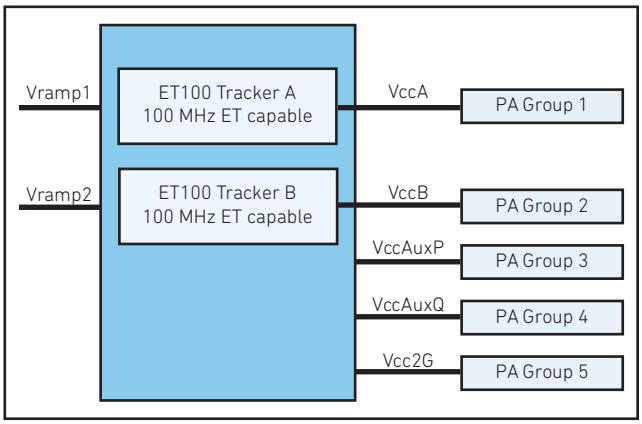
Qorvo's 100 MHz ET for 5G

Continuing Our ET Innovation Trend

As cellular technology advances and modulation complexity increases, the requirements on RF components have become more and more stringent. RF Power and linearity demands have continued to rise opposing the strong desire for decreased current consumption, which directly affects both battery life and thermal performance. 5G is no exception. 5G's specifications impose a difficulty multiplier, creating unprecedented RF challenges for our industry.

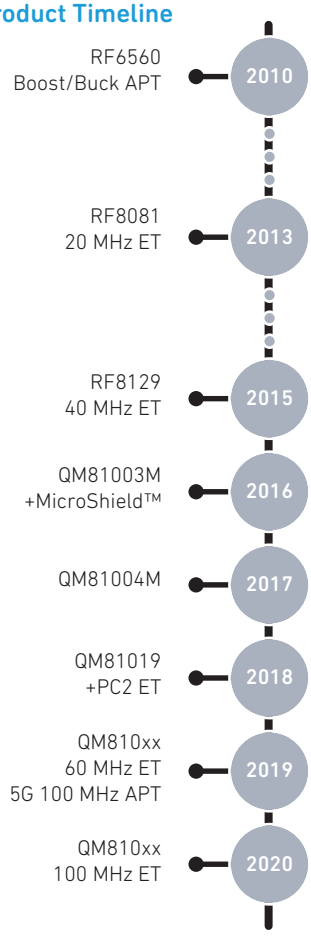
With the rise in handset RF complexity, envelope tracking (ET) has become the premium choice for efficient RF power amplification in mobile handsets, addressing all three core metrics simultaneously: superior linear power, lowest current consumption, and best thermal management. From the beginning, Qorvo has provided premium, innovative ET solutions.

QM810xx's Dual ET100: Conventional, Unified



Qorvo owns over 400 granted patents related to power management - 190 are related to ET, with numerous additional patent applications pending. With a strong legacy of innovation, Qorvo continues our leadership trend into 5G by delivering the world's first 100 MHz envelope tracking integrated circuit (ETIC) in a conventional, unified form factor. Achieving 100 MHz ET to meet 5G's new 100 MHz carrier bandwidth requirement is impressive. Doing so in this form factor while supporting placement around 2cm away from the PA is truly innovative. Simplifying the complex 5G world. That's what we do at Qorvo.

Qorvo's Power Tracking Product Timeline



Qorvo's long history goes back even before ET was the norm in handsets, back to the rise of average power tracking (APT). Qorvo has always been uniquely situated as a power amplifier (PA) power management supplier, designing both the PA and the power management - studying both to create optimized solutions. That is why in 2009 Qorvo drove the industry away from PA power modes toward the more efficient and flexible buck APT PA implementation. In parallel, Qorvo designed and delivered in volume production our own boost/buck converter in 2010, a first in our industry and highly successful in flagship handsets. Qorvo realized the tremendous leverage in adjusting the PA's collector supply (Vcc) based on the transmit requirements, and what's more, an efficient, boosted voltage, above battery supply, adds to the flexibility. This boost aspect became even more critical as the peak to average ratio (PAR) of LTE modulations became increasingly difficult to manage. Today, boost/buck configurations drive our ETIC industry and are a critical element in 5G as transmit waveform/modulation PARs are as much as 30% higher than LTE.

As the industry transitioned from APT to ET, Qorvo was there, releasing our first ETIC in 2013 in partnership with multiple chipset suppliers. This enabled strong LTE solution competition to the alternative, captive chipset solution. Since then, Qorvo has shipped over 365 million ETICs, establishing industry leadership in volume and support of multiple chipsets and RF front-end suppliers. Qorvo's support of strong RF eco-system creation remains a tenet of our ETIC design. This ensures that many can benefit from our ET innovations, rather than limiting either chipset or PA/RF front-end selection. This approach has relentlessly driven Qorvo's ETIC design team to deliver our 4th generation ETIC, aimed squarely at the challenging 100 MHz 5G demands. Retaining the conventional, unified form factor and capable of being implemented in realistic handset RF designs, Qorvo's ET100 5G ET core upholds our tradition - providing a straightforward interface enabling multiple 5G chipsets and 5G front-end suppliers. Let's take a closer look at the considerations for designing a 5G ET core and how ET100 performs.

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ET100: A Natural Evolution

4G LTE envelope tracking integrated circuits (ETICs) have progressed from 20 MHz to 60 MHz uplink carrier bandwidths. However, several 5G NR bands are capable of supporting 100 MHz carrier bandwidth, while also specifying power class 2 (PC2) power levels, new modulations with very low EVM requirements, alongside higher peak-to-average ratios (PAR). These 5G requirements take RF transmit system design to a whole new level of difficulty.

To meet the stringent linearity requirements of 5G, ETICs must generate highly accurate Vcc envelope signals that are aligned with RF envelope signals. **Figure 1** shows ET100 efficiently tracking a high PAR, 100 MHz wide modulation used in 5G, while being mated with PAs designed for high frequency, high power, PC2 operation, such as what is required in the 5G band, n41. Tracking spectrum, as shown in **Figure 2**, is a key metric in ETIC performance, indicating the accuracy with which an ET core linearly tracks the modulation signal's Vcc. Tracking with high accuracy is one core aspect, but to do so in a way that leaves the high linearity 5G demands is the final measure of exceptional performance. **Figure 3** demonstrates the resulting, passing E-UTRA linearity performance. Qorvo's ET100 has already been implemented and sampled in both dual core and single core product configurations, one of which was used for this set of measurement results.

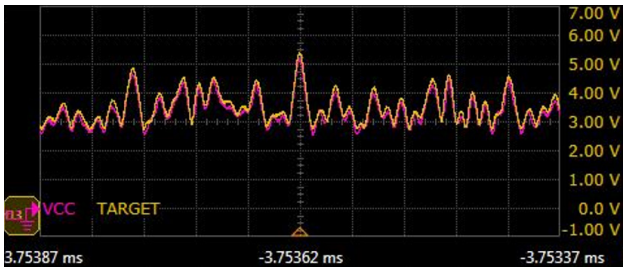

Figure 1: ET100 bench measurements, tracking (state waveform, etc), 100 MHz, n41

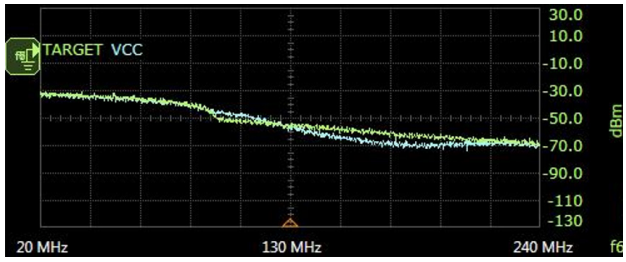

Figure 2: ET100 bench measurements, 100 MHz tracking spectrum

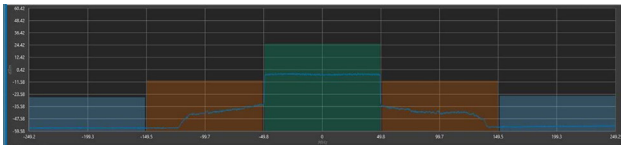

Figure 3: ET100 bench measurements, resulting 100 MHz E-UTRA performance

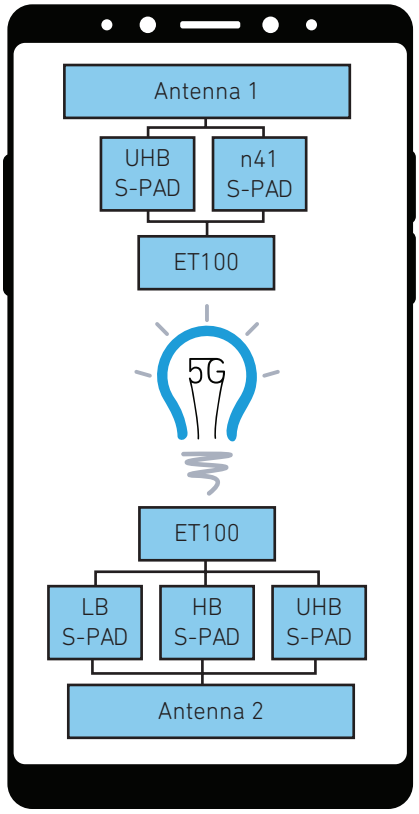

Figure 4: 5G NSA, EN-DC Implementation

Having such a strong 100 MHz ET core enables Qorvo to deliver 100 MHz 5G ETICs into the implementations that are best suited for our customers' 5G flagship handset designs. Qorvo's advanced 5G ET100 core overcomes the most difficult challenges without adding additional PCB complexity.

The conventional, unified architecture of ET100 was targeted at this specific aspect: providing customers with 100 MHz ET to complement their ecosystem, not force a new, undesirable implementation. Qorvo's ET100 core can drive high current, wide bandwidth 5G envelope signals across nominal, inductive phone board traces without corrupting the integrity of the signal. In fact, ET100 has a proprietary implementation that allows up to 2nH of trace inductance from the ET100 output to PA's Vcc input, or approximately 2cm in distance given common phone board designs. This means that the 5G ETIC can still be centrally located among multiple PAs like it was for 4G/LTE phone designs while expanding to the dual transmit requirements of 5G's EN-DC operation, depicted in **Figure 4**. With this capability, phone architectures only require incremental changes to support 5G bandwidths, while handset OEMs can continue to use their existing ecosystem of RF front-end partners - enabling a low-risk deployment of high-performance 5G devices.

At Qorvo, we believe a successful 5G deployment will transform the way you live, work, play, and communicate. That's what inspires us.

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