

High-Performance, Cost-Effective VDMOS RF Power Device Solutions for HF/VHF Applications

Overview

While much attention of late in RF power amplifier technology has been focused upon LDMOS devices for UHF applications, there are still many needs for industrial and military applications in the HF/VHF frequency range. Typical industrial applications in this range include broadcast, MRI, RF plasma generators for semiconductor processing, and laser drivers. These applications are typically CW or pulsed (industrial) and class AB linear (military communications). One part well-known to RF designers for these amplifier designs was the NXP (formerly Philips) BLF177, a 50V 150W VDMOS transistor in the familiar flanged ceramic SOT121B (M177) RF package. Recently this part has been discontinued by NXP leaving the STMicroelectronics SD3933 and the Microsemi VRF3933 as improved substitutes for the BLF177. The Microsemi VRF3933 however is a high-performance, cost-effective alternative to the ST device, as well as to the BLF177.

Maximum Ratings

A comparison of the maximum ratings of the three devices is shown in Table 1.

Table 1 - Maximum Ratings

Symbol	BLF177	SD3933	VRF3933
V_{DSS}	125	250	260
I_D	16	20	20
V_{gs}	± 20	± 20	± 40
P_{diss}	220	648	648
$T_j \text{ max}$	200	200	200
θ_{jc}	0.80	0.27	0.27

It can be seen that the older BLF177 VDMOS semiconductor structure had significantly less performance than the newer VDMOS devices offered by STM and Microsemi today. Maximum current (and RF power) is higher in the newer devices, but the most significant difference is in drain breakdown voltage which is ~100% higher relative to the older part. And while the maximum allowable junction temperatures are identical, the newer parts can dissipate considerably more power due to modern low θ_{jc} packages. In a comparison of maximum ratings, the Microsemi VRF3933 has higher operating drain voltage and gate-to-source voltage, which results in improved ruggedness and higher output power than the STM part.

Static Characteristics

Table 2 compares the significant static characteristics of the three devices.

Table 2 - Static Characteristics

Symbol	BLF177	SD3933	VRF3933
$V_{(BR)DSS}$	125	250	265
$V_{GS(TH)}$	2.0 - 4.5	1.5 - 4.0	2.9 - 4.4
C_{iss}	480	850	1000
C_{oss}	190	300	265
C_{rss}	14	30	13

As in the maximum ratings, the newer VDMOS devices exhibit twice the breakdown voltage vs. the maximum voltage. The Microsemi VRF3933 will provide additional power output margin and ruggedness due to its higher breakdown voltage vs. the STM part. Both of the VDMOS parts feature nearly twice the input and output capacitance naturally due to the larger die and resultant higher output power vs. the BLF177. This higher reactance and higher matching Q may result in slightly lower operational bandwidth but the higher absolute device gains can compensate. Of note however, is the higher C_{rss} or reverse transfer capacitance in the STM part. While this is not of major concern in class AB operation, switch mode designs such as class D & E will require significantly higher drive current to charge and discharge this internal drain to gate capacitance. In a switch mode amplifier that was designed with the NXP BLF177, the VRF3933 is a “drop in” as far as driver power is required. One last static characteristic to notice is the tight V_{th} range of the VRF3933: 2.9 – 4.4 for a total spread of only 1.5V. This can be compared to the SD3933 with a range of 1.5 – 4.0V with a total spread of 2.5V, nearly twice that of the Microsemi part. And while both companies will test and “bin” for this parameter, the tight process controls at the Bend, Oregon foundry ensure there will be adequate stocks of your designed in part at all production times.

Dynamic Characteristics

Table 3 provides the dynamic characteristics of the devices.

Table 3 - Dynamic Characteristics

Symbol	BLF177	SD3933	VRF3933
P_{out} (CW)	150	350	350
Gain (min)	19	25	23
Efficiency	70	60	60
Load mismatch	50:1	30:1	70:1
Z_{in}	3.0-j2.5	2.0-j2.5	2.9-j3.1
Z_{out}	6.25+j0	7.0-j7.5	9.7-j6.6

Similar to the tabulated results in the maximum and static ratings tables, the newer VDMOS devices again excel compared to the older generation. Maximum CW power is more than twice the BLF177 power for both STM and Microsemi parts. This is primarily a function of higher operating drain voltage, 50V_{DC} for the BLF177 vs. 100V_{DC} for the more modern devices. The higher CW power capability is also improved upon with the new lower thermal resistance packages. Of special note however, to a design engineer concerned with reliability: the clear winner in load mismatch capability is the Microsemi VRF3933. The 70:1 VSWR capability of the VRF3933 is equivalent to a 0.97 reflection coefficient and a 0.25dB return loss, which equates to virtually a short or open circuit over all phase angles on the Smith Chart. Many industrial applications, such as plasma RF generators, present these mismatch loads under fault conditions, prior to protection circuitry action. Power device manufacturers must balance off parameters, including mismatch tolerance, and maximum power capability in specifying data sheet parameters. Looking at the impedance data, neither the SD nor VRF part are true “drop in devices” impedance-wise for the BLF177. The

impedances are similar enough that major circuitry changes would not be required; and at 30MHz, simple changes in values, on the same PCB, may be sufficient.

Representative or Typical Data

The following representative or typical data sets contain detailed measurements of a randomly sourced STMicroelectronics SD3933 and a typical Microsemi VRF3933. The test fixture used consisted of a pre-matching circuit and auto tuners adjusted for optimum gain and power. The input and output impedance representing the optimum gain and power is shown on each graph. The measurements were made using a pulsed signal with sufficiently reduced duty cycle to produce maximum output power with an active (pumped) liquid cooled heatsink maintained at 25°C. Please note that some of the discrete data points may not exactly correspond to the noted parameter. This is due to the automated test system taking measurements quickly to avoid long thermal excursions (and possible device damage) and error caused by thermal drift.

Power In vs. Power Out & Gain

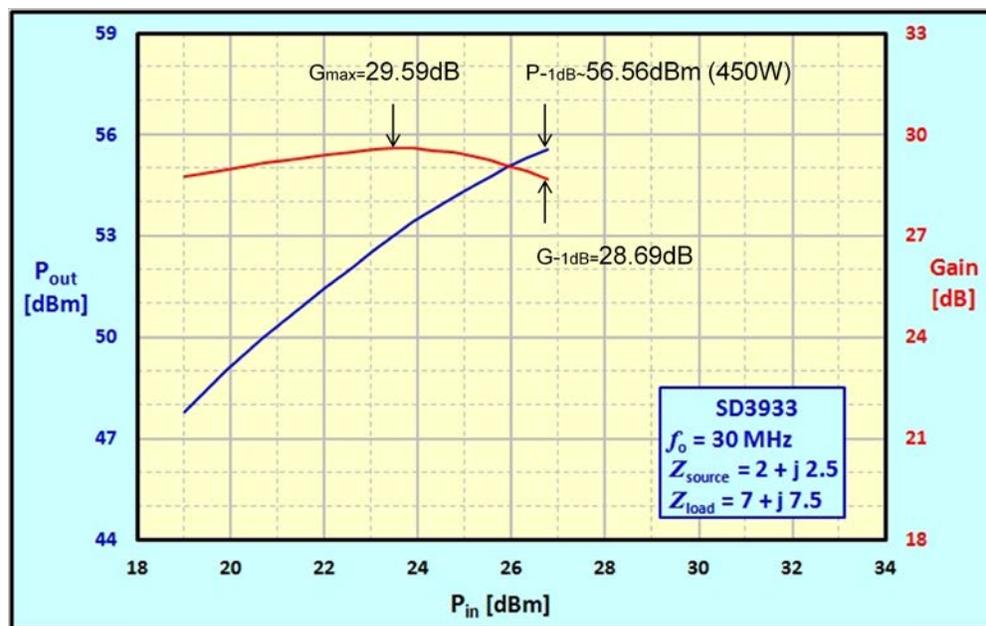


Figure 1 - STM SD3933

From Figure 1, one can see the measured gain of this specific STM SD3933 device is well above the manufacturer's minimum rated gain of 25dB, with good margin of ~5dB. P-1dB of ~450W demonstrates a similar margin to the device 350W continuous RF power rating. Slightly better performance might have been obtained if this specific device had been load pulled by the auto tuner. For purposes of comparison, the data was taken using both vendors' impedance data. Note that this power sweep was limited to the 1dB compression point to ensure the device would not be damaged.

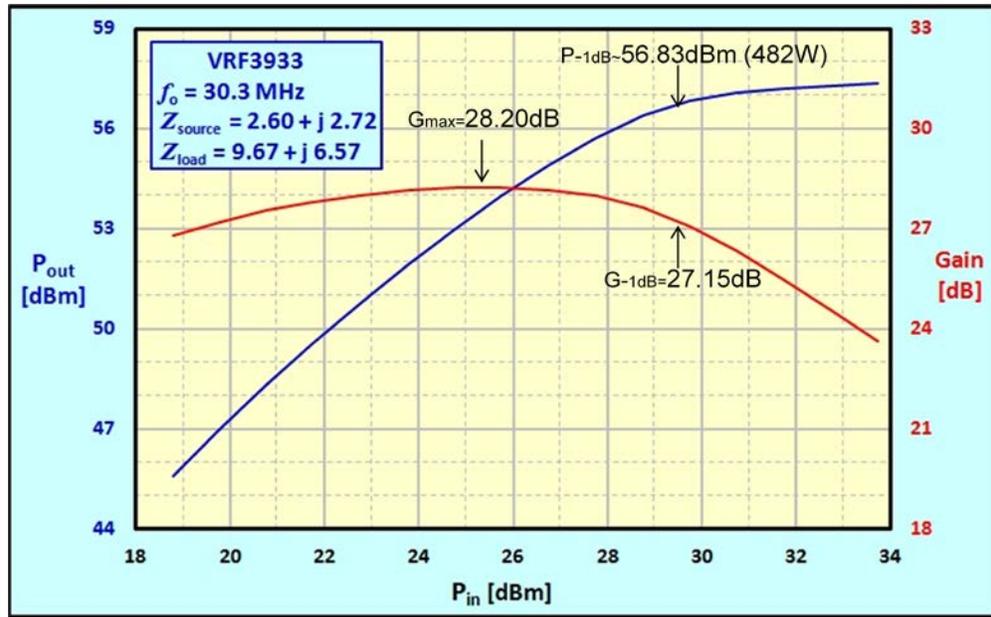


Figure 2 - Microsemi VRF3933

In Figure 2, the Microsemi VRF3933 has been driven well beyond the 1dB compression point to demonstrate the inherent ruggedness of the part. While the absolute gain of the Microsemi part is slightly lower than the competitor device, this random part demonstrates similar ~5dB margin to the minimum rated gain of 23dB. Typical driver stages at 30MHz will have excess gain such that the small difference in gain between the STM and VRF devices would not be a “show stopper” in most circuits. Both the STM and Microsemi devices well exceed the BLF177 rated gain of 19dB for replacement applications. One should note that the VRF device produces 482W at its 1dB compression point vs. 450W for the STM part.

Pin vs. Pout & Efficiency

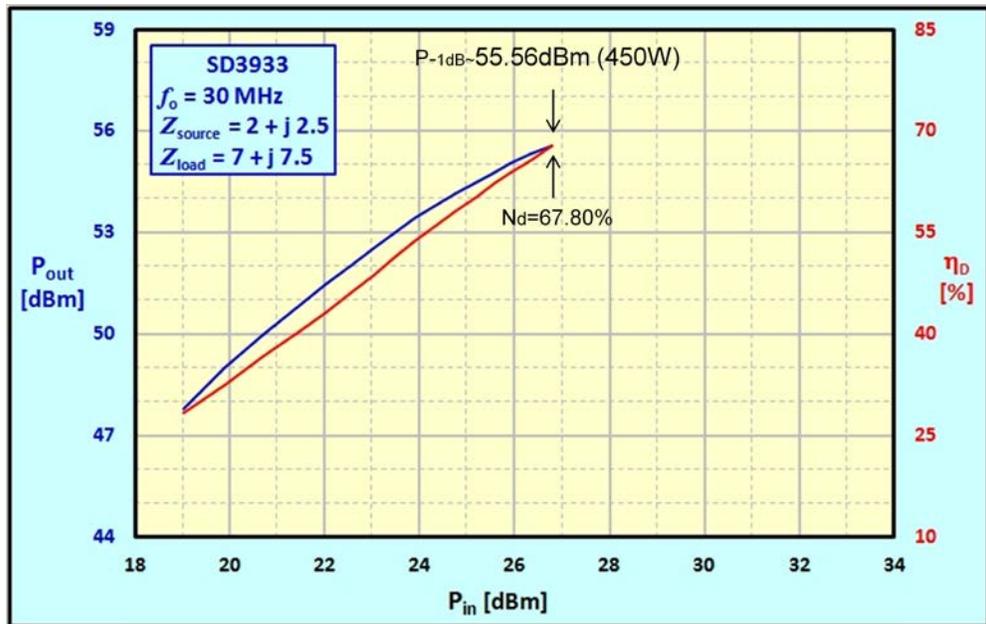


Figure 3 - STM SD3933

In Figure 3, the STM 3933 again shows margin to an important specification with 67.20% drain efficiency vs. a 60% minimum specification. This data is from the dataset shown in Figure 1, thus this efficiency is at the 1dB compression point.

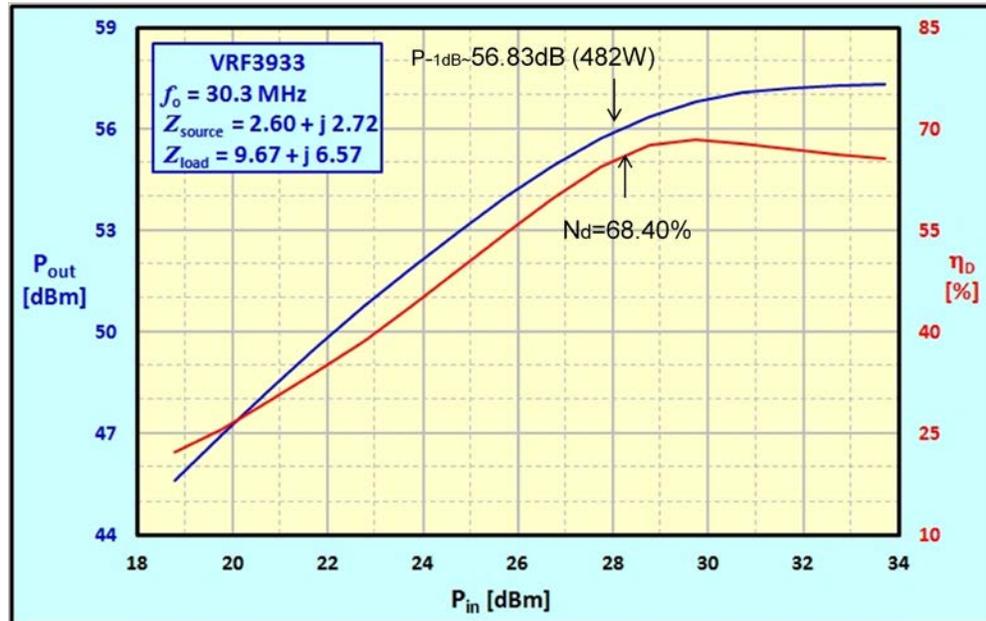


Figure 4 - Microsemi VRF3933

In similar fashion, the VRF3933, at 68.4% is well above its rated efficiency of 60%, but at a 1dB compression point of 482W vs. 450W. Based upon measured data vs. worst case minimum specifications, the VRF3933 can be considered a good alternative device choice vs. the STM SD3933 in all areas except for gain. Circuit-wise gain should not be an issue in circuits originally designed for the BLF177 which will have 4 – 6dB of excess gain based upon a minimum gain specification of 19dB.

Summary

Both the STMicroelectronics SD3933 and Microsemi VRF3933 have been shown to be excellent replacement parts for older RF circuits originally designed around the discontinued NXP (Philips) BLF177. The VRF3933 with its 70:1 mismatch capability and 260V drain breakdown, is clearly the more rugged device compared to the SD3933. The Microsemi VRF3933 should be considered by all RF engineers seeking a more rugged and cost-effective solution.



Microsemi Corporate Headquarters
One Enterprise, Aliso Viejo CA 92656 USA
Within the USA: +1(949) 380-6100
Sales: +1 (949) 380-6136
Fax: +1 (949) 215-4996

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