WBGlobalSemi, Inc.

SiC BJT Power Module With Intelligence Sam Ochi, VP Engineering, WBGS, Inc.

Power America RFI: Focus Area 3: Develop a simple to drive and use SIC BJT high power module to accelerate industry commercialization of SiC BJT devices and products.

BACKGROUND:

This power module is designed to be stackable and can be paralleled for either higher blocking voltages or greater currents.   Our design focuses on commercializing SiC BJT as it they show the most promise for many high power applications. Our target SiC BJT is a 6.5KV device that will be available for prototyping in CY 2019.

Proof of concept SiC BJTs have been fabricated and tested to 15KV. The main barriers to adoption are drivers, reference designs, and proven use cases. This RFI response addresses all three barriers to adoption with likely initial use cases in main grid, smart grid, and micro grid applications. A very current reference document from the Fraunhofer Institute, Erlangen, Germany is listed on page 2 of this document.

And our design approach can be applied to other SiC and GaN devices.

The SiC BJT power transistor has many of the high speed switching characteristics of SiC MOSFETs and GaN devices, without the problematic gate oxide issues which are probably most evident in high radiation field environments. Additionally, when compared to SiC IGBTs, BJTs lacks the well known layer junction issues that may trigger a four layer induced catastrophic latch-up that results in destruction of the IGBT.

The advantages of the BJT (and IGBTs) become clear at voltages above 1500V where conductivity modulation of the lightly doped drain areas significantly reduce effective on resistances for higher voltage 4.5KV and up devices. However, unlike the IGBT, the BJT has no diode in series with the main current path to cause an additional 2.5V or so of voltage drop.

For a 100A power device this amounts to 250Watts of additional power dissipation and a substantial 2.5KW for a 1000A device. Additionally, during turn-off, the IGBT can only rely on minority carrier lifetime reduction techniques to eliminate or remove the excess minority carriers prior to the device fully turning off, resulting in unwanted and energy robbing turn-off current tails. In contrast, the base of the BJT can be driven negative and with enough speed to sweep out the excess minority carriers during turn-off to approach the turn-off characteristics of SiC MOSFETs.

Regardless, it is well known that an MOS gate input with its simple high voltage gate inputs of +15V to +25V to turn on the device, and to apply a 0V or even some negative -5V to -10V to turn off the device are attractive features of MOSFET and IGBT devices. Further, the SiC or GaN MOS channel benefits of simply turning off immediately and without turn-off delays are hard to ignore.

This RFI serves to simplify the drive and thus the application of the SiC BJT by integrating into the SiC BJT power module an ASIC base driver that contains the circuits needed to simplify and at the same time take full advantages of the SiC BJT devices. The application focuses on SiC BJT devices designed for operation above 4.5KV so that the advantages over SiC MOSFETs and even SiC IGBTs are too compelling to ignore.

SPECIFICATION OF THE BASE DRIVER IC

The IC design incorporates the following key blocks to ease the driving and control of the SiC BJT:

1. Variable Base Drive Buck Regulator, VBDBR: This buck regulator takes the VCC= +15V input supply and converts to a base voltage needed to just turn-on the BJT. The BJT collector voltage is monitored and based on the base-current needed to sustain the VCEON voltage as measured by the Collector Voltage Sense, which is adjustable from 0.5V to 2V, the VBDBR. This circuit allows just enough base current to maintain the VCEON, and no more.

2. Collector voltage sensing: This circuit is a simple clamped attenuator so that as the VCE goes to ~ 6KV or so, the voltage is clamped to no more than a diode voltage above VCC. The voltage sensing is used primarily to discern the VCEON voltage which will be adjusted between 0.5V to 2V. This adjustment can either be done upon start-up and programmed into memory during start-up of the IC or simply hard-wired.
3. VDD Supply Generator. This is a low power VDD generator used primarily to power analog and digital CMOS circuits, either 1.8V or 5V depending on the process technology within the IC.
4. Base Driver: This circuit will provide an initial high current pulse to first turn on the BJT quickly. Once turned on as defined by the VCEON measured to be under pre-defined VCEON voltage, the Base Driver uses the output of the VBDBR to reduce the base current drive. This also reduces power dissipation and power consumption of the drive circuit system.
5. Emitter Current Sense Circuit: The IC uses a virtual ground Op Amp technique to monitor the current flowing from the mirror emitter of the driven BJT. This value of this emitter current when compared to the measured VCEON determines the base current provided by the IC.
6. Digital Logic, Timer, and Control Program Memory: This block can be used to provide variable programmed delays to provide precise turn and turn-off timing useful in stacking power devices for greater blocking voltage applications.

Basic block diagrams can be referenced on pages 3 and 4 of this RFI.

For more information on the development of standard power modules see:

Modular Multilevel Submodules for Converters, from the State of the Art to Future Trends

PCIM 2018 Conference, June 7th 2018 , Nurnberg, Germany

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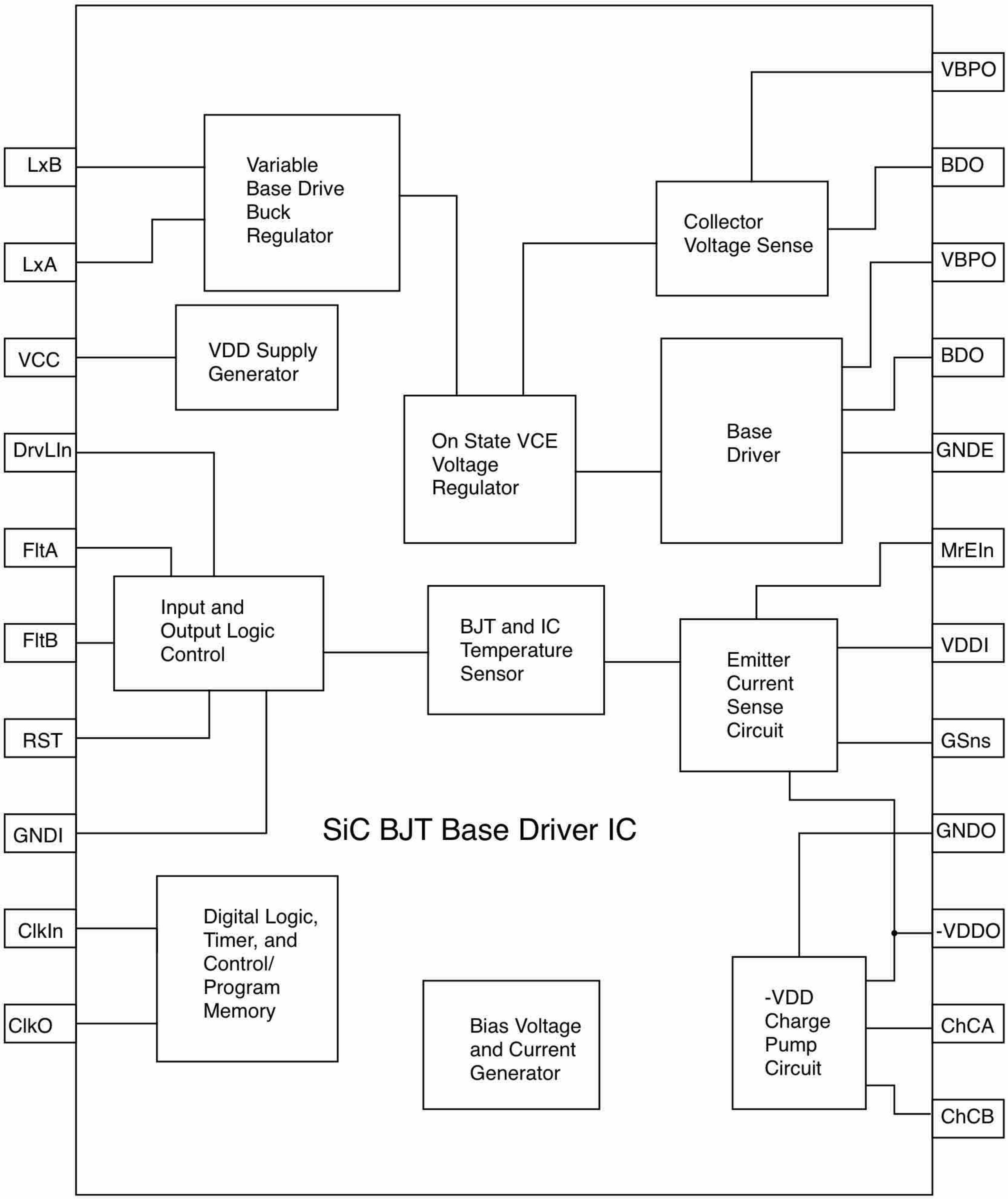

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