Education News

Student High-Efficiency Power Amplifier Design Competition

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Wireless communications is becoming more and more important. Cellular telephones, WiFi connections, Internet, television, and audio broadcasts directly from satellites are now part of our life. All these and many more applications depend on the efficient conversion of electrical power to RF and microwave signals. The conversion of electrical power usually in the form of dc voltage to a transmittable level of electromagnetic energy is the task of a microwave power amplifier (PA). Without efficient amplifiers, cell phones would not be practical because the batteries would not last sufficiently long. Efficient amplifiers are vital for satellite communications where the usefulness of a satellite is limited by the power available from its solar cells.

Despite the growing importance of RF and microwave technology in our lives, its study has not attracted the attention it should. Engineering students have favored more flashy computer and digital electronics, and the number of university students interested in microwave engineering has been on a decline despite high demands in the job market for graduates with these skills. The lack of new engineering graduates prepared to work in this field has become a concern of the IEEE's Microwave Techniques and Technology Society (MTT-S). As one step in remedying this situation, the MTT's Microwave High Power Amplifier Components Technical Coordinating Committee (MTT-5) in 2005 decided to sponsor a Student High-Efficiency Power Amplifier Design Competition. MTT-5 felt the contest might attract students to the study of microwave electronics by providing them an exciting challenge and at the least make them aware of its importance to our society.

Producing a working microwave PA is not easy. Both theoretical and practical skills are needed. To design a PA with the highest efficiency takes not only exceptional modeling ability but also knowledge of devices, materials and layout, creativity, and the capability to fabricate and test. The contests give students the opportunity to take a design from conception to a final result and experience the exhilaration of transforming an idea into reality.

The first competition took place at the 2005 International Microwave Symposium (IMS) in Long Beach, California, and the second competition was at the 2006 IMS in San Francisco, California. In 2007, the contest will be held at the IMS in Honolulu, Hawaii. IMS attracts authors from all over the world and is considered the most prestigious microwave conference.

Announcements of the contest are sent to universities throughout the world offering microwave-related study, are posted on the MTT-5 web site (http://www.mtt.org/committees/mtt-5/index.htm), and published in *IEEE Microwave Magazine* (see the contest announcement in this department). Both undergraduate students and graduate students are encouraged to enter. The contest rules require the PA to operate at a frequency greater than 1 GHz but less than 20 GHz and produce an output power of greater than 5 W, but less than 100 W into a 50-Ω load. The winning entry is the PA that demonstrates the highest power-added efficiency (PAE) during testing [PAE is defined as the (RF power out–RF power in)/(dc power)]. The contest takes place in the IMS Interactive Forum area during the Student Paper Competition. IMS attendees can observe the student contestant entries being measured at that time, an event that has drawn quite a crowd of observers. The results are on display during the session as they are measured. The winner receives a prize of US$1,000 and is invited to submit a paper describing the design to *IEEE Microwave Magazine*. All participants

Figure 1. *Calibrating the test setup at IMS 2006, San Francisco, California.*

Figure 2. *Getting set to measure a contestant's PA at IMS 2006.*

are invited to the Student Awards Luncheon and receive an Outstanding Achievement Award certificate, while the winner receives the Highest Efficiency Award.

The PAs are fabricated and tested prior to the contest and carried to IMS by the team members. The test equipment used to evaluate the PAs is provided by Agilent Technologies and has centered about a PNA vector network analyzer programmed to display PAE (Figure 1). Special thanks must be given to the Agilent and its volunteers headed by Dr. Ken Wong for their assistance with the measurements.

Each contestant is given time to optimize the bias of their amplifiers for the best efficiency, but no tuning is allowed. Most of the PAs operate near the minimum frequency of 1 GHz where high efficiency should most easily be achieved. The PAs are judged by a team of MTT-5 members headed by noted PA designer and author Steve Cripps (Figure 2).

The first competition attracted entries from students attending universities from around the world. Competitors came from Ecole Polytechnique de Montréal; Sogang University, Korea; University of California, Davis; University of California, San Diego; University of South Florida; and POSTECH University, Korea. The winning entry came from the University of South

TABLE 1. Final standings from the 2nd Annual Student Power Amplifier Competition.

Student	Advisor	Affiliation	Pout	Pin	Vdc/Idc	PAE	Technology	Design
Young Yun Woo	Prof. Bumman Kim	POSTECH (Pohang University of Science and Technology), Korea	36.965 dBm	20.003 dBm	26 V, 0.247 A	75.9%	Si LDMOS	1 GHz Inverse Class F
Hyunchul Park	Prof. Youngoo Yang	School of Information and Communication Engineering, Sungkyunkwan University, Suwon, Korea	37.105 dBm	22.13 dBm	28 V, 0.242 A	73.3%	Si LDMOS	1.2 GHz, Class F
Hyunchul Park	Prof. Youngoo Yang	School of Information and Communication Engineering Sungkyunkwan University, Suwon, Korea	36.947 dBm	21.946 dBm	31 V, 0.214 A	72.3%	Si LDMOS	1.2 GHz, Class F
David Schmelzer	Prof. Stephen Long	Department of ECE, University of California Santa Barbara	39.935 dBm	25.163 dBm	41.96 V, 0.337 A	67.3%	GaN HEMT	2 GHz, Class F
Nicholas Vacirca, Steve Hendrickson	Prof. Allen Katz, Dr. Marc Franco, Dr. Robert McGwier	The College of New Jersey	37.1 dBm	25.0 dBm	27 V, 0.29 A	61.5%	GaN HEMT	2.4 GHz, Class C
Jonathan Graham	Dr. J. Alan C. Webb	Department of Mechanical Engineering Technology, The Open University, United Kingdom	36.99 dBm	25.0 dBm	6.816 V, 1.223 A	56.2%	GaAs	1 GHz, Inverse Class F
Hoang V. Nguyen	J. Gauthier, Prof. C. Caloz	Poly-Grames Research Center, Ecole Polytechnique de Montreal	45.4 dBm	24.95 dBm	26 V, 2.878 A	45.9%	Si LDMOS	1 GHz, Class AB

Florida and was designed by Sonoko Akamatsu and advised by Prof. Larry Dunleavy. It produced an efficiency of 61.7% and operated near 1.5 GHz using a GaAs power FET in a circuit design modeled using software developed by Prof. Dunleavy. Since then Prof. Dunleavy has made his software available to all contestants through his company, Modelithics, Inc.

In 2006 the number of entries nearly doubled with contestants from Sungkyunkwan University, Korea; Ecole Polytechnique de Montreal; Ferdinand-Braun-Institut fuer Hoechstfrequenztechnik, Germany; University of California, Santa Barbara; University of Minnesota; The College of New Jersey; POSTECH University, Korea; Arizona State University; and The Open University, United Kingdom. Several of the universities had multiple entries. There was fierce competition with the contest ending in a near heat between three Korean entries (Table 1). Young Yun Woo from POSTECH captured first place with 75.9% PAE from a 1 GHz inverse class F Si LDMOS FET PA. He was closely followed by two entries from Sungkyunkwan University at 73.3% and 72.3% using similar class F designs, at 1.2 GHz. Next were UC-Santa Barbara with 67.3%, also from a class F PA but using a GaN HEMT at 2 GHz, and The College of New Jersey, with 61.7% from a class C GaN HEMET at 2.4 GHz. The College of New Jersey entry was the only class C design and the only entry from an undergraduate group.

Award certificates and the US$1,000 prize were presented at the Student Awards Luncheon at IMS 2006 in San Francisco (Figure 3).

Figure 3. *The Highest Efficiency Award is presented to Young Yun Woo by MTT-5 Chairman Dr. Jim Komiak.*

Interest is already building for the 2007 contest in Honolulu. It is not too early to start working on your design!

IMS 2007 Contest Announcement Student High-Efficiency Power Amplifier Design Competition

MTT-5 (High Power Amplifier Components) is pleased to announce the third Student High Efficiency Power Amplifier Design Competition, which will take place at the 2007 IEEE MTT-S International Microwave Symposium (IMS) in Honolulu, Hawaii.

This competition is open to all students and graduate students registered at an educational establishment. The competitors are required to design, construct, and measure a high-efficiency power amplifier, at a frequency of their choice above 1 GHz but less than 20 GHz, and having an output power level of at least 5 W but less than 100 W. The winner will be judged on the design that demonstrates the highest power-added efficiency (PAE). The power amplifiers must be brought to IMS 2007, where they will be tested to verify their performance. A representative of the design group must be present at the testing to assist with the evaluation. The winner will receive a prize of US$1000 and will be invited to submit a paper describing the design and the experience for *IEEE Microwave Magazine*. Questions can be sent to Dr. Kiki Ikossi at ikossi@ieee.org. Support for the testing is provided by Agilent Technologies. Modelithics, Inc. is offering models for student use in their power amplifier designs. Visit http://www.modelithics.com/trial.shtml (code PA_Comp_2007).

PA Competition Rules

1) The power amplifier (PA) design may use any type of technology but must be the result of student effort both in the amplifier design and fabrication.
2) The PA mechanical design should allow for internal inspection of all relevant components and circuit elements. The RF ports should be standard coaxial connectors, type N or SMA.
3) The PA must operate at a frequency of greater than 1 GHz but less than 20 GHz and have an output power level of at least 5 W but less than 100 W.
4) All amplifiers should require less than 25 dBm of input power to reach the output level required for maximum efficiency.
5) Amplifier entries should be submitted with measured data, including dc supply requirements, frequency, RF drive, output power, and PAE. PAE will be defined as $(RF_{out} - RF_{in})$/dc. Measurements will be under CW operation at room ambient conditions into a 50-Ω load. Only the power at the fundamental CW frequency will be included in the measurement of output power.
6) The decision will be based solely on the amplifier's PAE efficiency measured during official testing at IMS 2007. Award certificates will be presented to all participants at the Student Awards Luncheon. The decision of the judges will be final.

Contestants must notify the MTT-5 committee by e-mailing to Dr. Ikossi (ikossi@ieee.org) of their intention to compete in the contest before 1 April 2007. This notification should include information on the university or educational affiliation of the entry, the faculty advisor, and the PA's approximate power level, dc voltage requirements, and frequency of operation.