Coolteq.L Single-Chip Envelope Tracking Supply Modulator

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Nujira Company overview

• Fabless IC vendor

• World leader in Envelope Tracking
  • The only technology for broadband, high efficiency PAs
  • >250 man-years investment in High Accuracy Tracking™
  • Coolteq™ products cover power levels from <1W to 10kW+

• 133 patents granted & pending
  • Most extensive ET patent portfolio in the industry

• Headquartered in Cambridge, UK
  • Design Centres in Edinburgh and Bath, UK

• Founder member of OpenET Alliance

• Active participant in new MIPI ACI WG
  • Analog Control Interface – Envelope Tracking subgroup
  • Standardising physical interface between chips
Envelope Tracking – an overview

**Conventional PA**
- Baseband / RF up converter
- Power Amplifier
- DC/DC Converter

**Envelope Tracking PA**
- Baseband / RF Up converter
- Power Amplifier
- ET Power Supply

Planned standard from MIPI ACI Working Group

Fixed Supply Voltage
- Dissipated as Heat

Transmitted

Supply Voltage
- Dissipated as Heat

Transmitted
Envelope Tracking vs Average Power Tracking

Direct battery connection
- Simple, but poor efficiency
- Efficiency is strong function of waveform PAPR
- LTE dissipation ~2x W-CDMA

Average Power Tracking (APT) DC:DC
- Per-slot tracking based on TX power control level
- Improves efficiency at low power
- Doesn't help at high power
- Same waveform dependence

Envelope Tracking
- Dynamic, high bandwidth supply tracking of signal amplitude
- Improves efficiency in top 90% of TX power control range
- Waveform-independent; LTE dissipation ~1.2x W-CDMA
RF PA becoming the dominant consumer of power in handsets

- LTE data = 10x 3G voice
- Less than 1 day between recharges
- More than 3W
  - Gets hot!
  - Challenging thermal design
  - High peak currents
LTE PA spending significant time at maximum power


- Short bursts of TX data at max power
- Highest spectral efficiency
- PA spends >50% of its time at maximum power
60x increase in RF PA energy consumption from 3G to LTE

- Multiband LTE: 1800 mW
- LTE data: 1600 mW
- HSUPA data: 250 mW
- 3G voice: 26 mW

Waveform Peak-to-Average Power Ratio, dB vs. Average Handset transmit power control level, mW
Coolteq enables 4G transmissions using less power than today’s 3G PAs
>50% reduction in PA heat dissipation simplifies thermal design

**Fixed supply voltage**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Output Power</td>
<td>27.3 dBm</td>
</tr>
<tr>
<td>Dissipated Power (device)</td>
<td>1180 mW</td>
</tr>
<tr>
<td>Measured Case Temperature</td>
<td>62.9 °C</td>
</tr>
</tbody>
</table>

**Envelope Tracking**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Power</td>
<td>27.3 dBm</td>
</tr>
<tr>
<td>Dissipated Power (device)</td>
<td>487 mW</td>
</tr>
<tr>
<td>Measured Case Temperature</td>
<td>45.3 °C</td>
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</tbody>
</table>
ET enables multiband PAs which use less power than today’s 3G PAs.

3 broadband ET PAs cover 700 MHz – 2.7 GHz
Digital logic overhead: ~50K gates in transceiver
Fast DAC needed – similar spec to I/Q DACs
Envelope Interface A – differential analogue interface
  Specified by OpenET Alliance; also being worked on in MIPI ACI
PA efficiency and gain vary with supply voltage.
Under ET, a digital LUT controls the “shape” of the supply voltage.

- More gain
- Higher Efficiency
Nujira’s patented ISOGain™ ET linearizes the PA without requiring DPD

- Result: 6-10 dB ACLR improvement
- 2-3 dB more “linear power”
- Deliver full power LTE to the antenna
ET delivers more power and cleaner signals, even into an antenna mismatch

Measurements of a commercial handset PA demonstrate that Envelope Tracking delivers additional output power and maintains fully ACLR and EVM compliant signals, even into a poorly matched or de-tuned antenna.

For the user, this means faster data, better network coverage and no more "death grip" effects.
So what’s so difficult about Envelope Tracking?

• High power supply bandwidth requirement
  • 30-60 MHz for 20 MHz LTE
  • Very high slew rates

• Low noise power supply
  • ACLR spec is “easy” to hit
  • RX-band noise (self desens) much harder

• High efficiency ET supply modulator
  • Needs ~80% power conversion efficiency

• ET<>PA supply feed is critical
  • ET chip replaces decoupling capacitor
Envelope Tracking ecosystem status

• 12 of 14 platform chipset vendors are committed to include an Envelope Tracking interface
  • 4 with silicon now
  • 4 in silicon design phase
  • 4 at specification / architecture phase

• All PA vendors have an active ETPA program
  • First stage: “ET Capable” PAs available now
  • Next step: “ET Optimised” PAs starting to show up

• MIPI ACI working on interoperability standard

• Expect ET-enabled reference platforms 2H2012
Coolteq.L Envelope Tracking chip for smartphones & terminals

- Single chip ET supply modulator
- 0.18u CMOS process
- Replaces DC:DC converter to supply the RF PA
- Supports 20 MHz LTE bandwidths
- Includes ET and APT operating modes
- MIPI RFFE V1 control interface
- OpenET analogue differential Envelope interface
Thank you – Questions?

Pushing the envelope of PA efficiency