New Developments in RET Technology

Resistor-Equipped Transistors (RETs) – also known as digital transistors or pre-bias transistors – offer many benefits, including saving space, reducing manufacturing costs and increased reliability. This article looks at their structure and design considerations, and considers the suitability of new, 80 V parts that target emerging 48 V EV systems. **Burkhard Laue, Application Marketing Manager and Reza Behtash, Application Marketing Manager at Nexperia Europe**

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 values, in NPN or PNP configuration and a variety of packages including SOT23 and SOT323 and SOT363.

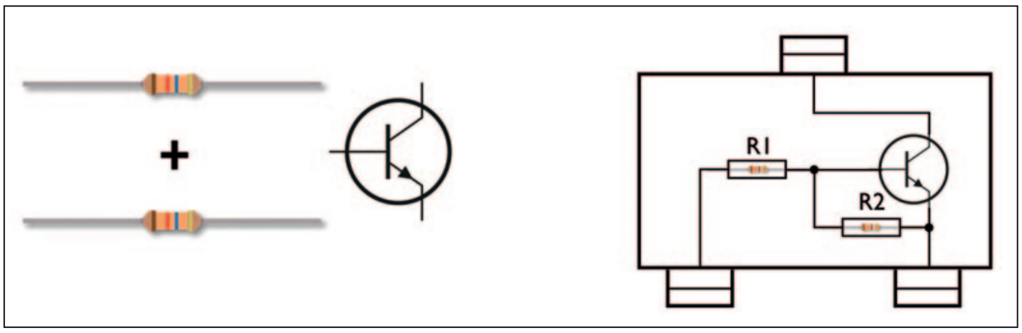
Bipolars for automotive applications

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 behavior. 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.

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.

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.

The 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



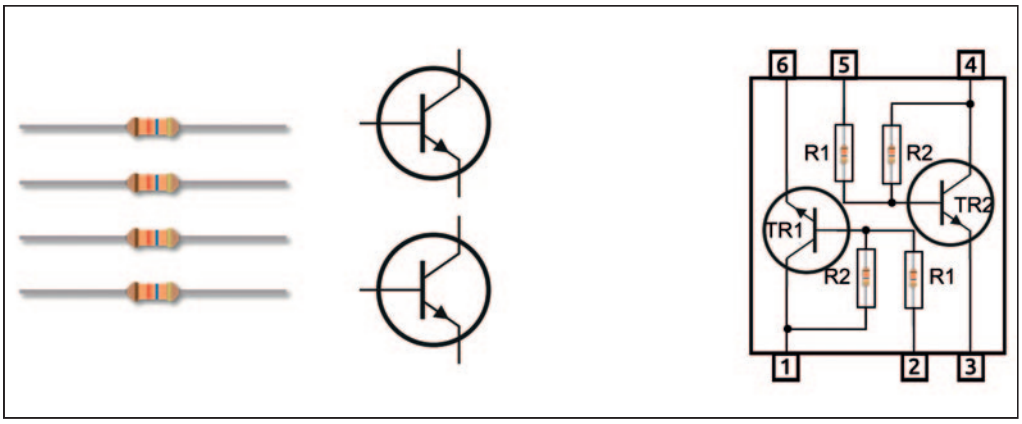


Figure 1: Two common forms of RETs, two resistors and a transistor are integrated with a single NPN transistor (a), dual version with two transistors and four resistors (b)

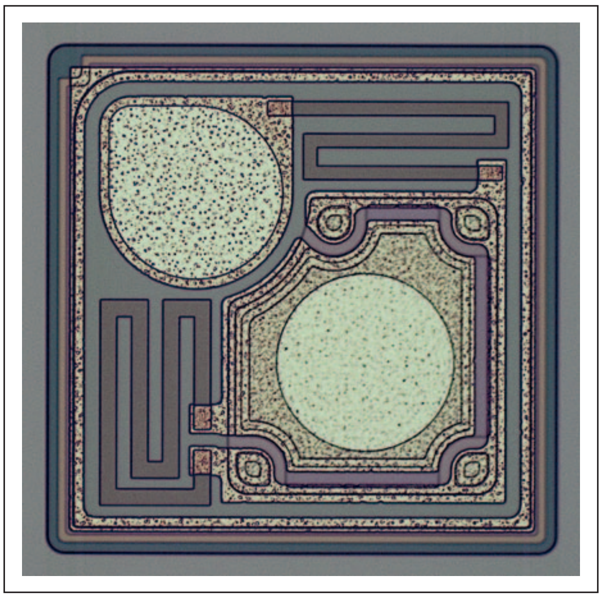
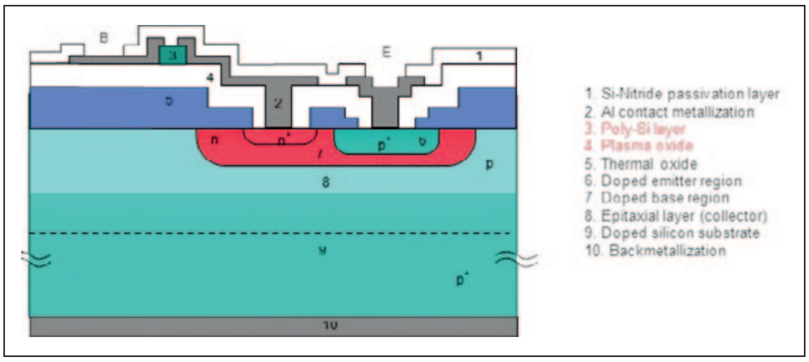


Figure 2: Resistance 'meander' created using a standard device processing step

Below Figure 3: Cross section of a 100 mA automotive RET



on, even at high load currents. Also, the residual voltage across this switch and the on status is lower compared to a standard transistor, so overall they achieve a much better power efficiency. Dies size can also be reduced.

In use it is important that as little heat is generated in the load path transistor, so again, it is useful if the transistor has a good current amplification (h_{FE}), which does not degrade and improves with temperature over the load current. As an example, Figure 4 shows the performance of PBRN113ZT 600 mA, 40 V R1/RT2 1 kΩ/10 kΩ NPN performance-based RETs.

Another benefit of the 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.

Design considerations

While RETs offer many significant benefits, some important design considerations should be noted. 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, $V_{i(off)max}$ 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 Vi(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's fine, for example, in an autonomous vehicle application in a hot climate; however, if you drive in a cold climate you have to be careful 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 V_{BE} 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 NHDTC series RETs.

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.

New 80 V automotive RETs

BJTs are preferred in many automotive applications due to their robustness.

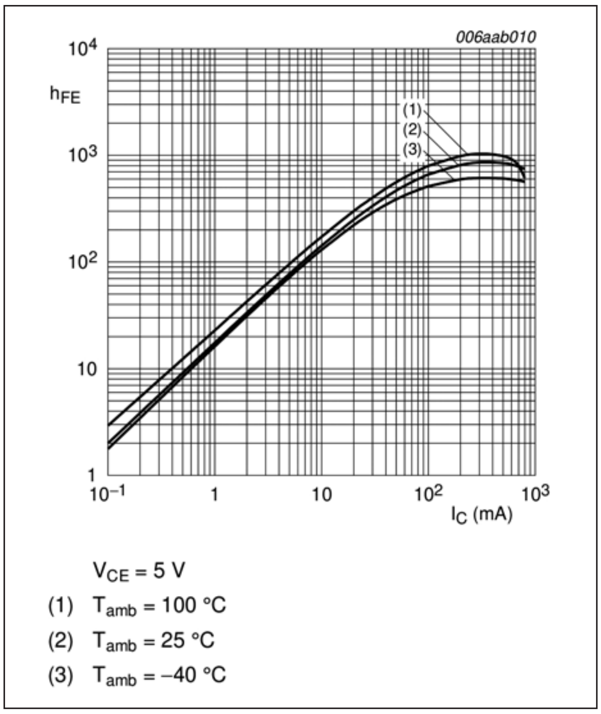


Figure 4: Performance of PBRN113ZT 600 mA, 40 V R1/RT2 1 kΩ/10 kΩ NPN RET

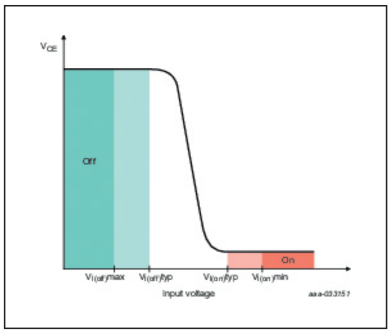


Figure 5: Switching characteristic of a RET

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. Now, with the introduction of 80 V parts, they are suitable for 48 V e-vehicles and hybrid applications.

RETs provide a simple way to switch and drive loads directly from logic devices. Some example circuits are shown in Figure 6. This has not been too challenging for RETs when the battery voltage V_{cc} is 12 V. However, with the uptake in electric vehicles with a 48 V board net, much more headroom has become necessary. Nexperia's 80 V RETs provide the safe operating margin required.

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.

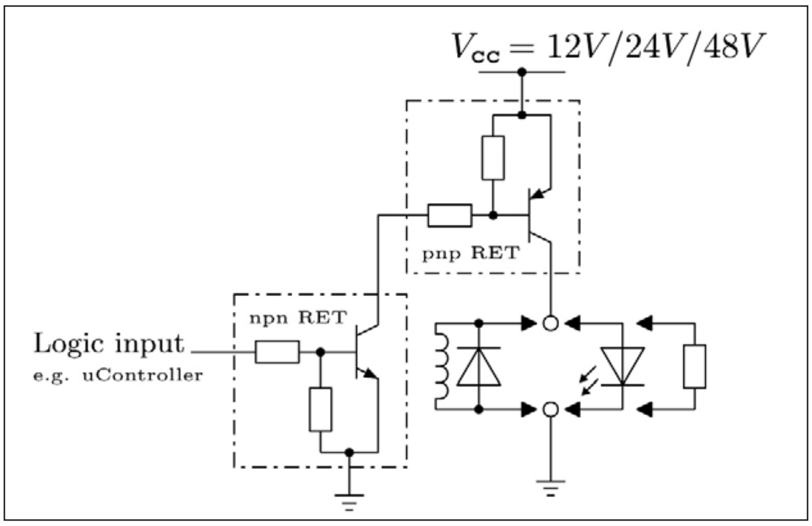


Figure 6: Example application circuits

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.

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

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