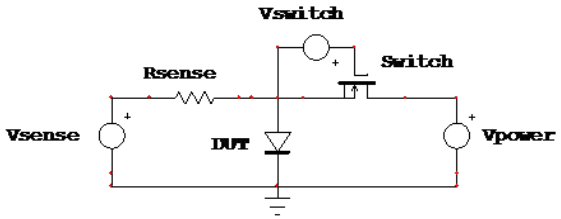
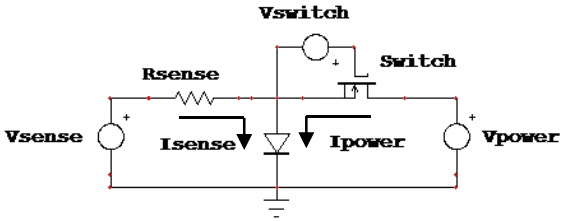
Great Wall Semiconductor
Thermal Measurement Method

July 9th, 2007

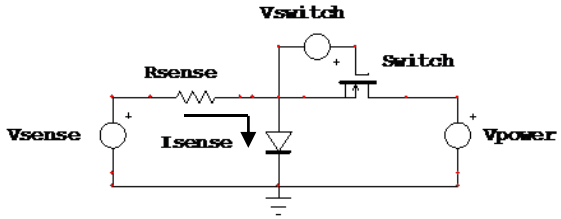
Basic Thermal Measurement Circuit and Method



Basic Test Circuit



High Current Device Heating

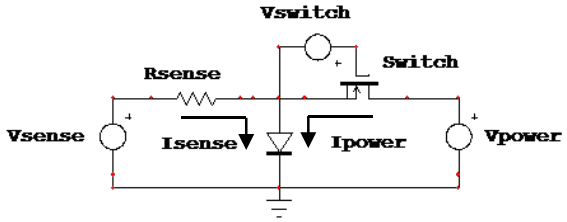


Vf Sense Measurement (~1ma)

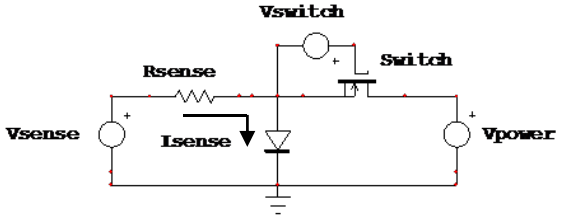
•The body diode of the MOSFET (DUT) is used for both heating and junction temperature measurement of the device.

•The device is forward biased with high current to provide device heating and then switched to low current levels for Vf temperature sensing.

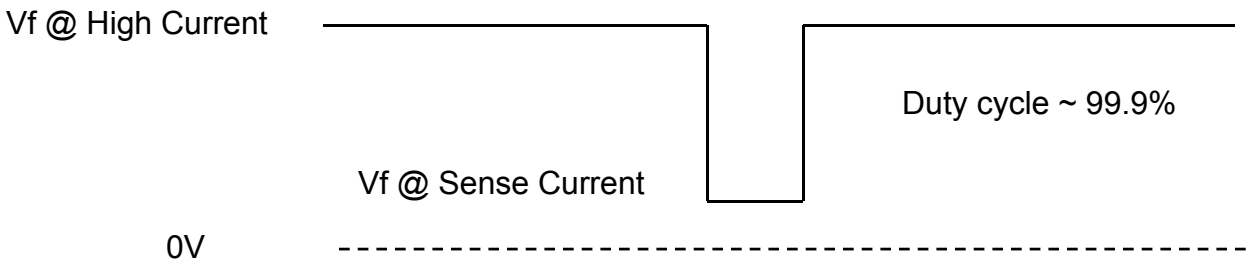
Basic Thermal Measurement Method



High Current Device Heating



Vf Sense Measurement (~1ma)



- The MOSFET body diode is forward biased with high current to heat up the device's junction. During this time, the Vf value measured is relatively high.
- To measure the junction temperature, the high current is briefly switched off and the Vf is measured at sense current level (~1ma).
- The switching between high and sense current levels continues at a duty cycle of ~ 99.9% which for all practical purposes is considered steady state power.

Basic Thermal Measurement Method

•Using pre-calibrated Vf sense measurements collected at 1ma versus temperature for the device, the Vf value measured during the sense current phase can tell us the devices junction temperature while under power.

•Measuring the Vf and total current during the heating phase tells us the power being consumed by the device (power = Vf * Iheating).

•Using the following equation we can then determine the thermal resistance from the devices junction to any reference point (θjr).

$$\theta jr = (Tj - Tr) / power$$

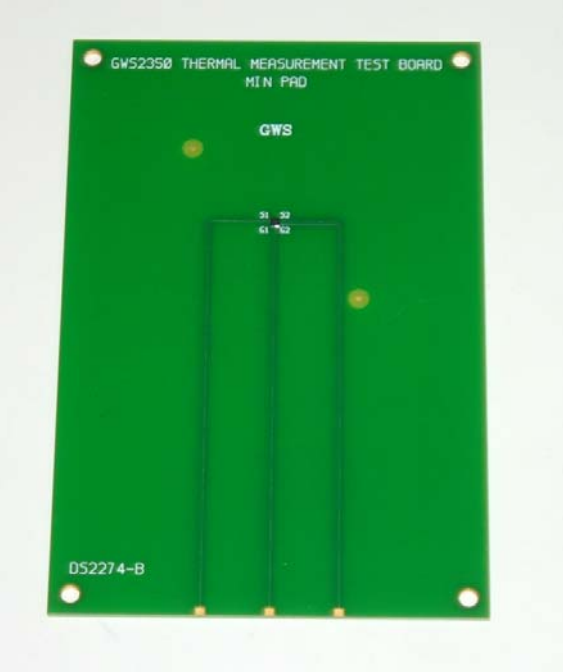
Where:

θjr = thermal resistance junction-to-reference point
Tj = junction temeprature
Tr = reference point temperature
power = power consumed by device during heating

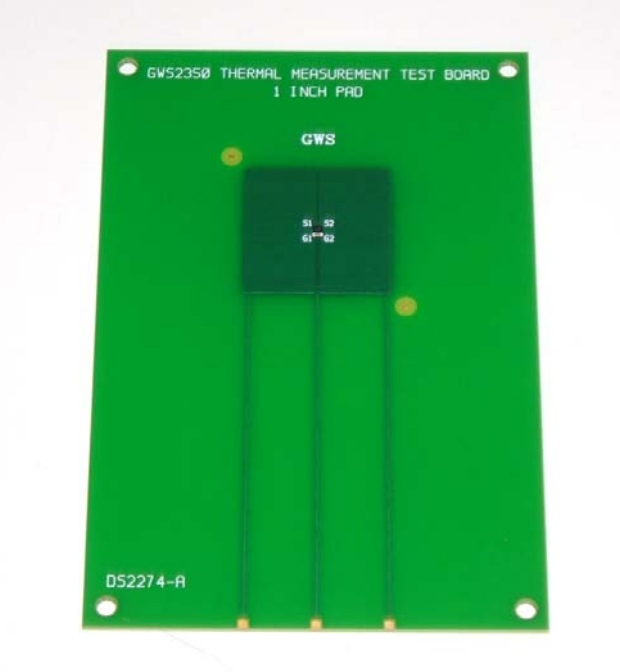
JEDEC Style Thermal Measurement Boards

•The thermal measurement board the device is mounted to has a significant impact on the actual values measured. For this reason, most manufactures follow JEDEC EIA/JESD 51-X series standards.

•Manufacture data sheets will generally indicate thermal resistance numbers based on measurements taken from either a Min Pad Board, 1inch Pad Board or both.



Min Pad Board



1inch Pad Board

Thermal Reference Points

•Thermal resistance is always listed from the device junction to some reference point. There are many reference points used in the industry

θja = Thermal Resistance Junction-to-Ambient (˚C/W)
θjc = Thermal Resistance Junction-to-Case (˚C/W)
θjb = Thermal Resistance Junction-to-Board (˚C/W) or, Junction-to-Ball

•In order to measure Junction-to-Ball thermal resistance, one would have to be able to measure the temperature of the solder ball surface. This isn't practical and any physical technique used to do so would most likely lead to errors in the measurement.

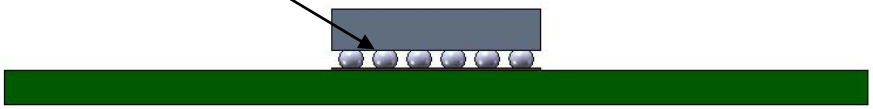
•In order to provide accurate Junction-to-Ball thermal resistance values, a good approach is to use a Finite Element Thermal Modeling technique.

•Finite Element Thermal Modeling techniques can be calibrated to actual thermal resistance measurements like Junction-to-Ambient or Junction-to - Case in order to improve the accuracy of the model.

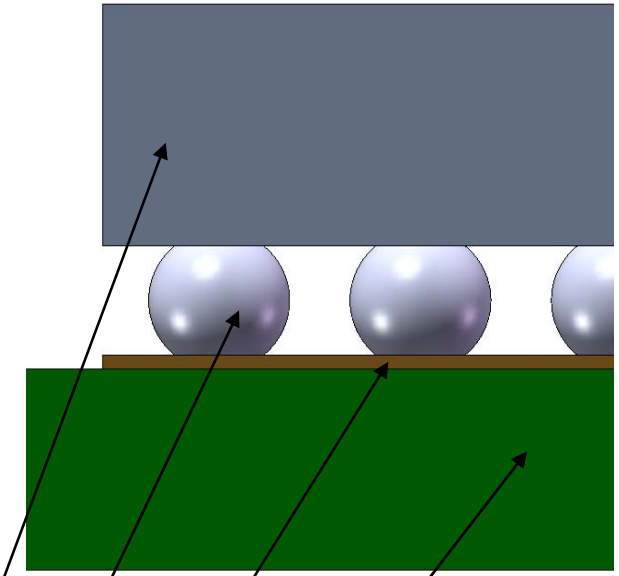
Finite Element Thermal Modeling

Materials and General Boundary Conditions

Junction Power loss = 1.0 W

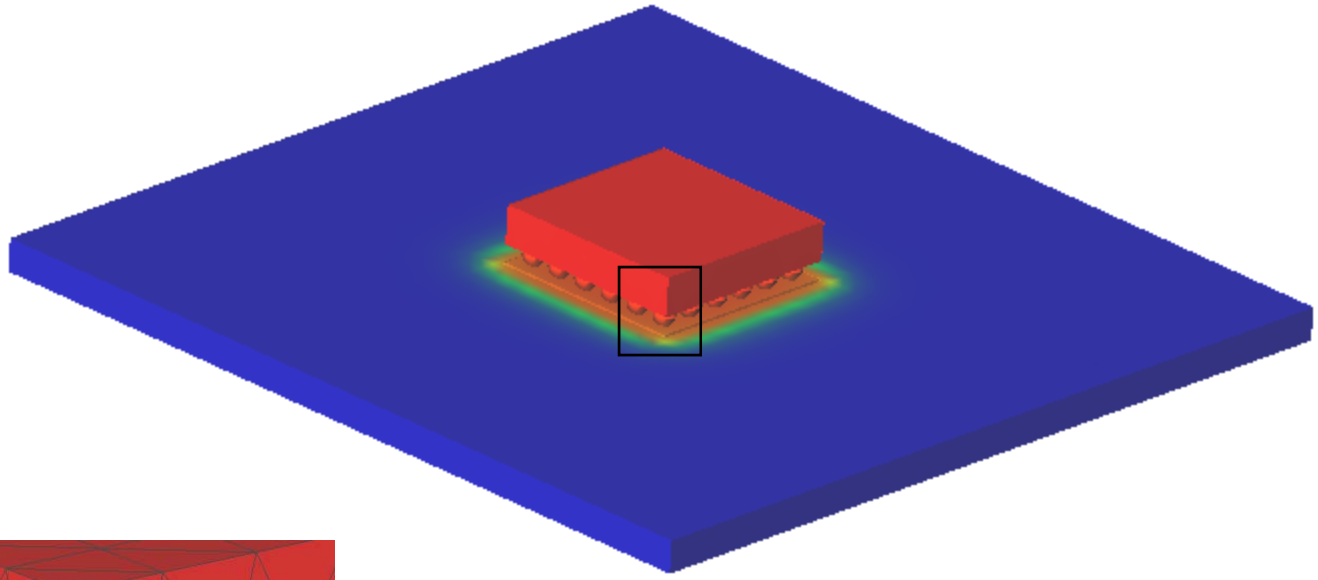


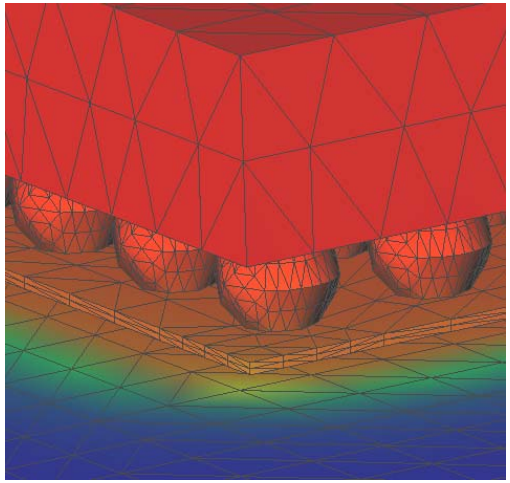
PCB Back side Temp = 25C



Silicon
Sn Solder
Cu PCB Metal
FR4 PCB substrate

Finite Element Thermal Modeling





Max Junction Temp: 50.96C
Max Ball Temp: 49.25C

$Rth_{J\text{-}Ball}$ = 1.71 C/W
$Rth_{J\text{-}Amb}$ = 25.96 C/W

Summary

•The MOSFET body diode can be used as both a heating element and a temperature sensing device for thermal resistance measurements.

•The PCB the device is mounted to when taking thermal measurements has a large impact on the actual values measured. The industry standard thermal measurements boards used are per JEDEC EIA/JESD 51-X series standards.

•MOSFET manufactures will specify thermal values based on either min-pad thermal boards, 1inch pad thermal boards or both.

•Junction-to-Ball thermal measurements are not physically practical to perform. As such, finite element thermal modeling techniques are used. These models can be calibrated to actual measurements of Junction-to-Ambient or Junction-to-Case in order to improve the models accuracy.

Parametric Comparisons for DC-DC Bump Configurations

Item	Parameter	Value			Unit
Bumps	Pitch	500	650	800	um
	Bump Dia.	350	350	500	
	# Bumps	36	25	16	#
	D-S Inductance	0.005	0.01	0.02	nH
PCB	Trace Space	0.150	0.256	0.362	mm
Thermals	Rthja	25.96	27.5	26.11	˚C/W
	Rthjb	1.71	3.20	1.97	
GWS24N07	$V_{(BR)DSS}$ (min)	8	8	8	V
	Rdson (Vg=4.5V) typ	1.25	1.28	1.3	mΩ
	Ciss (typ)	3000	3000	3000	pf
	Qg (typ)	21	21	21	nC
GWS15N15	$V_{(BR)DSS}$ (min)	15	15	15	V
	Rdson (Vg=4.5V) typ	2.8	2.85	2.9	mΩ
	Ciss (typ)	3000	3000	3000	pf
	Qg (typ)	24	24	24	nC
GWS12N30	$V_{(BR)DSS}$ (min)	30	30	30	V
	Rdson (Vg=4.5V) typ	5	5	5	mΩ
	Ciss (typ)	1500	1500	1500	pf
	Qg (typ)	14	14	14	nC
GWS6N60	$V_{(BR)DSS}$ (min)	60	60	60	V
	Rdson (Vg=8.0V) typ	17	17	17	mΩ
	Ciss (typ)	860	860	860	pf
	Qg (typ)	12	12	12	nC
GWS6N90	$V_{(BR)DSS}$ (min)	90	90	90	V
	Rdson (Vg=8.0V) typ	34	34	34	mΩ
	Ciss (typ)	580	580	580	pf
	Qg (typ)	9	9	9	nC