

# **High Power RF LDMOS Transistors for Avionics Applications**

**A novel approach to the use of LDMOS transistors in pulsed Avionics Applications**

**By**

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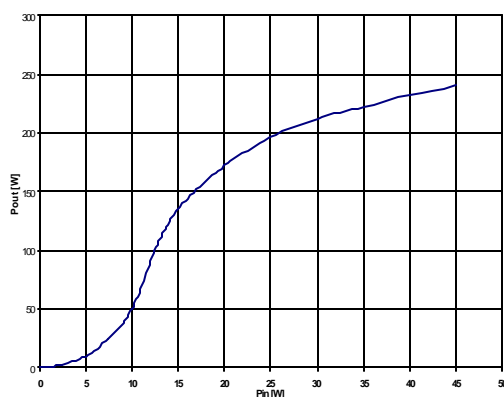
## **Introduction:**

Today's continuous growth of airborne freeways, adds new challenges in safety and efficiency which will impact the design of the transponder. Traditional ground based air traffic control systems excel in managing incoming/outgoing routes but lack the real-time performance in airborne Traffic Collision Avoidance Systems (TCAS). Onboard every commercial/Military aircraft, these transponders transmit and receive essential data such as forward speed, altitude, and coordinates to other aircraft occupying similar airspace. This data is disseminated by the transponder and provides the pilot instructions to safely direct the flight path. In addition, flight crews depend of other safety features like weather radar, distance measuring, navigation and communications. As the number of aircraft "tools" increase, space becomes a premium within the electronics bay. System redundancy also detracts from available room. As TCAS shares the same frequency domain as other critical systems, integration of "multi-box" units into one is becoming the most recent design criteria. Consolidation offers reduction in overall size and weight enhancing installation and maintenance. A "multi-box" concept also reduces the number of power supplies and related circuitry improving overall power efficiencies. Utilizing one multi-function transponder should also improve overall costs in procurement, installation and maintenance.

With multi-carrier operation, managing critical performance factors such as pulse shapes can be difficult. Pulse on-off transition times, linearity, compression all come into play. Maximizing overall power added efficiency reducing surrounding ambient bay temperatures using less DC current is also a concern. This article is dedicated to devices that will greatly improve this performance. It is a discussion regarding the Microwave power amplifiers used in TCAS transponders and where the latest LDMOS technology has taken this application. Differences in traditional common-base configuration, Class C bipolars versus linear, higher gain, lateral structure FET's. The used LDMOS technology wasv originally designed for use in GSM and PCS base station cellular sites. Minor optimizations in the technology have made the structure extremely suitable for avionics applications. The line-up discussed in this article features a 200-watt output part using an all-gold metal system. Enhancements were made to the gates for this application as well as input and output matching over the 1030-1090 MHz frequency band.

### **Device performance: high gain and good gain linearity over large dynamic range.**

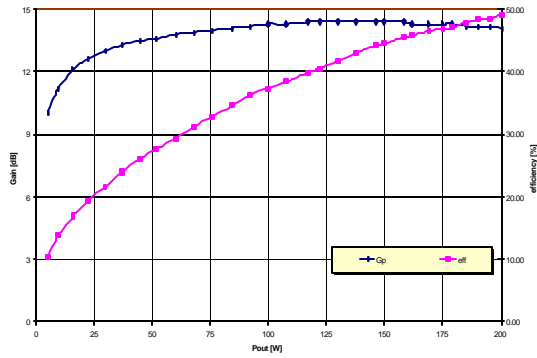
Up to now amplifiers were designed with bipolar devices which imposed a number of problems when designing the complete line-up with the above mentioned requirements taken into consideration. The most significant of these being the gain linearity over a large dynamic range of the output power. In



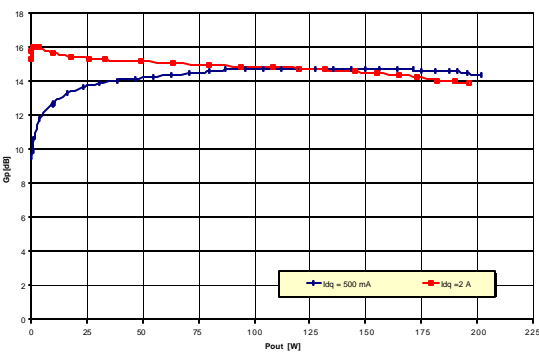
**Figure 1 :** Typical plot  $P_L$  vs  $P_{IN}$  Bipolar transistor.

figure 1 a typical plot of the output power versus input power of a 200 W bipolar transistor, intended for use in Avionics Applications, is depicted. It can be seen that the gain varies over the entire range of the input power. Obviously using such a device has serious implications for the gain linearity of the entire line-up. A device using LDMOS technology was used to overcome these problems. With this technology devices can be made which show an excellent linearity over a large dynamic range. In figure 2 the gain and efficiency versus output power for such a LDMOS device is depicted. At 200W the device is still far from saturation, with a dynamic range of more than 30 dB. Moreover

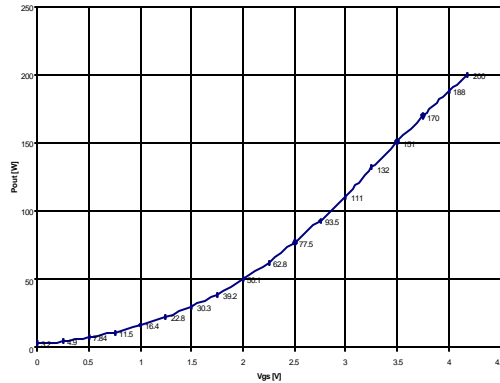
the device has a typical gain of 14 dB compared to the typical 8 dB of bipolar devices. This means that a considerable reduction in number of components and reduction of PC-board space can be achieved for the complete line-up. In addition overall power added efficiency is improved.



**Figure 2 :** Gain and efficiency as function of output power at low quiescent current (150mA).

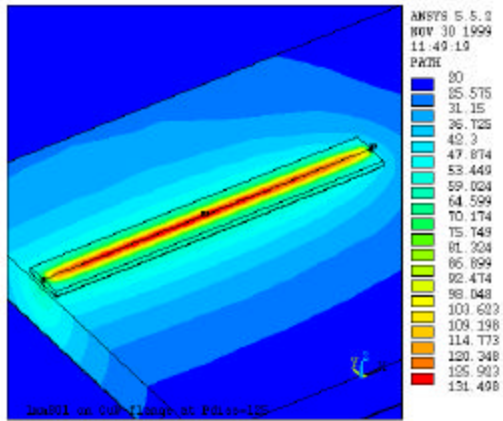


**Figure 3 :** Gain as function of output power at different values of quiescent current.

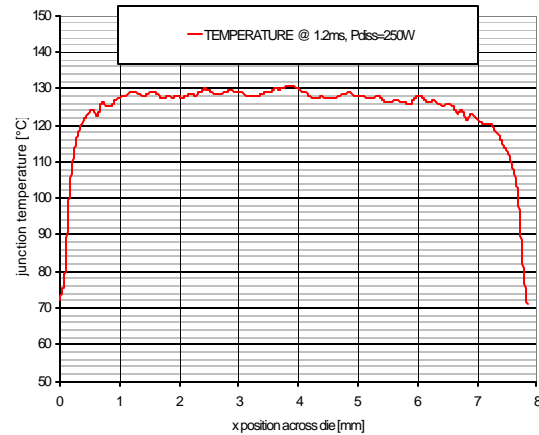


## High reliability by gold metallization and good thermal behaviour.

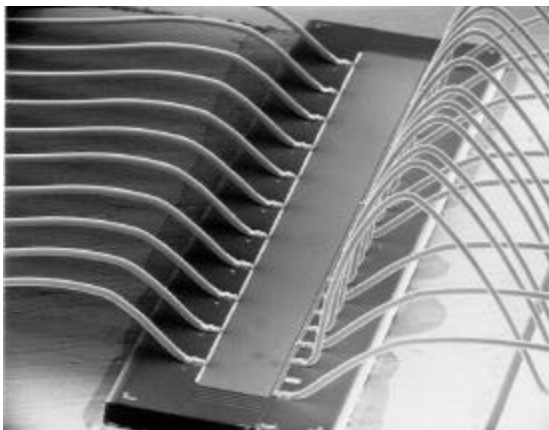
One big advantage of LDMOST compared to bipolar is that the mode of operation is common source (source connected to ground) reducing parasitic source inductance combined with an excellent thermal interface. In bipolars the bulk of the material is the collector which has to be electrically isolated from ground (which is usually the heatsink) without degrading the thermal impedance. This results in a better thermal behaviour of the LDMOST compared to the bipolar. In figure 6 and 7 the results of thermal transient Finite Element Method (FEM) simulations for the used die are depicted.



**Figure 6:** Temperature distribution in SOT502 at  $t=1.2\text{ms}$ ,  $I_h=50\%$ ,  $P_{\text{diss}}=250\text{W}$  and  $T_{\text{hs}}=20^\circ\text{C}$ .



**Figure 7:** Temperature profile in SOT502 at  $t=1.2\text{ms}$ ,  $I_h=50\%$ ,  $P_{\text{diss}}=250\text{W}$  and  $T_{\text{hs}}=20^\circ\text{C}$ .

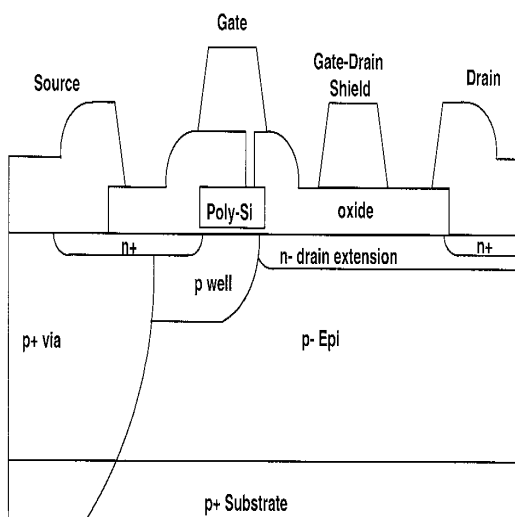


**Figure 8 :** Wirebonding of single LDMOST die

In the simulations a uniform distribution of power is illustrated, under RF conditions. This uniformity will largely be dominated by the quality of the assembly process of the device. The quality and consistency of the assembly process is largely depending on the use of automated die attach and wire bond equipment, minimising lot to lot variation (see figure 8).

## Technology.

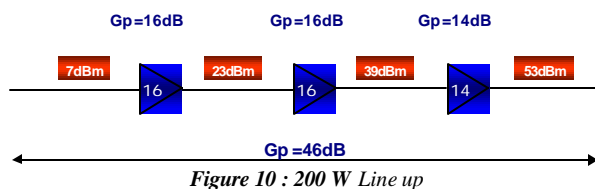
Figure 9 shows the cross section of an LDMOST structure. The  $P^+$  via is to ensure good electrical contact between the source contact and ground, and eliminates the use of source bonding wires which lowers the source inductance and increases the intrinsic device gain. Between gate and drain a shielding is placed to reduce the feedback capacitance. The die technology used in 200W device is based on 1 GHz technology optimised for the specific requirements of avionics applications. Enhanced gate periphery is used in the 200W device. Also the design is optimised to meet the required gain linearity over a large dynamic range, this will improve both gain and IMD performance as well as the RF stability of the device. The MonoMOS structure –the



**Figure 9 :** Cross section 1 GHz technology LDMOST

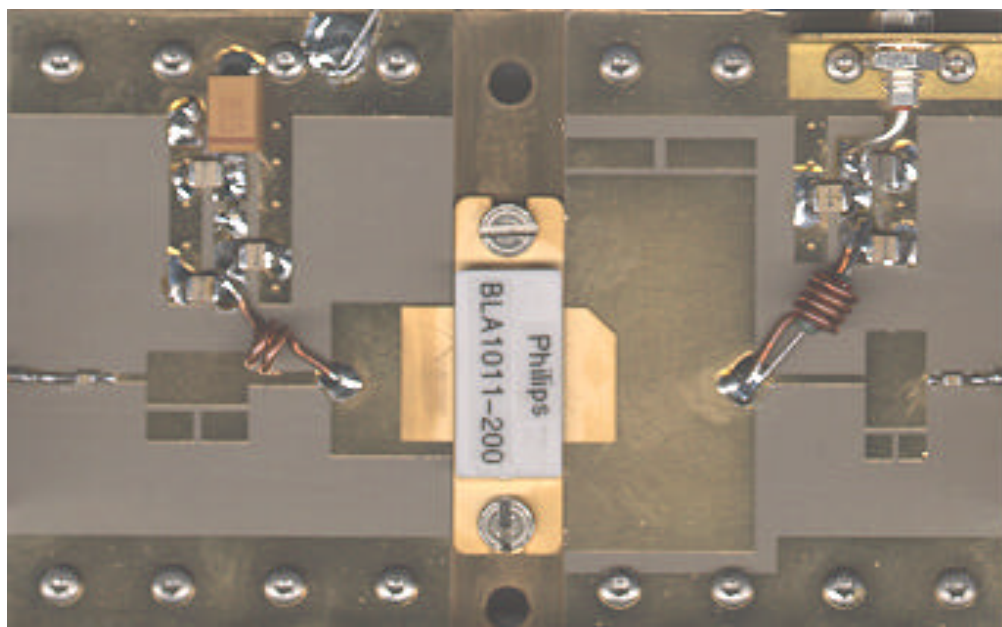
separate active areas of a conventional high power RF die are replaced by one highly integrated area- lends itself to incorporate internal input and output matching in an easy way. The MonoMOS uses metallized gates to reduce series resistance in order to increase power gain. The structure was designed for minimum  $I_{dq}$  drift. Without any burn-in, the typical  $I_{dq}$  drift is below 10% over 20 years. The gold top metallization in combination with the gold bond wires avoids inter metallic issues where the flexibility of gold compared to aluminium bond wires ensure excellent reliability under pulsed operation. The concept of this die has proven to be very reliable, based on large volume production in base station products. In order to provide a cost effective approach, the device uses a commercial off the shelf non-hermetic package.

#### Application information.



In figure 10 the total line up of a 200 W LDMOS amplifier is given. The overall gain of 46 dB is achieved using three amplifier stages. A comparable bipolar line up would consist of approximately six amplifier stages –depending on individual device gain- to reach similar overall gain. Figure 11 shows the application circuit for the 200W device used for the

characterisation contained in this report. This device contains internal input and output matching which makes the design of the application circuit simple. The internal matching brings the device impedances to a level which is favourable in a manufacturing environment. Higher impedances create a situation which is less critical for component placement and substrate tolerances, enhancing final test yield while eliminating rework.



**Figure 11:** Application Circuit of LDMOS 200W device for 1030-1090 MHz,  $\epsilon_r=6.15$

**Conclusion:**

The use of LDMOS transistors in Avionics amplifiers greatly improves design architecture.

- These parts are designed, built and tested for avionics applications.
- Improved RF performance meets or exceeds Avionics critical performance factors.
- Higher device gains reduce number of transistors and surrounding circuitry, minimising real estate and simplifying overall amplifier design.
- Overall cost savings due to lower part count.
- Higher power added efficiency will reduce power supply cost.
- High reliability due to proven “all gold metallization system” and improved thermal performance.
- Automated die attach and wire bonding equipment, ensures device consistency in large volume production, which will enhance customer yield and reduce rework.

**About the authors:**

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