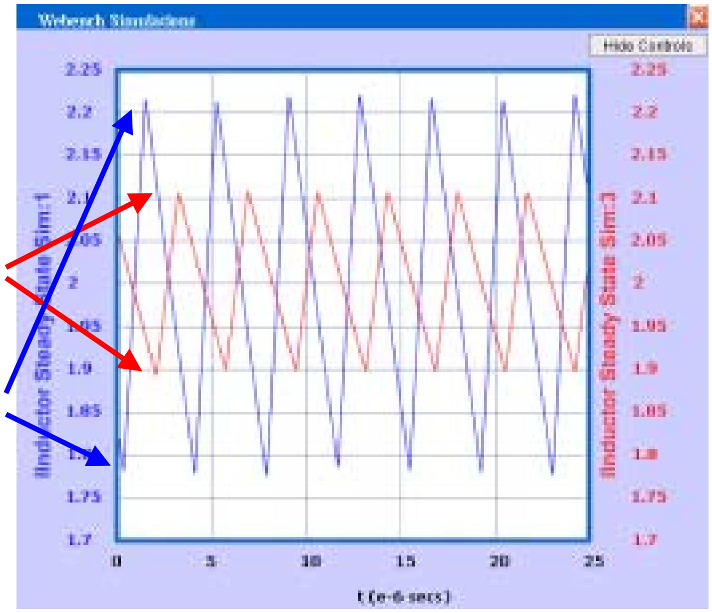
Longer ON times and lower inductance values mean more inductor ripple current and higher peak current.

Note: When creating a design, the rule for sizing an inductor is to try for +/- 15% inductor ripple current.

Effect of Inductance on Inductor/Switch Ripple Current

Peak-to-Peak inductor ripple current:
for 68uH = .21A

Peak-to-Peak inductor ripple current:
for 33uH = .44A



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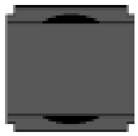
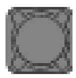
We see that the peak-to-peak inductor current, ILpp, is reduced from .44A down to .21A by increasing the inductor from 33uH to 68uH.

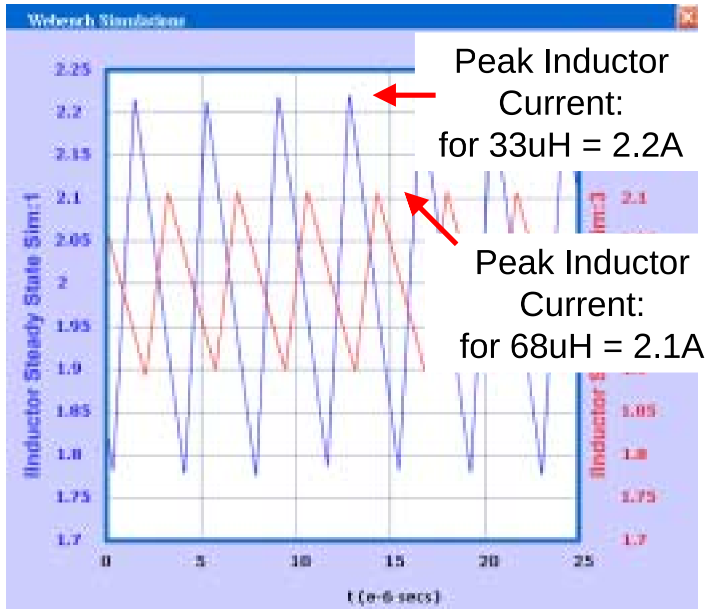
Effect of Inductance on Peak Current and Size

68uH
$2.47



33uH
$0.84





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We also see that since changing the inductor has negligible effect on the average output current, the peak inductor current was also reduced from about 2.2A down to 2.1A. This follows since:

ILpeak = ILaverage + ½ ILpp where ILaverage = Iout (neglecting the effect of inductor DC resistance).

Perhaps more importantly for this design, the larger ripple current that we get with the smaller inductance translates into higher output voltage ripple since, as we saw earlier:

Vout Ripple = Inductor Ripple Current * Cout ESR

so higher inductance benefits the design from the standpoint of reduced Vout ripple. However, increasing the inductance can result in a significantly larger footprint at more cost.

Power Supply Tradeoffs

- For the design we have just explored, we have found the following:
- Higher Cout ESR:
  - More phase margin - *good*
  - Worse Vout ripple - *bad*
- Lower inductance
  - More phase margin - *good*
  - Less Vout overshoot during load transient - *good*
  - Higher peak switch current - *bad*
  - Worse Vout ripple - *bad*
  - Smaller footprint/price - *good*
- Some of these relationships can change depending on the specifics of the design
- Power supply design is a series of tradeoffs
  - Need to optimize for your specifications

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What's Behind WebTHERM™?

- Developed in cooperation with Flomerics
- Uses Flomerics Smart Part models for the IC
- Uses lumped cuboid models for passive components
- Board modeled as a separate part, with traces modeled explicitly
- 3D conduction
- Radiation
- Convection modeled through correlations

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WebTHERM™ uses two types of models for electrical simulation. For the IC, WebTHERM uses Flomerics Smart Part models which are highly detailed and based on the internal construction of the parts. For other passive components, lumped cuboid models are used which assume the power is distributed evenly across the cubic volume of the component. Since the passive parts do not generate a lot of heat in these designs, this type of model is appropriate. The board traces are modeled explicitly to accurately portray how heat is transferred over the copper.

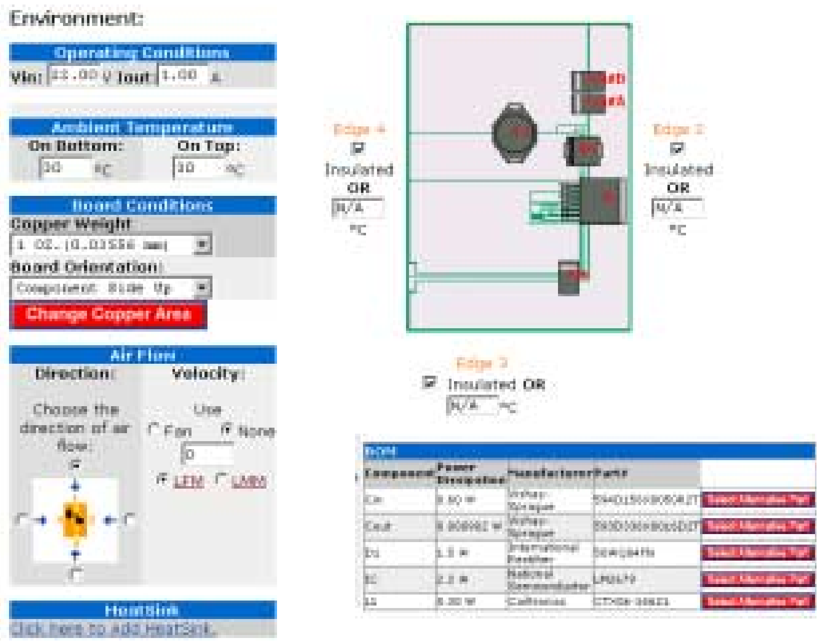
The simulation engine uses full 3-D conduction and radiation solvers. Convection (including air flow) is modeled through correlations, this is because full CFD simulations for air flow require extended simulation times which are too long for WEBENCH™.

WebTHERM™ Inputs

Change copper area

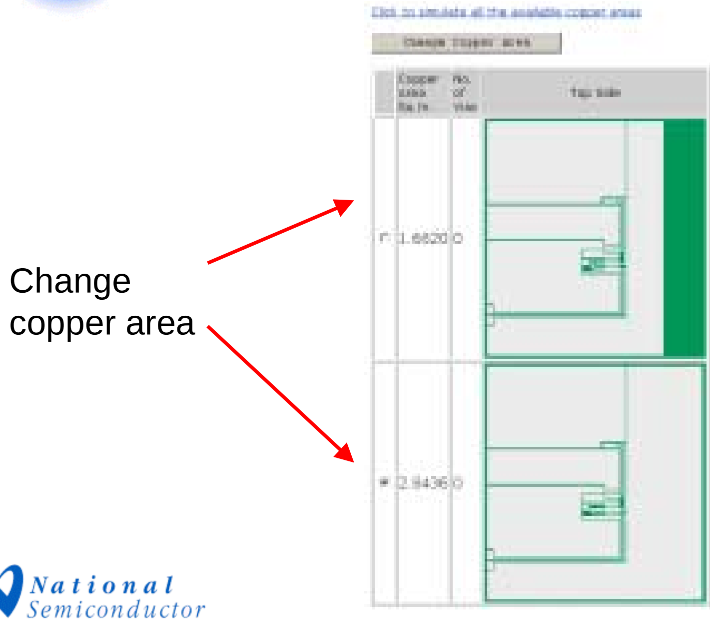
Change air velocity and direction

Add heat sink



This is the initial parameter entry screen of WebTHERM™ where you can view the reference printed-circuit-board layout, adjust the air flow velocity, change the copper area or thickness, adjust the top and bottom ambient temperatures, and specify the board edge boundary temperatures, either insulated or fixed. In addition you can enter the orientation of the board, and/or enter comments about the design. Here, we are looking at a TO-263 surface mount design. To change the copper area, click on the red "Change Copper Area button"

WebTHERM™ Inputs



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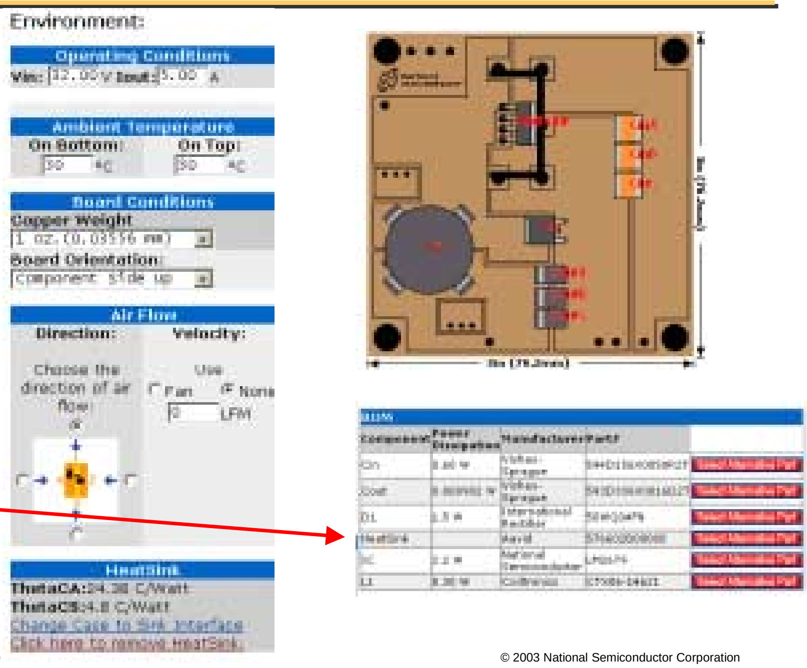
To change the copper area on a TO-263 surface mount design, simply select the desired board layout and click on the gray "Change Copper Area" button. You can also simulate all the copper areas at once by clicking on the "Simulate All Available Copper Areas" link at the top of the page.

WebTHERM™ Inputs



Change or remove heat sink

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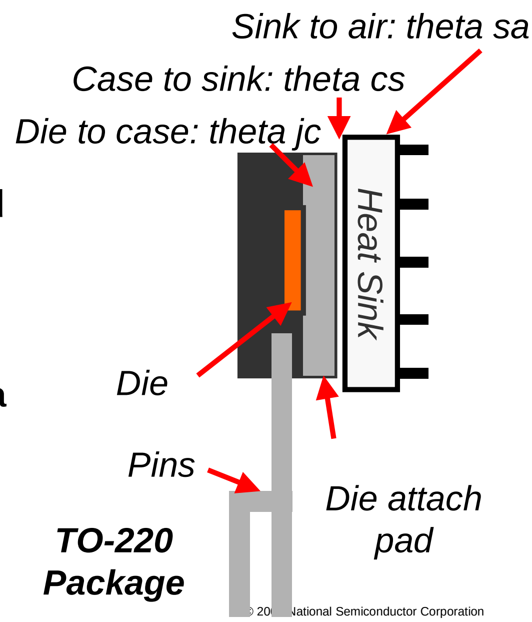
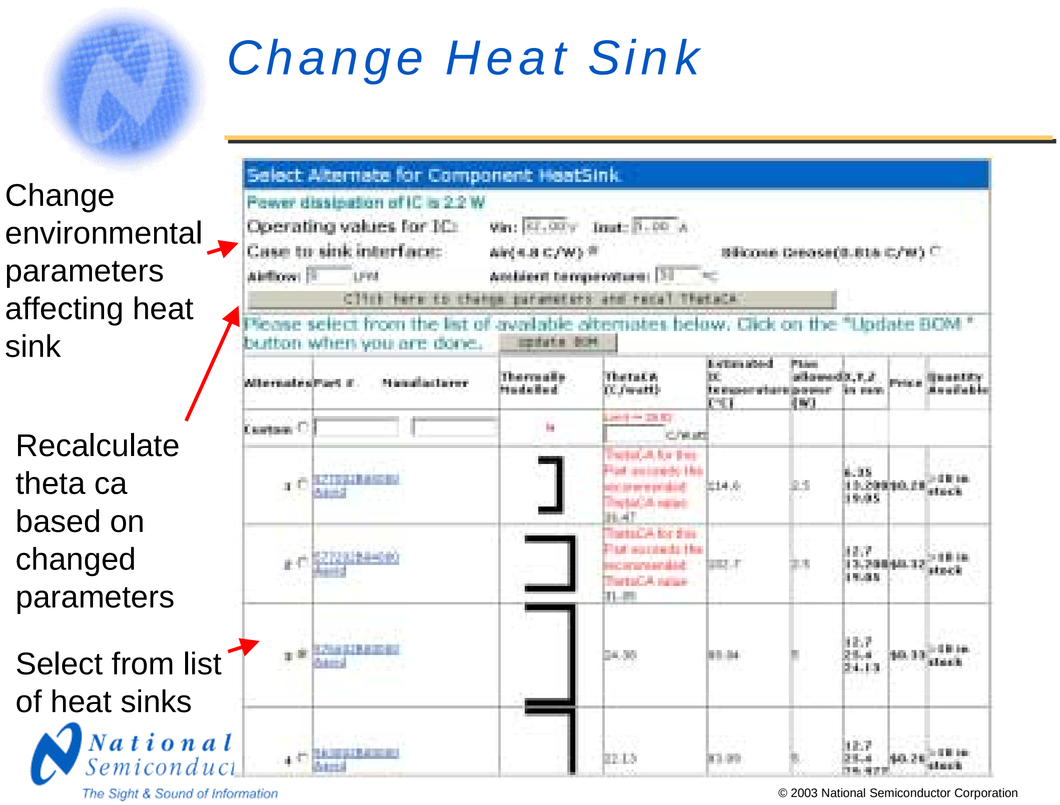
Here is the screen showing the parameters for a heat sink design. This is similar to the surface mount version except it has added links to change the heat sink parameters.

Factors Affecting the Heat Sink

- **Thermal resistance for heat sink: theta ja =**
  - **theta jc + theta cs + theta sa**
- **Airflow: natural vs forced**
  - **For natural convection, the power dissipation determines the theta sa**
  - **For forced air, the velocity determines theta sa**
- **Interface material: theta cs**



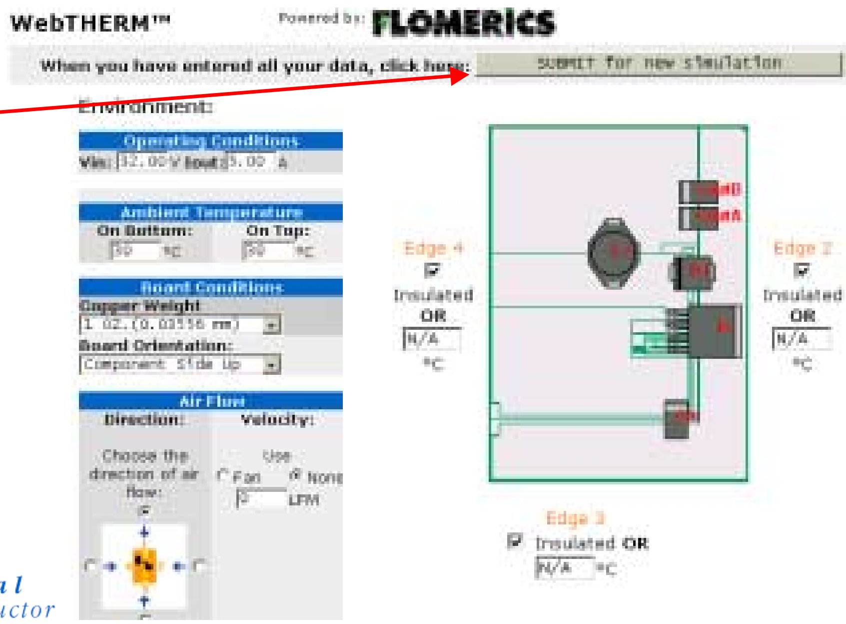
The thermal resistance for a package using a heat sink can be broken down into several components. This begins with the theta jc or thermal resistance from junction to case, for the package which is about 2.0 degrees C/W for a TO-220 type package. Next is the theta cs or thermal resistance from case to sink which is about .8 C/W for silicone grease and about 4.8 C/W for air. Lastly is the theta sa or thermal resistance from the sink to air which can range broadly depending on the design of the heat sink. The heat sink is also affected by the airflow: for natural convection (no fan), the power dissipation affects the theta sa. This is because as more power is dissipated, the part gets hotter and generates airflow around the heat sink due to the hot air rising. The input voltage and load current on the power supply are used in this case to determine the theta sa. For forced airflow, the air velocity determines the theta sa.



On this screen you enter the parameters affecting the heat sink. This includes the voltage and current which determine the power dissipation, the case to sink interface which can be air or grease, the airflow for forced convection if a fan is used, and the ambient temperature. After clicking on the "recal ThetaCA" button, the parameters for each heat sink will be recalculated. This makes it easy to select the best heat sink based on estimated IC temperature and cost. When you are finished selecting the heat sink, click on the "update BOM" button to save the choice and return to WebTHERM™.

Submit Simulation

Submit simulation



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When we are finished entering the environmental information, click on the "SUBMIT" for new simulation button to begin the simulation.

Simulation Status Screen

Simulations take about 2 – 3 minutes to run excluding queue time

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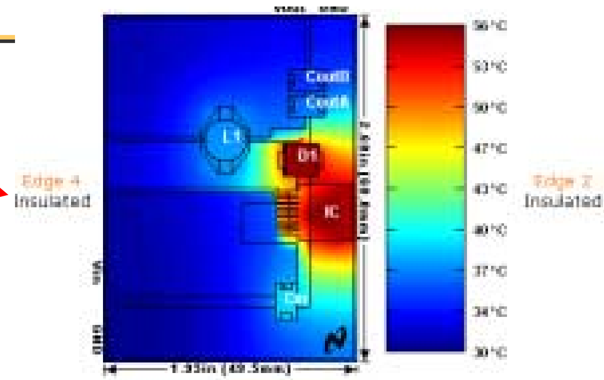
All your simulations are listed on the simulation status screen. A simulation may be in queue, which means that it is waiting to start, in process, which normally takes about 2 to 3 minutes, or completed. To view a completed simulation, click on the link for the simulation, you can start a new simulation by clicking on the "Start a new WebTHERM™" simulation button. You can get back to this screen from anywhere in WebTHERM™ by clicking on the "Thermal Simulation" tab near the top center of the screen.

WebTHERM™ Results

Board level interactions and temperatures of each component



Operating Temperatures

Layer	Max Temp.	Manufacturer	Part#
Cin	40°C	Vishay-Sprague	593D475X0050D2T
Cout	38°C	Vishay-Sprague	593D476X0010D2T
D1 - Diode	56°C	General Semiconductor	SL43-T/R
IC - Die	57°C	National Semiconductor	LM2673
IC - Top	57°C		
L1 - Inductor	38°C	Vishay-Dale	IDC-5020-47UH-20
PCB	57°C		

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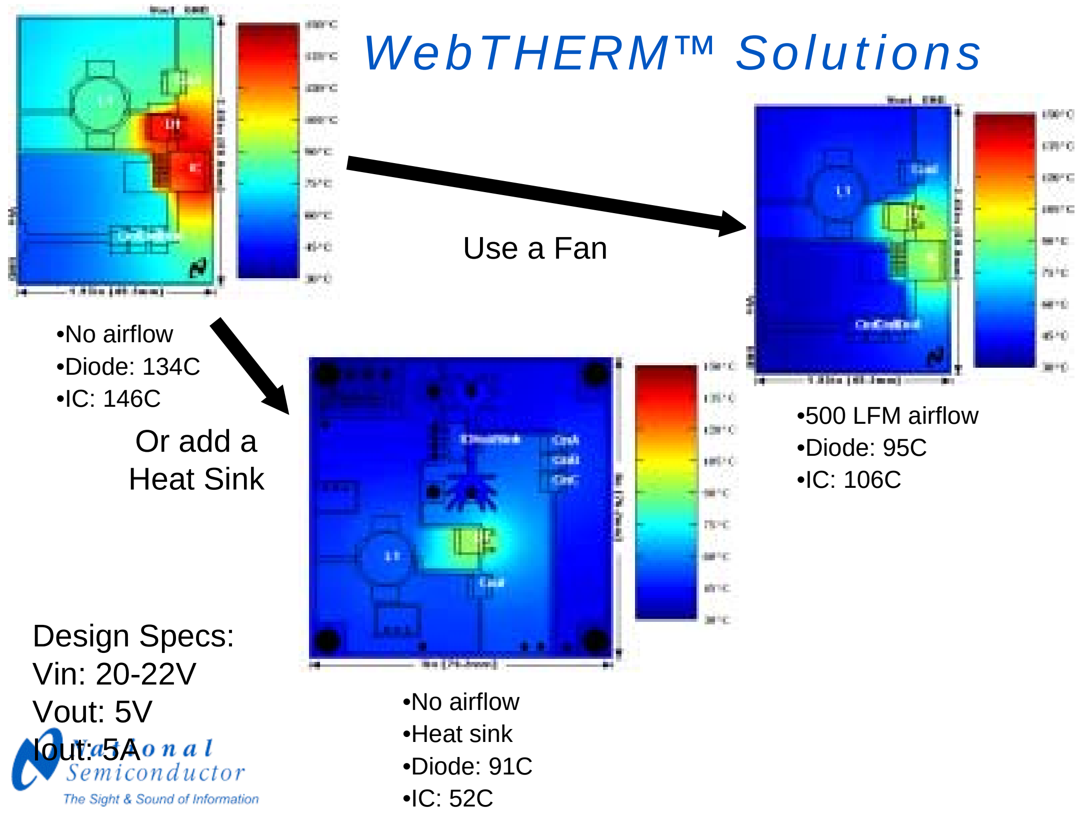
After about 2 to 3 minutes, depending on the complexity, the simulation is complete. The simulation results screen shows a color map of the temperatures across the PC board. It also indicates the temperature of each component. The plot can be rescaled to match other simulations, if desired. The user can go back and adjust the environmental variables or change the operating conditions of the design to improve the behavior if necessary. This can save a lot of time by reducing the number of iterations in the temperature lab.



Here is an example of how WebTHERM™ can be used to solve a temperature problem. We have created a power supply design with Vin ranging from 20 to 22 volts, Vout = 5 volts and Iout = 5 amps. With this high-current design, the components tend to get quite hot. In the first simulation, using no fan or heat sink, the regulator is over 140°C and the diode is over 130°C. We can add a fan with an air velocity of 500 linear feet per minute and the simulation shows that the temperature of the IC and diode drop to less than 110 degrees. However, the design is still too hot. Another approach is to add a heat sink which brings the temperature of the IC down to less than 60°C and the diode less than 100°C. Other possibilities are to increase the copper area or thicken the copper.

We are now done analyzing and optimizing our design and will proceed to the “Build It” step.

Benefits Experienced - WebTHERM

- Save time
  - Color representation of the temperature of your board enables quick tracking down of temperature problems
- Improve design quality
  - Change the environment and the properties of the board to see the effects on temperature:
    - Ambient temperature, air flow, copper weight, copper area, board orientation and heat sink
- Save money
  - Make tradeoffs, for example board area vs. heat sink vs. airflow

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Design Documentation

Click Documentation tab

Customized documentation

Download CAD files

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We are now in the last step of the WEBENCH™ process, which is called “Build It”. In the Documentation page of Build It, you can view customized documentation for your design. This starts with the assembly document which contains information for constructing your power supply, including an assembly diagram, schematic, bill of materials and instructions for building and testing the power supply.

From the Design Doc link you can also get full documentation of the design including the specifications, operating values and thermal simulation results.

A detailed summary of the integrated circuit with links to the datasheet and application notes is in the product folder.

My orders shows your custom power supply kit order status and history.

Downloadable schematic, layout and Gerber files are also available on this page. The schematic and layout files are in Protel format, so you must have Protel software or other software which can read the Protel file format to take advantage of these. The Gerber file is for the custom board used for this design.

Build It

Order:

- Unassembled custom kit
- National parts in volume
- Free samples of National parts
- Generic (not custom) demo board

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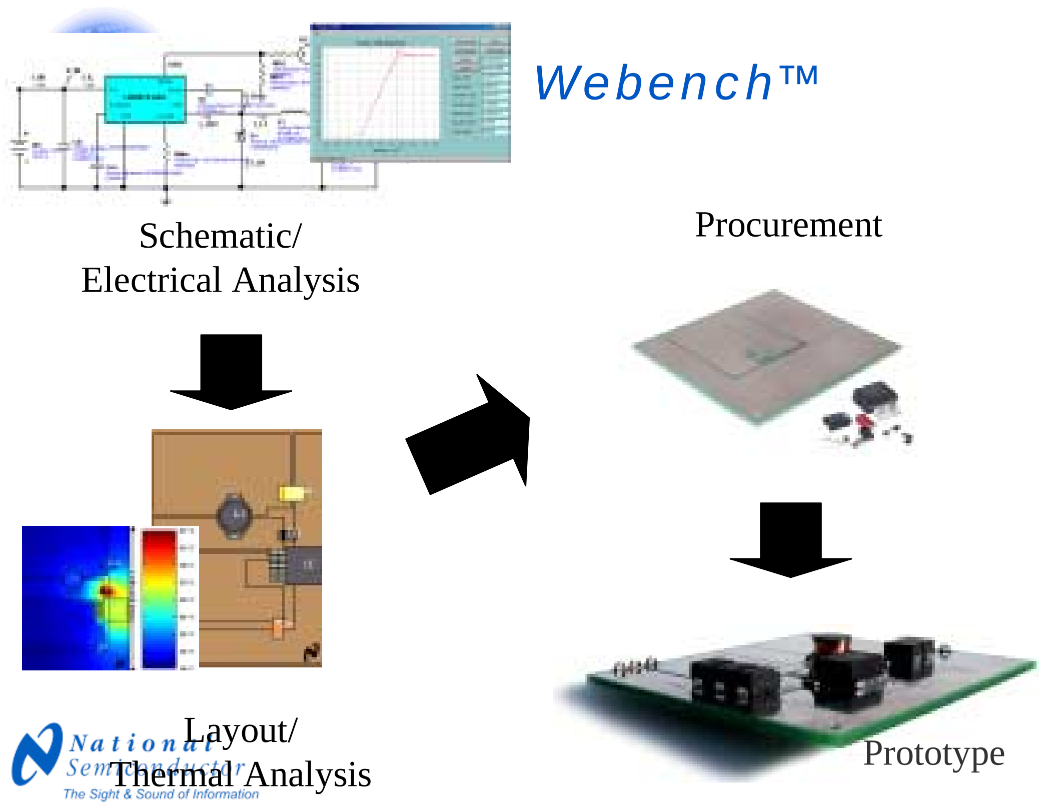
On the Buy It page of Build It you have a number of options to get your prototype quickly. Here you can get a custom kit for your design. This is sent to you within 2 days via overnight carrier. The kit has all the parts for your design which allows you to solder your prototype faster than ever. You can also order free samples of the National Semiconductor regulator (up to 5) or order larger quantities of the regulator. Lastly, if a generic demo board is available, you can order that. However the generic demo board is not customized to your design.



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