HIGH PERFORMANCE SINGLE SUPPLY POWER AMPLIFIERS FOR GSM AND DCS APPLICATIONS USING TRUE ENHANCEMENT MODE FET TECHNOLOGY

Elizabeth Glass, Michael Shields, Adolfo Reyes

Motorola, Inc. Semiconductor Product Sector 2100 E. Elliot Road M/D EL720 Tempe, AZ 85284

Abstract - ***Two high performance single supply power amplifier IC products have been developed for GSM and DCS applications using true enhancement mode FET technology. At VD=3.2V, under CW conditions, the GSM IC supplies +35.5 dBm output power at 58% PAE and the DCS IC supplies +33.5 dBm at 46% PAE. These ICs have low leakage currents similar to HBT and LDMOS and do not require the use of a drain switch. In addition, due to a high threshold voltage (Vth=+0.6V), they exhibit excellent RF isolation at Vref=0.1V and Pin=+5 dBm and do not require on-chip attenuators.***

I. INTRODUCTION

Single supply GSM and DCS ICs utilizing quasi-enhancement mode technologies have been reported [1]-[2]. Their off-state leakage currents are high and they require the use of a drain switch. In addition, their low threshold voltages prevent them from supplying the required RF isolation at Vref=0.1V with Pin=+5dBm and consequently they require the use of an on-chip attenuator which degrades noise performance.

The true enhancement mode FET technology that we have reported on previously [3]-[5] has extremely low off-state leakage current similar to HBT and LDMOS technologies and eliminates the need for a drain supply switch. The high threshold voltage, (Vth=+0.6V), in comparison to the quasi-enhancement mode E-HEMT's (Vth=0V to +0.3V) prevents the amplifier from being turned on by the RF signal (+5dBm) when in the off state (Vcont=0.1V). Incidentally, the high threshold voltage does not degrade the maximum current available from the device.

FET technology is an excellent choice for wireless power amplifier applications, because unlike the HBT, zero power consumption RF switches can be easily integrated with the power amplifier in a single IC.

II. DC PERFORMANCE

Table I compares the leakage currents of quasi-enhancement mode E-HEMTs, HBT and LDMOS solutions with our true enhancement mode FET technology.

TABLE I

Technology	$I_{LEAKAGE}$ GSM IC
Alpha Quasi-E-HEMT [1]	$3x10^{-04}$ A
Fujitsu Quasi-EHEMT [2]	$12x10^{-04}$ A
RFMD2138	$10x10^{-06}$ A
Hitachi PF08122B	$25x10^{-06}$ A
This Work	$20x10^{-06}$ A

The leakage current of Motorola's GSM IC is the same order of magnitude as RFMD's AlGaAs HBT and Hitachi's LDMOS ICs, while the quasi-enhancement mode ICs are one to two orders of magnitude higher and are too high to allow the elimination of the drain switch.

Table II lists the nominal values of key DC performance parameters for Motorola's true enhancement mode FET technology. The nominal threshold voltage is +0.6V and nominal device gate length is 0.85um. Despite the relatively high threshold voltage and gate length, the power density and efficiency performance is better or comparable to quasi-enhancement mode E-HEMTs having lower threshold voltages and shorter gate lengths [1]-[2]. The nominal value of ID_{MAX} at VDS=1.5V and VGS=1.5V is 215 mA/mm with a corresponding gate to drain breakdown voltage at 1mA/mm of 15V.

Another key feature of this device technology is a high Schottky turn-on voltage, V_{TO}, of +1.8V at 1mA/mm compared to +0.8V for the quasi-enhancement mode E-HEMT. A high V_{TO} is desirable for power amplifier applications because the output power capability of the device is limited by V_{TO}- V_{TH}. In addition, the high V_{TO} also reduces the amount of gate current developed under high RF drive levels.

TABLE II

IDmax (VDS=1.5V VGS=+1.5V)	V_{TH}	V_{TO} (1mA/mm)	BVgdo (1mA/mm)
215 mA/mm	+0.6V	1.8V	15 V

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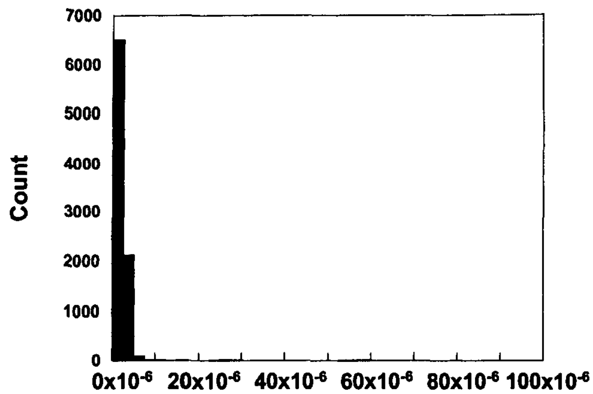

Figure 1. Total Drain Supply Leakage Current in Off-State for GSM IC.

Figure 1 shows the total drain supply leakage current for the packaged GSM IC in the off-state (Vref=0.1V) for approximately 10,000 units. The leakage is typically lower than $20x10^{-6}$A. This is more than adequate to allow the elimination of the drain switch.

III. RF PERFORMANCE

These GSM and DCS ICs achieve high efficiency power amplification. Both GSM and DCS ICs employ a three-stage topology with on-chip input and interstage matches and active bias networks. An off-chip output matching network is required. They are packaged in a 4mm x 4mm, 20 micro-lead package plastic package (MLP-20). All of the data presented in this paper was measured on packaged ICs in a demo board, so the data incorporates both the losses of the package and the external output matching components and demo board.

Figure 2 shows a plot of the output power, gain, power-added efficiency vs. input power at 880 MHz, 900 MHz and 915 MHz at V_{DS} =3.2V for the GSM IC. At 880 MHz and +5 dBm CW input power, the GSM IC provides +35.5 dBm output power at 58% PAE with 30 dB gain.

Under the same test conditions, the DCS IC at 1880 MHz provides +33.5 dBm of output power at 46% PAE. Figures 3 and 4 show the power control curves for the GSM and DCS ICs, respectively, vs. frequency at an input power of +5dBm.

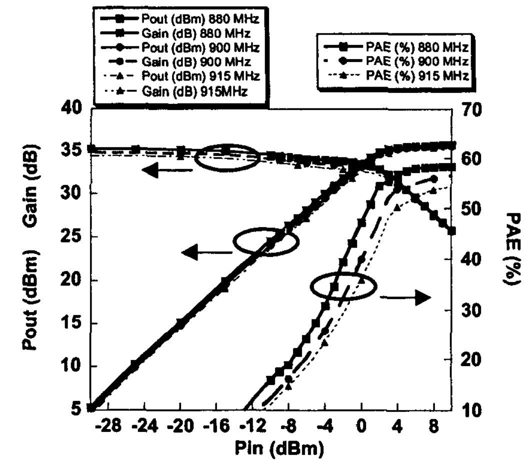

Figure 2. Input power vs. output power, gain and PAE for the GSM IC.

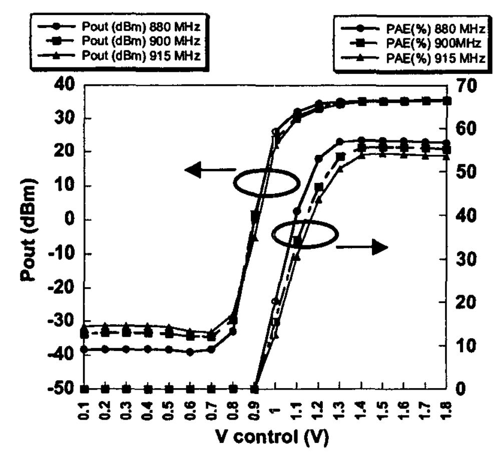

Figure 3. GSM power control curves vs. frequency at Pin=+5dBm.

At 900 MHz, Pin=+5 dBm, the output power of the GSM power amplifier ranged from –31.5 to +35.5 dBm over the reference voltage range Vref=0.1V to 1.8V, corresponding to a 67 dB dynamic range. At 1880 MHz, Pin=+5 dBm, the output power of the DCS power amplifier ranged from –26 dBm to +33.5 dBm, corresponding to a 59dB dynamic range.

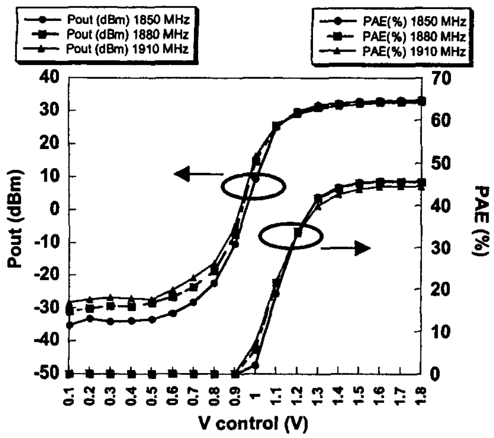

Figure 4. DCS power control curves vs. frequency at Pin=+5dBm.

Figure 5 shows a layout of the GSM amplifier IC. It is comprised of a three stage amplifier topology utilizing 1mm, 6mm and 42mm devices for the first, second and third stages. Active bias circuitry is on-chip. All matching networks are on-chip with the exception of the final stage output match.

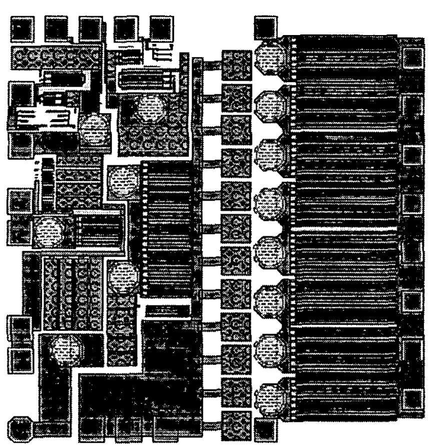

Figure 5. Layout of GSM amplifier IC.

The DCS amplifier IC also contains a three-stage amplifier utilizing 1mm, 6mm and 38mm devices for the first, second and third stages.

Figures 6 and 7 show the forward isolation vs. frequency for the GSM and DCS amplifiers at Pin=+5dBm and Vref=0.1V. The GSM amplifier provides better than 36 dB isolation over the entire GSM band and the DCS amplifier provides over 29 dB of isolation over the entire DCS band. No additional attenuator is required due to the excellent forward RF isolation provided by the +0.6V threshold devices. This is desirable since the attenuator typically degrades the noise performance of the amplifier.

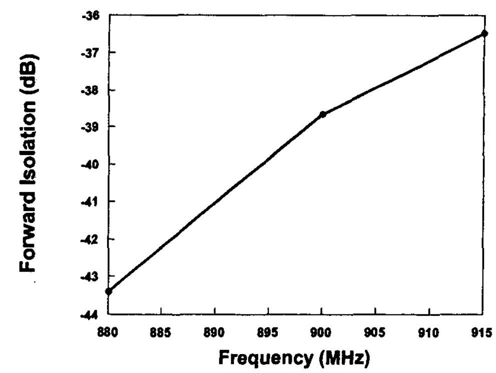

Figure 6. Forward isolation of GSM amplifier vs. frequency at Pin=+5 dBm and Vref=+0.1V.

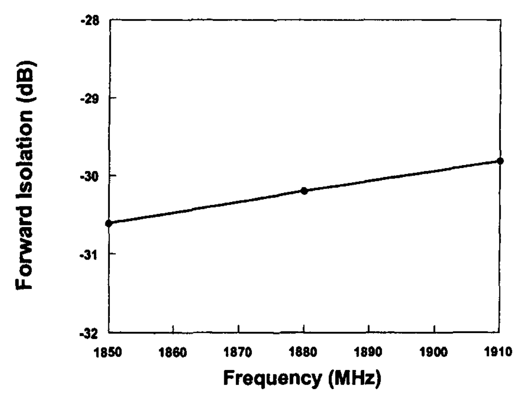

Figure 7. Forward isolation of DCS amplifier vs. frequency at Pin=+5 dBm and Vref=+0.1V.

The noise power performance at VDS = 3.2V and Pin = +5dBm is –87dBm/100 kHz for the GSM amplifier and –90dBm/100 kHz for the DCS amplifier.

The ICs are extremely rugged and easily survive exposure to a 20:1 VSWR with VDS=5.5V at a maximum output power condition. We have evaluated the ruggedness under more severe conditions than specified for the applications and have determined the ICs survive the ruggedness specification with a several volts margin on VDS.

In summary, high performance single supply GSM and DCS ICs have been developed in a 4mm x 4mm MLP-20 plastic package, which have high power density and high efficiency. The GSM IC provides +35.5 dBm output power with 58% PAE at 3.2V and the DCS IC provides +33.5 dBm output power with 46% PAE. Both ICs do not require the use of a drain switch or an attenuator.

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