EPICS\(^{(3+4=7)}\) on RTEMS 4.12

(Within the scope of CRYVISIL)

May 16th, 2017
H. Junkes, M. Heyde, P. Marschalik
Fritz-Haber-Institute, Berlin, Germany
Why?

Scientific background

- Project CRYVISIL(*) (to resolve glass dynamics)
- Build up of a very high speed scanning tunneling microscope (VHS-STM)
- High data rate (up to 100 MByte/s for ~5hrs)
- EPICS Control System with VMEbus

(*)This project has received funding from the European Research Council (ERC) under the European Union’s Advanced Grant (AdG), 2014, ERC-2014-ADG
Why?  

- STM tip driven by piezo actuators
- traditional scanning (sawtooth for x-y)
- reverse movement at high speed leads to distortion
- new scanning with spirals

Scientific background
Why?

Scientific background

Archimedean spiral

Fermat’s spiral
Decisions made

- EPICS framework, CSS as operator interface
- high density and/or fast I/O -> VMEbus, RTEMS
- all other systems should run Unix as OS
- integration of vendor locked Labview system (SPECS, Windows OS)
- must include archiver, snapshots, backup
- internetworking with Ethernet/IP, GigE-Cameras
Implementation

- EPICS R3.16.0.1-DEV, CSS 4.x with BOY as operator interface
- MVME6100 CPU (beatnik), VMEbus, rtems-4.11.99.0 (aka 4.12)
- Unix-Server (DELL) with Ubuntu OS
- LabView-CA-interface, archiver-appliance
- NetApp - Storage, TSM Backup
- development of own devices: HV - amplifier
VMEbus based control system

- MVME6100 (MPC7457) as main cpu, rtems-4.11.99.0 (will become 4.12)
- MVME2500 (QorIQ P2020) as communication cpu, rtems-4.11.99.0 (will become 4.12)
- Highland V375 arbitrary waveform generator
- SIS3316 Digitizer, 14bit, 16 channel, 250 MSample/s
- Wiener Crate 6U VME 395 Mini with CML Shelf Manager
EPICS v3 + v4

- EPICSv3 with channelAccess does not meet the requirements e.g. data rate
- EPICSv4 (bundleCPP 4.6.x) must be used
- Strong use of e.g. C11 smart pointers
- Modern compilers needed
RTEMS why new Version

- To meet the requirements high network data rate necessary
- Multiple 1Gbit/s Ethernet interfaces must be controlled simultaneously
- Multiple CPU’s with multiple cores must be handled
- Need SMP support
EPICS for RTEMS 4.12

- MVME6100 (beatnik), bsp included in rtems build (*)
  ```
  ../../../rtems/configure --enable-maintainer-mode --prefix=/home/rtems/RTEMS/rtems-4.12 --target=powerpc-rtems4.12 --enable-rtemsbsp="beatnik" --enable-posix --enable-cxx --enable-networking
  ```

- MVME2500 (QorIQ P2020), bsp included in rtems build (*)
  ```
  --enable-rtemsbsp="QorIQ"
  ```

- RTEMS closely corresponds to POSIX Profile 52
  (single process, threads, filesystem)

- includes a port of the FreeBSD TCP/IP stack, NFS

- SMP (Symmetric Multiprocessing) extension in 4.12 available

(*) Thanks to Sebastian Huber, embedded brains
EPICS for RTEMS 4.12

- Beginning with rtems >= 4.11.99 we will use as much as possible from the posix path in src/libCom/osi/os
  - mainly added osdMessageQueue.[h cpp]
  - some changes to existing posix/osdPosix.cpp
    - using _Thread_local as a replacement for posix_key’s as thread local data storage

(*) Thanks to Sebastian Huber, embedded brains
EPICS for RTEMS 4.12

- Build system supports “extended” OS_CLASS’s

```plaintext
#--------------------------------------------------
# operating system class (include/os/<os_class>)
OS_CLASS = RTEMS
#--------------------------------------------------
# operating system API (src/os/<os_class>-<os_api>)
OS_API_4.7 = kernel
OS_API_4.8 = kernel
OS_API_4.9 = kernel
OS_API_4.10 = kernel
OS_API_4.11 = $(error RTEMS-4.11 is not currently supported)
# Later RTEMS versions will use posix, no need to specify
OS_API = $(firstword $(OS_API_$(RTEMS_SERIES)) posix)
```
EPICS for RTEMS 4.12

- open issues
  - intensive tests so far only for powerPC (beatnik bsp)
  - C11 threads support is not yet common
  - can’t test it on i386, C++ atomics on i386 is broken or fragile
  - binding to loopback and multicast addresses
  - need more test on other platforms
  - registers in exception frame
- not yet merged into base
EPICS for RTEMS 4.12

- works in our environment …
  - asyn, autosave
  - Control System Studio
  - archiver appliance
  - python
- stable and reliable so far
<table>
<thead>
<tr>
<th>NAME</th>
<th>EPICS ID</th>
<th>PTHREAD ID</th>
<th>OSIPRI</th>
<th>OSSPRI</th>
<th>STATE</th>
<th>STACKSIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>main</em></td>
<td>0x36aff0</td>
<td>0xB010001</td>
<td>91</td>
<td>191</td>
<td>OK</td>
<td>16384</td>
</tr>
<tr>
<td>errlog</td>
<td>0xa7af98</td>
<td>0xB010003</td>
<td>10</td>
<td>110</td>
<td>OK</td>
<td>16384</td>
</tr>
<tr>
<td>timerQueue</td>
<td>0xa87638</td>
<td>0xB010004</td>
<td>60</td>
<td>160</td>
<td>OK</td>
<td>32768</td>
</tr>
<tr>
<td>timerQueue</td>
<td>0xa87598</td>
<td>0xB010005</td>
<td>60</td>
<td>160</td>
<td>OK</td>
<td>32768</td>
</tr>
<tr>
<td>awgport update</td>
<td>0xa88f00</td>
<td>0xB010007</td>
<td>51</td>
<td>151</td>
<td>OK</td>
<td>16384</td>
</tr>
<tr>
<td>timerQueue</td>
<td>0xe11620</td>
<td>0xB010009</td>
<td>70</td>
<td>170</td>
<td>OK</td>
<td>32768</td>
</tr>
<tr>
<td>cbLow</td>
<td>0xe11840</td>
<td>0xB01000A</td>
<td>59</td>
<td>159</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>cbMedium</td>
<td>0xe11a80</td>
<td>0xB01000B</td>
<td>64</td>
<td>164</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>cbHigh</td>
<td>0xe11cc0</td>
<td>0xB01000C</td>
<td>71</td>
<td>171</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>dbCaLink</td>
<td>0xe0cce8</td>
<td>0xB01000D</td>
<td>50</td>
<td>150</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>taskwd</td>
<td>0xe0d180</td>
<td>0xB010008</td>
<td>10</td>
<td>110</td>
<td>OK</td>
<td>16384</td>
</tr>
<tr>
<td>scanOnce</td>
<td>0xe77100</td>
<td>0xB01000E</td>
<td>67</td>
<td>167</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>scan-10</td>
<td>0xe87548</td>
<td>0xB01000F</td>
<td>60</td>
<td>160</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>scan-5</td>
<td>0xe97748</td>
<td>0xB010010</td>
<td>61</td>
<td>161</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>scan-2</td>
<td>0xea7948</td>
<td>0xB010011</td>
<td>62</td>
<td>162</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>scan-1</td>
<td>0xeb7b48</td>
<td>0xB010012</td>
<td>63</td>
<td>163</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>scan-0.5</td>
<td>0xec7d48</td>
<td>0xB010013</td>
<td>64</td>
<td>164</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>scan-0.2</td>
<td>0xed7f48</td>
<td>0xB010014</td>
<td>65</td>
<td>165</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>scan-0.1</td>
<td>0xee8148</td>
<td>0xB010015</td>
<td>66</td>
<td>166</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>CAS-TCP</td>
<td>0xefce50</td>
<td>0xB010016</td>
<td>18</td>
<td>118</td>
<td>OK</td>
<td>32768</td>
</tr>
<tr>
<td>CAS-UDP</td>
<td>0xf05038</td>
<td>0xB010017</td>
<td>16</td>
<td>116</td>
<td>OK</td>
<td>32768</td>
</tr>
<tr>
<td>CAS-UDP2</td>
<td>0xf1dd90</td>
<td>0xB010018</td>
<td>16</td>
<td>116</td>
<td>OK</td>
<td>32768</td>
</tr>
<tr>
<td>CAS-beacon</td>
<td>0xf36528</td>
<td>0xB010019</td>
<td>17</td>
<td>117</td>
<td>OK</td>
<td>16384</td>
</tr>
<tr>
<td>NAME</td>
<td>EPICS ID</td>
<td>PTHREAD ID</td>
<td>OSIPRI</td>
<td>OSSPRI</td>
<td>STATE</td>
<td>STACKSIZE</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------</td>
<td>---------------</td>
<td>--------</td>
<td>--------</td>
<td>-------</td>
<td>-----------</td>
</tr>
<tr>
<td><em>main</em></td>
<td>0x4e8c40</td>
<td>0x0B010001</td>
<td>91</td>
<td>191</td>
<td>OK</td>
<td>16384</td>
</tr>
<tr>
<td>errlog</td>
<td>0xbfcf28</td>
<td>0x0B010003</td>
<td>10</td>
<td>110</td>
<td>OK</td>
<td>16384</td>
</tr>
<tr>
<td>timerQueue</td>
<td>0xc68b60</td>
<td>0x0B010005</td>
<td>70</td>
<td>170</td>
<td>OK</td>
<td>32768</td>
</tr>
<tr>
<td>cbLow</td>
<td>0xc68d80</td>
<td>0x0B010006</td>
<td>59</td>
<td>159</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>cbMedium</td>
<td>0xc68fc0</td>
<td>0x0B010007</td>
<td>64</td>
<td>164</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>cbHigh</td>
<td>0xc69200</td>
<td>0x0B010008</td>
<td>71</td>
<td>171</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>dbCaLink</td>
<td>0xc69c88</td>
<td>0x0B010009</td>
<td>50</td>
<td>150</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>scanOnce</td>
<td>0xc6bade8</td>
<td>0x0B01000A</td>
<td>67</td>
<td>167</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>scan-10</td>
<td>0xc6bdd0</td>
<td>0x0B01000B</td>
<td>60</td>
<td>160</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>scan-5</td>
<td>0xc6bf8</td>
<td>0x0B01000C</td>
<td>61</td>
<td>161</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>scan-2</td>
<td>0xc0be68</td>
<td>0x0B01000D</td>
<td>62</td>
<td>162</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>scan-1</td>
<td>0xc0c028</td>
<td>0x0B01000E</td>
<td>63</td>
<td>163</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>scan-0.5</td>
<td>0xc0c208</td>
<td>0x0B01000F</td>
<td>64</td>
<td>164</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>scan-0.2</td>
<td>0xc0c3e8</td>
<td>0x0B010010</td>
<td>65</td>
<td>165</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>scan-0.1</td>
<td>0xc0c5e0</td>
<td>0x0B010011</td>
<td>66</td>
<td>166</td>
<td>OK</td>
<td>65536</td>
</tr>
<tr>
<td>taskwd</td>
<td>0xc68648</td>
<td>0x0B010004</td>
<td>10</td>
<td>110</td>
<td>OK</td>
<td>16384</td>
</tr>
<tr>
<td>CAS-TCP</td>
<td>0xd435f0</td>
<td>0x0B010012</td>
<td>18</td>
<td>118</td>
<td>OK</td>
<td>32768</td>
</tr>
<tr>
<td>CAS-UDP</td>
<td>0xd4b7d8</td>
<td>0x0B010013</td>
<td>16</td>
<td>116</td>
<td>OK</td>
<td>32768</td>
</tr>
<tr>
<td>CAS-UDP2</td>
<td>0xd4530</td>
<td>0x0B010014</td>
<td>16</td>
<td>116</td>
<td>OK</td>
<td>32768</td>
</tr>
<tr>
<td>CAS-beacon</td>
<td>0xd7ccc8</td>
<td>0x0B010015</td>
<td>17</td>
<td>117</td>
<td>OK</td>
<td>16384</td>
</tr>
<tr>
<td>ntndarrayServer</td>
<td>0xdc0590</td>
<td>0x0B010016</td>
<td>90</td>
<td>190</td>
<td>OK</td>
<td>16384</td>
</tr>
<tr>
<td>ntndarrayServer</td>
<td>0xe03590</td>
<td>0x0B010017</td>
<td>90</td>
<td>190</td>
<td>OK</td>
<td>16384</td>
</tr>
<tr>
<td>TCP-acceptor</td>
<td>0xe151b0</td>
<td>0x0B010019</td>
<td>50</td>
<td>150</td>
<td>OK</td>
<td>32768</td>
</tr>
<tr>
<td>pvAccess-server</td>
<td>0xe106a0</td>
<td>0x0B010018</td>
<td>25</td>
<td>125</td>
<td>OK</td>
<td>16384</td>
</tr>
<tr>
<td>UDP-rx 0.0.0.0:0</td>
<td>0xe3dc18</td>
<td>0x0B01001A</td>
<td>50</td>
<td>150</td>
<td>OK</td>
<td>16384</td>
</tr>
<tr>
<td>UDP-rx 0.0.0.0:5</td>
<td>0xe865a8</td>
<td>0x0B01001B</td>
<td>50</td>
<td>150</td>
<td>OK</td>
<td>16384</td>
</tr>
<tr>
<td>UDP-rx 0.0.0.0:5</td>
<td>0xe8a838</td>
<td>0x0B01001C</td>
<td>50</td>
<td>150</td>
<td>OK</td>
<td>16384</td>
</tr>
<tr>
<td>UDP-rx 224.0.0.1</td>
<td>0xeb2ee8</td>
<td>0x0B01001D</td>
<td>50</td>
<td>150</td>
<td>OK</td>
<td>16384</td>
</tr>
<tr>
<td>startPVAServer</td>
<td>0xf32890</td>
<td>0x0B01001E</td>
<td>50</td>
<td>150</td>
<td>OK</td>
<td>65536</td>
</tr>
</tbody>
</table>