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Wide Band Gap Academy—Education and Workforce Development for the 21st Century Power Electronics and Power Systems Industries

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Introduction

Power electronics convert, control, and distribute electrical power across our national grid system and in an enormous array of commercial, consumer, and military products. The future of power electronics is centered on wide band gap (WBG) semiconductor technologies such as the ones used in LED lighting. WBG-based power electronics are extremely compact and energy efficient, which translates to lower manufacturing and operating costs (Semiconductor Science and Technology, (2016)). However, there are several new skills that must be mastered in order to effectively and efficiently design with WBG based components. To meet this challenge, we are establishing the Wide Band Gap (WBG) Academy

Methodology

The overarching mission of the WBG Academy is to act as a catalyst in building a WBG semiconductor-centric education ecosystem that enables individuals to attain the skills required to enter the career pathways of design, development, and manufacturing of new and innovative WBG-enabled technologies and products.

Other components of the course include:

- Functionality of basic test equipment, including; Oscilloscopes, multimeters, and function generators.
- Detailed circuit analysis of a Buck converter that is to be constructed so that participants will gain an intuitive understanding of its method of operation.
- Proper soldering techniques before commencing the assembly of the buck converter and its associated components.
- Testing and troubleshooting of fully assembled Buck converter built by course participants.

Proposed Course Outline

The course has been broken into four separate modules with topics and objectives detailed for each module.

Module I: Basics of electronics

- *Kirchhoff's Laws* - An overview of current and voltage laws pertaining to circuits. A few example problems with solutions will be shown.
- *Ohm's Law* - Review of Ohm's Law (V=IR) and how it is used to calculate power in circuits.
- *Basic Electronic Components* - An overview of resistors, capacitors, inductors, diodes, MOSFETs, BJTs, and Op-Amps. Explanations of their operation and uses will be given.
- *Basic Electronic Topologies* - A detailed review of functional "building block" topologies, such as amplifiers and rectifiers, will be given so that participants gain an intuitive understanding of how the previously explained components are used at a system level.
- *Examples of Electronic Systems* - Following discussion of basic topologies, high level systems (such as radios, audio amplifiers, etc) will be explained using "groups" of the previously mentioned topologies.

Proposed Course Outline (Continued)

Module II: Power Electronics and Systems

- *Transformers and AC distribution* - Principles of AC power distribution including step-up/step-down transformers, admittance, power generation. Students will gain an understanding of the importance and versatility of AC power distribution while also being exposed to alternative power distribution methods, such as HVDC, in the subsequent module.
- *Electric Motors* - Basic electric motor operation and relation to electric generators. New advances in this area, mainly pertaining to electric vehicles will be discussed. The increasing practicality of electric motor vehicles, coupled with advanced in battery technology, will also be discussed.
- *Power Supplies* - Switch mode power supplies, inverters, full/half bridge converters, associated filters and voltage regulators.
- *DC-DC Converters* - Buck, Boost, Buck-Boost, and Cuk converters. This topic will be re-visited in the lab portion of the course.

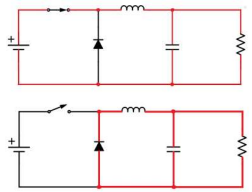

Figure 1: Buck converter "on-off" operation.

Module III: Wide Band Gap Semiconductors and Their Impact

- *Semiconductor Devices* - Review of semiconductor devices and their role in electronic circuits. The focus will first be on Si and its use in MOSFETs, BJTs, and diodes.
- *Wide Band Gap Semiconductor Devices* - WBG materials, (GaN and SiC) will be introduced and explained.
- *Comparisons of Technologies* - Comparisons between Si, GaN, SiC materials will be discussed and the material based advantages of WBG devices will be detailed.
- *Applications of WBG devices* - Operational advantages of WBG devices will be discussed in context of use in DC-DC converters, power supplies, electric motors, power distribution, and smart grid applications.
- *Case Studies* - Examples of WBG device implementation in current use. Such as in high performance power converters and military applications, will be discussed.
- *Implications for the Future* - Discuss future applications of WBG devices and their importance to the proliferation of sustainable technologies.

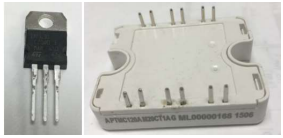

Figure 2: Si-Based MOSFET (left). 3.2kV SiC MOSFET.

Proposed Course Outline (Continued)

Module IV: Lab and Demonstration

- *Test Equipment Overview* - Overview of basic test equipment that is to be used during the lab (Oscilloscope, function generator, multimeter, power supply). Demonstration of how to measure current and voltage.

Figure 3: Detailed instruction on test equipment functionality will be provided.

- *Soldering Techniques* - Demonstration of proper soldering in preparation for buck converter assembly.
- *Buck Converter Analysis* - Detailed explanation of the operation of the buck converter that will be built during the lab. This will include explanation of continuous and discontinuous operating modes.
- *Buck Converter Component Analysis* - Detailed explanation of the components used in the buck converter (MOSFET, inductor, capacitor) in the context of their respective roles in the overall operation of the converter.
- *Construction of Buck Converters* - The course participants will be mentored through the soldering and assembly of a fully functioning buck converter.
- *Testing of Buck Converters* - Assembled Buck converters will be tested using the available test equipment. Switching waveforms will be analyzed and discussed.
- *Demonstration of GaN Based Converter* - A pre-assembled GaN based Buck converter will be used to demonstrate the operational advantages of WBG devices.

Lab Practical Section - Details

A central component of the course is the practical lab section. Through the assembly of a Buck converter, the participants will gain experience in test equipment operation, soldering techniques, and the electronic functionality of a Buck converter.

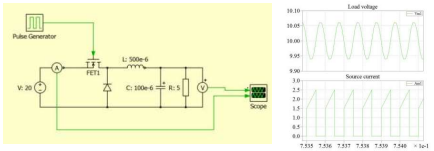

Figure 4: Circuit and simulation of proposed Buck Converter to be built by course participants.

Lab Practical Section – Details (Continued)

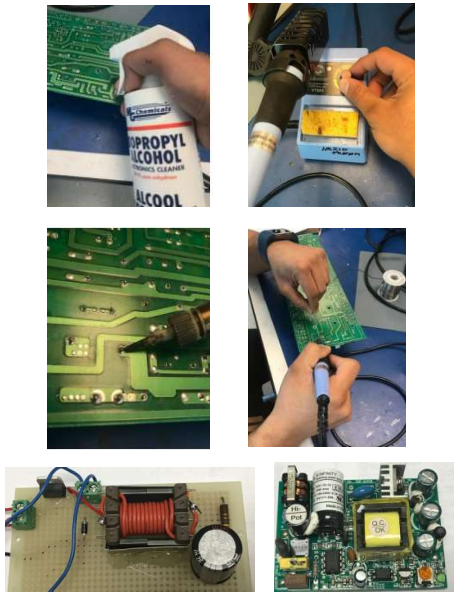

Figure 5: Images showing soldiering techniques detailed in the practical lab section and the proposed Buck converter to be assembled by course participants.

Conclusions

Through this course, participants will gain a basic understanding of the laws of circuit analysis, familiarity with basic electronic components, topologies and electronic systems relating to power conversion and distribution. Furthermore, familiarity with the operation of WBG devices and how they compare to traditional semiconductor devices and an understanding of the wide ranging applications and broad implications of WBG technology is detailed. Familiarity with basic test equipment, soldering techniques, and electronic circuit construction/testing is also gained. The practical section emphasizes an understanding of the operation of a Buck converter and the role of each of its constituent components. Lastly, participants gain an understanding of the advantages of WBG devices through demonstration of a GaN based Buck converter and participant assembled Si based Buck converter.

References

Suda, Jun, et al. "Special issue on wide-bandgap semiconductor power electronics." *Semiconductor Science and Technology* 31.3 (2016): 030301.