Whitepaper

RET devices provide robust, cost-effective means of switching and driving loads directly from logic devices

Availability of 80 V rated devices suits higher 48 V automotive board net voltages

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In response to the need for higher efficiency and higher power, many electronic systems today in automotive, industrial and even consumer applications are shifting to fast switching through the use of MOSFETs or wide bandgap devices, primarily silicon carbide or gallium nitride. However, this is not the whole story. Every system or sub-system, even in new automotive 48 V designs, has a range of switching requirements. For low frequency, medium voltage switching, Resistor Equipped Transistors (RETs) – also known as digital transistors or pre-bias transistors - are commonly the preferred choice. Often used to provide a simple way to switch and drive loads directly from logic devices, RETs offer benefits including reductions in size and manufacturing costs, coupled with increased reliability and robustness. This paper discusses the operation, structure and design considerations of Nexperia's portfolio of RETs, and considers the suitability of new, 80 V parts that target emerging 48 V EV systems.

1) RET Operation

Bipolar transistors are controlled using the base current. However, because the voltage drop across the base-emitter path is highly temperature-dependent, in most applications a series resistor is required to keep the base current at the desired level, thereby ensuring the stable and safe operation of the transistor. To reduce the component count and to simplify board designs, RETs combine single or dual bipolar transistors with the bias resistors which are integrated on the same die. Because these internal resistors have higher tolerances than commonly used external resistors, RETs are suitable for switching applications where the transistor operates in either on- or off-state. This is why RETs are often referred to as digital transistors. RETs are available in many voltage, current and resistance ratings, in NPN or PNP configuration and a variety of packages including SOT23 and SOT323 and SOT363.

2) RET Types & Structure

Two common forms of RETs are shown in Figure 1. In Figure 1a, two resistors and a transistor are integrated with a single NPN transistor. The base series resistor is labeled R1 and a second resistor, R2, in parallel to the base-emitter path completes the base divider circuit. The base divider provides fine tuning and better turn-off characteristic behaviour.

Nexperia offers R1 values from 2.2 kΩ to 47 kΩ and R2 values from 10 kΩ to 47 kΩ. The ratio of the resistors R2/R1 can be 1, 2.13, 4.55, 10 and 21. Figure 1b shows a dual version with two transistors and four resistors.

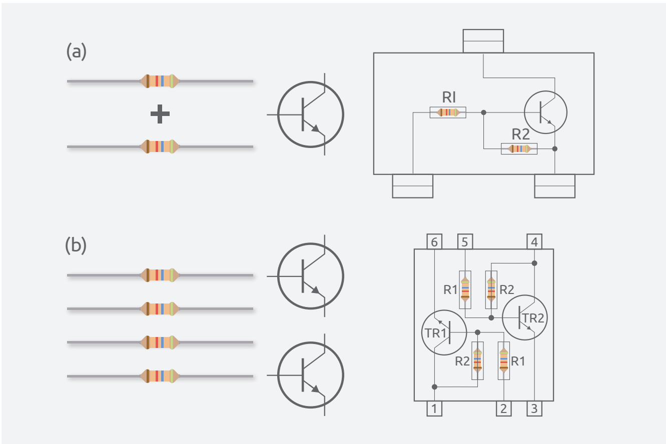

Figure 1: Two common forms of RETs, two resistors and a transistor are integrated with a single NPN transistor (a), dual version with two transistors and four resistors (b).

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The RET structure is very similar to the well-understood standard BJT. Figure 2 shows the resistance 'meander' created using a standard device processing step where a polysilicon layer is deposited on the die and then etched back, structured and patterned to form the integrated resistor layer. Figure 3 shows a cross section of a 100 mA automotive RET.

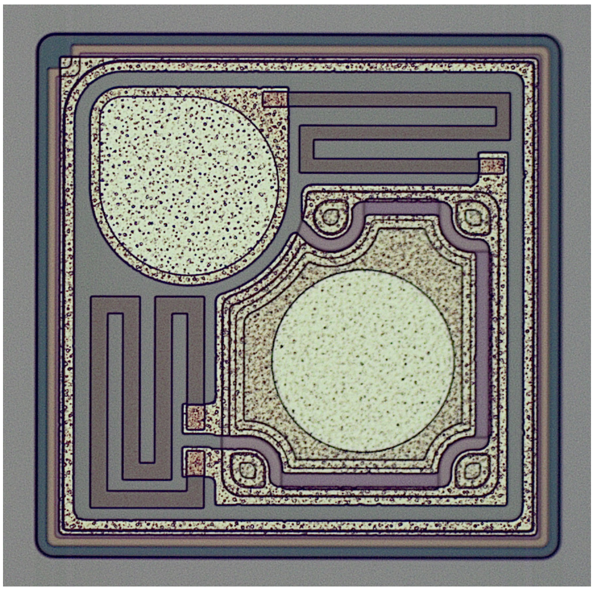

Figure 2: The resistance 'meander' is created using a standard device processing step.

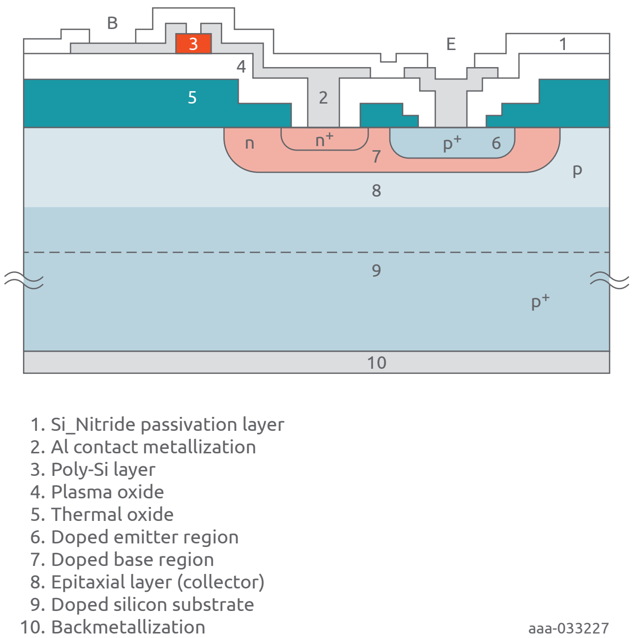

Figure 3: Cross-section of a 100 mA automotive RET.

3) Nexperia RET portfolio

Nexperia offers two types of RETs: so-called performance-based 600 mA 40 V RETs; and standard devices which are available as 50 V devices and 80 V parts which have recently been uprated, primarily to cope with new 48 V automotive systems.

600 mA RETs are based on the company's performance-based, low VC saturation BJTs that have a good current amplification. This gain stays high at high-collector currents, which is very important because less base energy is required, so the transistor can more easily be turned on, even at high load currents. Also, the residual voltage across this switch and in the on-state is lower compared to a standard transistor, so overall they achieve a much better power efficiency. Die size can also be reduced.

When in use, it is important that heat generation in the load path transistor is minimized, so again, it is useful if the transistor has a good current amplification, which does not degrade and improves with temperature over the load current. As an example, Figure 4 shows the performance of Nexperia's PBRN113ZT 600 mA, 40 V R1/R2 1 kΩ/10 kΩ NPN performance-based RETs.

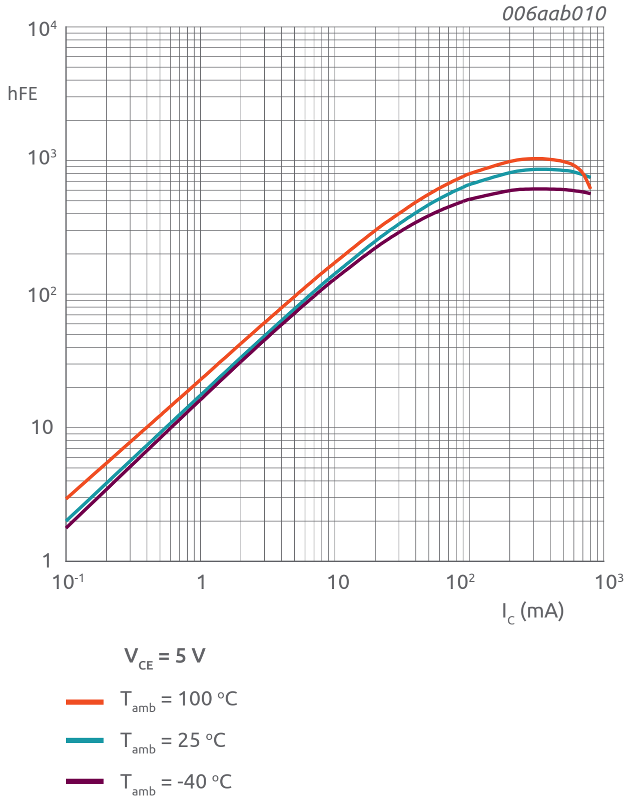

Figure 4: Performance of PBRN113ZT 600 mA, 40 V R1/R2 1 kΩ/10 kΩ NPN RET.

Another benefit of the Nexperia technology is the relative tight tolerance of the R1/R2 ratio of the integrated resistors for RETs with current values above 100 mA, which at +/-10% are three times more accurate than other products. This enables the input voltage safety margin to be reduced.

4) Design considerations

While RETs offer many significant benefits, some important design considerations should be noted.

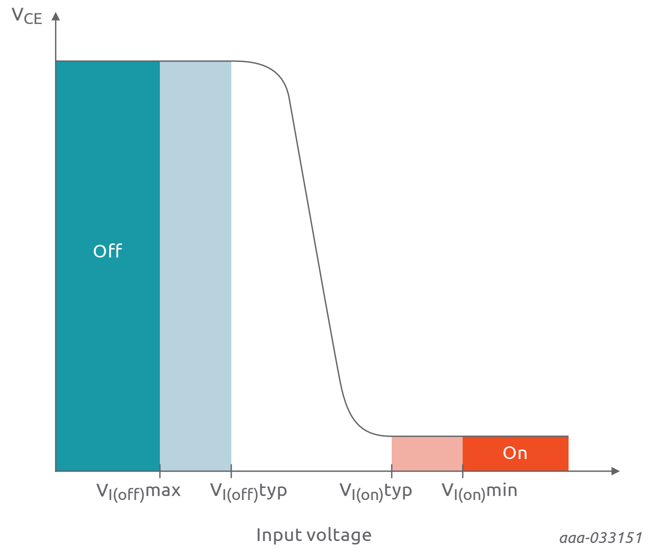

Figure 5: Switching characteristic of a RET.

Figure 5 shows the switching characteristic of a RET plotting V_{CE} versus V_i. $V_{i(off)}$ is the input voltage the RET turns off. The condition required for an off-state is that the collector leakage current must be 100 µA at a collector-emitter voltage of 5 V. For safe turn-off, $V_{(ioff)}$max must not be exceeded. When determining the on-state, $V_{i(on)}$min must be considered. The circuit controlling the RET has to provide at least this voltage for a safe turn. On-state is defined as a collector current of 10 mA while the collector-emitter voltage is 0.3 V. The datasheet V_i rating is valid for the test condition defined only. If a bigger collector current shall be switched the RET requires more base drive voltage $V_{i(on)}$.

$V_i < V_{I(off)max}$ - a RET is in off-state for every device shipped.
$V_i < V_{i(off)typ}$ - a typical RET is in off-state
$V_i > V_{i(on)typ}$ - a typical RET is in on-state
$V_i > V_{i(on)min}$ - a RET is in on-state for every device shipped.

It is also important to consider the same diagram at different temperature ranges. BJT switches become more effective as the temperature goes up, so they will safely stay on if temperature becomes higher. That is suitable, for example, in an autonomous vehicle application in a hot climate; however, if the vehicle is required to operate in a cold climate care has to be taken to ensure that the BJT stays in on-state, because at low temperatures the BJT gain goes down and the BJT current gain goes down and the voltage drop VBE increases, so a higher turn-on voltage is required.

Table 1 shows the dependency of the on- and off-state input voltages on the resistor divider configuration in RETs from Nexperia's NHDTC series RETs.

R1/R2	$V_{I(on)}$min	$V_{I(on)}$ typ	$V_{I(off)}$typ	$V_{I(off)}$ max	RET Type
10k/10K	2.5	1.8	1.15	0.8	NHDTC114ET
22K/22k	3	2.3	1.15	0.8	NHDTC124ET
47k/47k	5	3.3	1.15	0.8	NHDTC144ET
2.2k/47k	1.2	0.81	0.595	0.5	NHDTC123JT
4.7/47k	1.4	0.95	0.625	0.5	NHDTC114YT
10k/47k	1.6	1.22	0.690	0.5	NHDTC143ZT

Table 1: Dependency of the on- and off-state input voltages on the resistor divider configuration.

The selection of a proper resistor divider option is also important to ensure that the control voltage window of the RET matches the driving stage.

5) Applications

RETs are used in many automotive and industrial applications due to their robustness. As mentioned, they provide a simple method that can be used to switch and drive loads directly from logic devices. Some circuit examples are shown in Figure 6. In Configuration 1, the NPN RET serves as a low-side switch, enabling the resistive load or LED, or an inductive load which is connected directly to the battery to be switched. The important point to note here is that the voltage swing of the logic device such as a microcontroller is enough to switch the RET. In Configuration 2, the NPN RET is now used as a high-side switch in the control path, and is driving a PNP RET with the load switched directly by the logic input such as a microcontroller. Nexperia's standard 50 V, RETs are to be found in very many automotive applications. One typical application is converting from a low voltage, such as 3-3.3 V for a microcontroller to the battery voltage of 12 V.

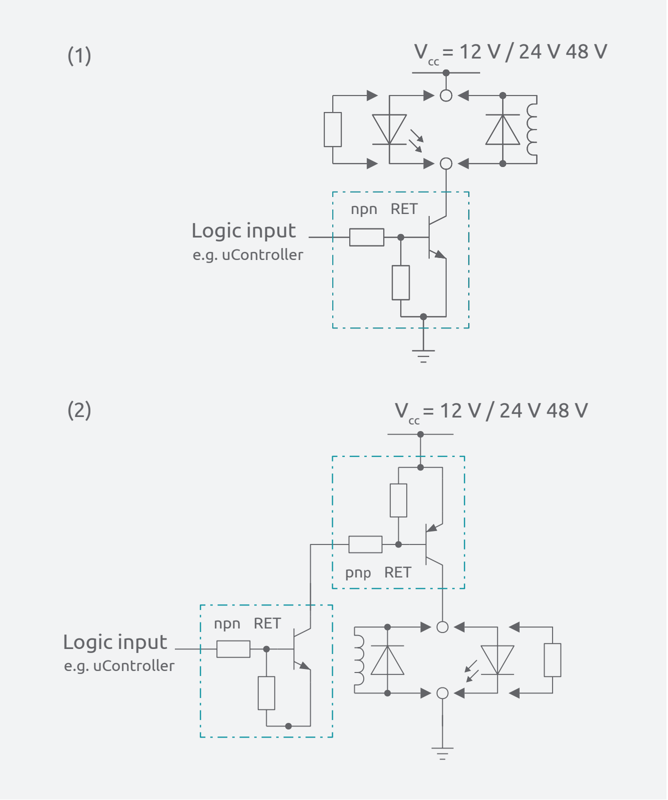

Figure 6: Two circuit examples using RETs: Low-side switch (1), high-side switch (2)

6) New 80 V automotive RETs

Whilst in conventional piston-driven cars, the battery voltage can be 12 V, it can also be as high as 24 V or 25 V in trucks and up to 48 V in mild hybrid cars. Therefore, with the uptake in electric vehicles with a 48 V board net, much more headroom than can be provided by 40 V or 50 V RETs has become necessary. To meet this need, Nexperia has introduced 80 V RETs to provide the safety margin required to switch the loads at these higher voltage board nets.

There is another driver. Automotive customers are now demanding that devices meet pulse tests in accordance with ISO 7637-2:2011, the standard that defines robustness against transients along the power supply bus. At the behest of a major Tier 1 supplier to the EV industry, Nexperia's 80 V RETs have been tested and withstand the required 20 V across base-emitter junction. This is vital for 24 V systems in trucks and lorries, and 48 V automotive systems.

7) Conclusion

Nexperia has many millions of RETs delivering safe, reliable and efficient switching in automotive and many other applications. The company's new range of AEC-Q101-certified 80 V products has the performance, robustness and efficiency required to provide safe operation in 48 V board net e-mobility applications. With the move towards autonomous vehicles, reliable switching systems are going to be required in even more automotive applications. 80 V RETs provide the solution.

To find out more, visit
www.nexperia.com/rest

About Nexperia

Nexperia is a leading expert in the high-volume production of essential semiconductors that are required by every electronic design in the world. The company's portfolio includes diodes, bipolar transistors, ESD protection devices, MOSFETs, GaN FETs and analog & logic ICs. Headquartered in Nijmegen, the Netherlands, Nexperia annually ships more than 100 billion products, meeting automotive standards. These products are recognized as benchmarks in efficiency – in process, size, power and performance — with industry-leading small packages that save valuable energy and space. Nexperia has over 12,000 employees across Asia, Europe and the US.

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