FPGA Based Rapid Prototyping Platforms for Telecommunications
BEE7 is an off-the-shelf communications platform that can be used for early algorithm exploration, research and development, real time verification, prototyping, limited deployment and product upgrades. BEE7 is in a double wide ATCA form factor allowing for up to 6 blades together in a single chassis.

- Flexible and scalable full speed interconnected blades
- Full speed network I/O – 1.1 Terabit/sec throughput
- 4 Xilinx VX690T FPGAs
  - 80 GTH SerDes
  - 3600 DSP slices per FPGA
- 400 Gbps on-board full mesh inter-FPGA connection
- 4 FMC-HPC front panel slots with up to 200 Gbps throughput
  - 8 GTH SerDes from each FPGA to its dedicated FMC
  - 80 LVDS pairs from each FPGA to its dedicated FMC
- Clock recovery with one CPRI clock per FPGA
- Less than 300 fs typical rms jitter
- DDR3 -1333 ECC RDIMM RAM
  - Two banks per FPGA
  - 64 GB
  - 10600 MB/s throughput per channel
- Full CPRI support
  - Master or slave-mode operation
- Up to 640 Gbps throughput on Rear Transition Module (RTM)
- Optional 480 Gbps front panel optical connectors
- Advanced and flexible expansion options:
  - 10, 40 and 100 Gigabit Ethernet on SFP+, QSFP, and CxP ports
  - Up to 5.6 Gsps ADC/DAC and RF interfaces on FMC slots
RTM 64: Rear transition module
• 64 break outs to 16 multi-gigabit transceivers from each of the BEE7’s 4 FPGAs
  - Provides SFP+ and QSFP connectivity
• 16x SFP+ (160 Gbps total)
• 12x QSFP (400 Gbps total)
• 640 Gbps aggregate throughput
• Accommodates a variety of high-speed digital standards including 10 Gb Ethernet and 40 Gb Ethernet
• Compatible with copper cables
• Compatible with fiber cables
  - Connected through electrical-to-optical transceiver modules plugged into the SFP+ or QSFP cage

FMC108: ADC For LTE Applications
• Direct RF Sampling
• I/Q sample
• MIMO antenna capability
• 4.5 MHz to 3 GHz RF range in 1st Nyquist zone
• 650 MHz to 4 GHz RF range in 2nd Nyquist zone
• Single channel and Dual Channel
• 4 Gsps ADC in single channel configuration
• 2 Gsps ADC in dual channel configuration
• 12-bit resolution ADC
• VITA-57 FMC-HPC form factor compliant
• TI ADC12D2000RFIUY ADC chip

FMC109: RF-DAC for LTE Applications
• Direct RF Sampling
• Dual Channel
• 2x-16x interpolation
• MIMO antenna capability
• 4.5 MHz to 3 GHz RF range in 1st Nyquist zone
• 650 MHz to 4 GHz RF range in 2nd Nyquist zone
• Up to 5.6 Gsps DAC
• Direct RF synthesis at 2.8 GHz
• 14-bit resolution ADC
• VITA-57 FMC-HPC form factor compliant
• 2X Analog Devices AD9129 DAC chips
BEE7 Expansion Modules

FMC106: Multichannel Baseband ADC for MIMO Applications
- Baseband IF Sampling
- MIMO antenna capability
- 0.4 MHz to 500 MHz RF range
- Quad channel
- 500 Msps ADC
- 14-bit resolution ADC
- VITA-57 FMC-HPC form factor compliant
- Four Intersil ISLA214P50 ADC chips

FMC107: Multichannel IF DAC for MIMO Applications
- Direct IF Sampling
- MIMO antenna capability
- 4.5 MHz to 1500 MHz RF range
- Quad Channel
- 1500 Msps DAC
- 16-bit resolution DAC
- VITA-57 FMC-HPC form factor, connector & pinout
- Texas Instruments DAC 34SH84 chip
FMC105: Wideband DAC for Millimeter Wave, UWB, and Optical Interface Applications
- Direct RF or IF Sampling
- 6.5 MHz to 2500 MHz RF range
- Single Channel
- 5 Gsps DAC
- 12-bit resolution DAC
- VITA-57 FMC-HPC form factor complaint
- Single-ended or Differential input versions
- Euvis MD662H High Speed DAC chip

FMC104: Wideband ADC for Millimeter Wave, UWB, and Optical Interface Applications
- 1, 2 and 4 channel modes
- 5 Gsps ADC in single channel mode
- 2.5 Gsps ADC in dual channel mode
- 1.25 Gsps ADC in quad channel mode
- 10-bit resolution ADC
- Direct RF or IF Sampling
- VITA-57 FMC-HPC form factor complaint
- Single-ended or differential input versions
- e2v Semi EV10AQ190 5Gsps ADC Chip
MegaBEE is optimized for massive MIMO applications with built-in capabilities for 8x8 MIMO

- Optimized for 5G cellular RF bands worldwide
- 4G capable including LTE, LTE Advanced, TD-LTE
- Flexible 8x8 MIMO SDR with RF range from 70MHz - 6 GHz
  - 56 MHz bandwidth
  - Software tunable within RF range
  - Clock synchronization (local or network based)
- Ultra low jitter clock source
- Synchronous Ethernet
- 3GPP UE compatible radio categories 1-8
- Dual-core ARM Cortex A9 SoC
- Fully programmable FPGA logic with Xilinx Zynq Z7100 chips
- 1U rack mount chassis for high density
- Digital interfaces
  - 8x SFP+ (10 G Ethernet/CPRI)
  - 2x QSFP
  - 2x HDMI in and out
  - 2x USB v 2.0 (Host)
  - 2x RJ-45 (1G Ethernet)
MegaBEE Massive MIMO Solution

Unique clocking structure allows 8x8, 16x16, 32x32, ... 256x256 antenna modules to be dispersed over a multi kilometer radius while maintaining phase coherence, enabling the system to be used for distributed MIMO as well as massive-MIMO systems with greater coverage and capacity.

- Flexible, programmable antenna unit with tunable RF front end, scalable up-to 256 antennas
- Distributed Zynq Z7100 for localized physical and link layer processing
- High throughput data aggregation/distribution
- High performance Xilinx Virtex 7 FPGAs for centralized MIMO processing
- Large capacity DRAMs for data storage
- 480 Gsps iMot(120 Gbps per FPGA) for further interconnect expansion
nanoBEE is a real-time terminal or gateway emulator for the next generation of wireless communication systems research, development, and testing.

- Optimized for 5G cellular RF bands worldwide
- 4G capable including LTE, LTE Advanced, TD-LTE
- 3GPP compliant Terminal categories 1-7
- Dual-core ARM Cortex A9 SoC
- Fully programmable FPGA logic with Xilinx Zynq Z7100
- UE or RRH configuration
- Clock synchronization (local or network based)
- Flexible 2x2 or 4x4 MIMO SDR with RF range from 70MHz - 6GHz
  - 56MHz bandwidth
  - Software tunable within RF range
- **Covered RF Bands**

<table>
<thead>
<tr>
<th>RF Band</th>
<th>Frequency (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTE 1</td>
<td>1920 - 1980 / 2110 - 2170</td>
</tr>
<tr>
<td>LTE 3</td>
<td>1710 - 1785 / 1805 - 1880</td>
</tr>
<tr>
<td>LTE 7</td>
<td>2500 - 2570 / 2620 - 2690</td>
</tr>
<tr>
<td>LTE 38</td>
<td>2570 - 2620</td>
</tr>
<tr>
<td>LTE 39</td>
<td>1880 - 1920</td>
</tr>
<tr>
<td>LTE 40</td>
<td>2300 - 2400</td>
</tr>
<tr>
<td>LTE 41</td>
<td>2496 - 2690</td>
</tr>
<tr>
<td>LTE 42</td>
<td>3400 - 3600</td>
</tr>
<tr>
<td>LTE 43</td>
<td>3600 - 3800</td>
</tr>
<tr>
<td>ISM 2.4</td>
<td>2400 - 2500</td>
</tr>
<tr>
<td>U-NII 1</td>
<td>5150 - 5250</td>
</tr>
<tr>
<td>U-NII 2</td>
<td>5250 - 5350</td>
</tr>
<tr>
<td>U-NII 2e</td>
<td>5470 - 5725</td>
</tr>
<tr>
<td>U-NII 3 (ISM)</td>
<td>5725 - 5875</td>
</tr>
</tbody>
</table>

Wideband Mode 70 MHz - 6 GHz

- **3GPP UE Radio Categories**

<table>
<thead>
<tr>
<th>UE Category</th>
<th>MIMO Requirement</th>
<th>BEEcube Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1</td>
<td>1</td>
<td>nanoBEE-5G-2x</td>
</tr>
<tr>
<td>Category 2</td>
<td>2</td>
<td>nanoBEE-5G-2x</td>
</tr>
<tr>
<td>Category 3</td>
<td>2</td>
<td>nanoBEE-5G-2x</td>
</tr>
<tr>
<td>Category 4</td>
<td>2</td>
<td>nanoBEE-5G-2x</td>
</tr>
<tr>
<td>Category 5</td>
<td>4</td>
<td>nanoBEE-5G-2x</td>
</tr>
<tr>
<td>Category 6</td>
<td>2 or 4</td>
<td>nanoBEE-5G-4x</td>
</tr>
<tr>
<td>Category 7</td>
<td>2 or 4</td>
<td>nanoBEE-5G-4x</td>
</tr>
</tbody>
</table>

- 4x SFP+ (10G Ethernet/CPRI)
- 1x QSFP
- HDMI in and out
- USB v2.0 (host)
- RJ-45 (1G Ethernet)
- 4GB flash memory
- 32GB MicroSD
- GPIO UART
- 12Vdc input (allows for external battery pack)
- 9-axis internal measurement unit
BPS is a hardware/software co-development tool that works at system level and greatly accelerates the successful implementation of complex algorithms. BPS automatically generates all platform-specific hardware and corresponding drivers.

- Tight Integration with MATLAB® and Xilinx® Tools
- All interface IP included
- API for accessing FPGA resources from host PC
- Xilinx MicroBlaze® soft-core included in all designs
- Supported on Windows®
- Supported on Linux

BPS allows designers who want to focus only on DSP development with MATLAB to hide all FPGA design details such as high-speed I/O installation and configuration, timing closure for multiple clock domains, HW/SW interfaces and IP integration. All connections outside the core algorithm are mapped through IP modules accessible directly in the BPS GUI.
BPS IP Import Utility

BPS IP Import Utility (IPIU) allows you to import your own custom hardware components into the BPS environment as a new block. The IPIU captures an NGC or EDIF netlist as an input and generates an equivalent Simulink block.

BPS provides a Simulink based blockset for each supported hardware platform. Below is a sample of the library blocks in BPS.

- Shared FIFO
- Shared BRAM
- ChipScope Configuration
- ChipScope Probe
- High-Speed Inter-FPGA I/O
- Ethernet MAC localink
- Aurora Streaming Serial Link
- RXAUI Interface
- 10G Ethernet
- CPRI
- FMC Expansion Board ADC/DAC Interface
- DDR3 MIG
- Software Register (w/ and w/0 strobe)
- DDRS FIFO

BEEcube is continuously creating more blocksets in BPS that fit our customer’s needs.

IP Modules

BPS includes all the necessary IP modules for the successful integration of your design within BEEcube’s platforms by providing verified hardware and software interfaces.

**High-Speed Networks**
- Aurora Interfaces
- 10G Ethernet

**External Memory**
- DDR3 ECC DRAM

**HW/SW Interfaces**
- System Configuration
- RD/WR Registers
- Shared BRAM

**Expansion Interfaces**
- HDMI
- ADC/DAC/RF
- GPIO
## Rapid Prototyping Platform Comparison Chart

<table>
<thead>
<tr>
<th></th>
<th>BEE7</th>
<th>MegaBEE</th>
<th>nanoBEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terra MACs</td>
<td>5</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Digital Gbps I/O</td>
<td>1,100</td>
<td>160</td>
<td>80</td>
</tr>
<tr>
<td>#FMC Card Slots</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Clock Jitter</td>
<td>300fs</td>
<td>300fs</td>
<td>300fs</td>
</tr>
<tr>
<td>#MIMO Ch/Blade</td>
<td>4 - 16</td>
<td>8</td>
<td>2 - 4</td>
</tr>
<tr>
<td>#MIMO Ch/Rack</td>
<td>144 - 576</td>
<td>256</td>
<td>N/A</td>
</tr>
</tbody>
</table>

## RF Card Comparison Chart

<table>
<thead>
<tr>
<th></th>
<th>FMC 104</th>
<th>FMC 105</th>
<th>FMC 106</th>
<th>FMC 107</th>
<th>FMC 108</th>
<th>FMC 109</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applications</td>
<td>E-band radio</td>
<td>WLAN</td>
<td>LTE Advanced</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sampling</td>
<td>Direct RF or IF</td>
<td>MIMO Baseband &amp; IF</td>
<td>Direct RF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency Range (MHz)</td>
<td>5 - 2500</td>
<td>0.4 - 500</td>
<td>4.5 - 1500</td>
<td>4.5-3000 1st Nyquist 650-4000 2nd Nyquist</td>
<td>4.5-3000 1st Nyquist</td>
<td></td>
</tr>
<tr>
<td>Function</td>
<td>ADC</td>
<td>DAC</td>
<td>ADC</td>
<td>DAC</td>
<td>ADC</td>
<td>DAC</td>
</tr>
<tr>
<td>Channels</td>
<td>1, 2 or 4</td>
<td>Single</td>
<td>Quad</td>
<td>1 or 2</td>
<td>Dual</td>
<td></td>
</tr>
<tr>
<td>Rate (Gsps)</td>
<td>5 Single 2.5 Dual 1.25 Quad</td>
<td>5</td>
<td>0.5</td>
<td>1.5</td>
<td>4 Single 2 Dual</td>
<td>5.6 with 2x Interpolation</td>
</tr>
<tr>
<td>Resolution</td>
<td>10</td>
<td>12</td>
<td>14</td>
<td>16</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>2.5 GHz</td>
<td>250 MHz</td>
<td>750 MHz</td>
<td>1.0/2.0 GHz</td>
<td>1.4 GHz</td>
<td></td>
</tr>
</tbody>
</table>
Founded in 2006 after 10 years of research at UC Berkeley focusing on delivering leading prototyping, test and production equipment for cellular, defense and education markets. In 2015 BEEcube became a National Instruments Company. BEEcube boasts a global presence with customers in telecom, defense and academic research. BEEcube is headquartered in the Silicon Valley with design and support centers in Shanghai, China.

**Applications**

- Wireless Communications
- Digital Communications
- Radar Applications
- Signal Intelligence
- Signal Warfare
- Software Defined Radio
- Data Mining
- Bioinformatics
- High Speed Networking
- Computer Architecture
- HD Video Imaging

**Technology Features**

**Reconfigurable Platform**
- Scalable, full speed interconnected modules
- Flexible expansion options

**Architecture**
- Symmetrical “4-FPGA” based architecture
- Large built-in trace memory

**Nectar OS**
- Distributed C based OS
- Allows for direct real-time debugging

**I/O**
- Prebuilt IP for inter-FPGA and module Interfacing
- ADC/DAC modules up to 5.6 Gsps

BEEcube strives to continually improve its products. BEEcube reserves the right to change its products and the information within this document at any time.