Introduction to ApplicationCore.

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DESY MSK

How it all began...

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- DOOCS example:
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- Of course one has to decide for one implementation, but no fundamental difference in the application

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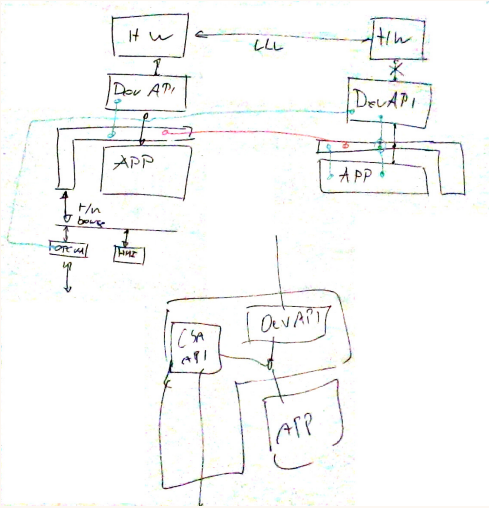
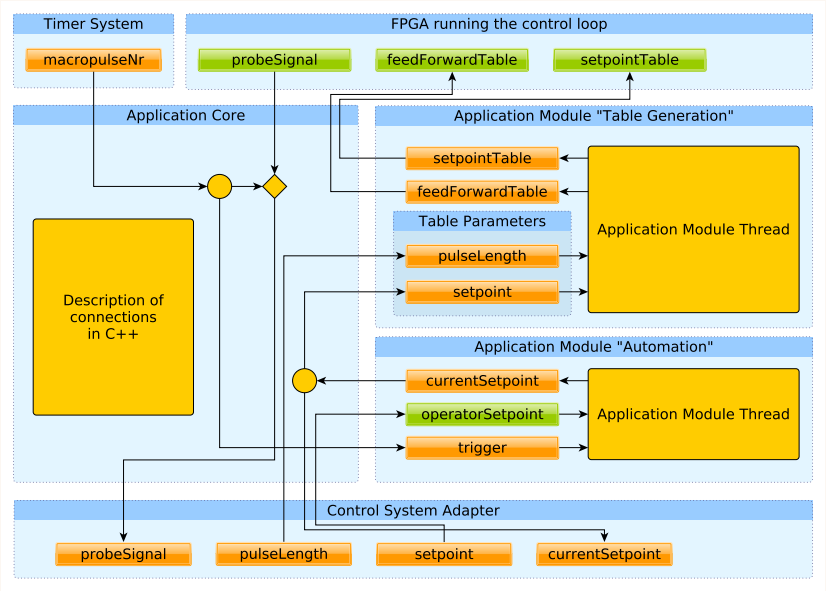


The structure of ApplicationCore



Central ideas for ApplicationCore

Goal: provide framework for implementing applications which are "naturally" control-system-independent

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- Encourage modular applications (even beyond DOOCS locations)
- Clean and simple interface, avoid boiler plate code as much as C++11 allows
- Avoid the need for user callback functions (excessive use makes code unreadable)
- Allow publishing a device register into the control system with a single code line

Short refresh of C++ 11

- Default arguments to member constructors with braces

```
struct SomeClass {
  std::string myText{"Hello World"};
};
```

Short refresh of C++ 11

- Default arguments to member constructors with braces

```
struct SomeClass {
  std::string myText{"Hello World"};
};
```

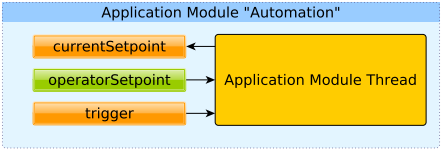
- Brace-initialisers when passing arguments

```
void someFunction(std::vector<int> values);
void main() {
  someFunction({1, 42, 33});
}
```

Central ideas for ApplicationCore

$$\text{Variable} = \text{Register} = \text{Property}$$

Application Module



Application Module (idealised code)

```
struct Automation : public ctk::ApplicationModule {

  ctk::ScalarInput<double> opSP{"opSP", "MV", "Setpoint given by operator"};
  ctk::ScalarOutput<double> curSP{"curSP", "MV", "Automated setpoint"};
  ctk::ScalarInput<int> trigger{"trigger", "", "Macropulse trigger"};









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  ctk::ScalarInput<int> trigger{"trigger", "", "Macropulse trigger"};

  void mainLoop() {
    while(true) {
      trigger.read();          // wait until next trigger
      opSP.readLatest();       // just get the current value
      if(std::abs(opSP - curSP) > 0.01) {
        curSP += std::min( std::max(opSP - curSP, 0.1), -0.1);
        curSP.write();
      }
    }
  }
};
```

Application Module (towards actual code - step 1)

```
struct Automation : public ctk::ApplicationModule {

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Application Module (towards actual code - step 1)

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      if(std::abs(opSP - curSP) > 0.01) {
        curSP += std::min( std::max(opSP - curSP, 0.1), -0.1);
        curSP.write();
      }
    }
  }
};
```

Need to know the owner!

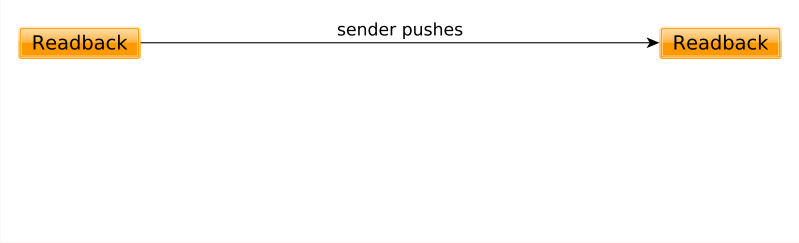
Application Module (towards actual code - step 2)

```
struct Automation : public ctk::ApplicationModule {
  using ctk::ApplicationModule::ApplicationModule;      ⟵ Inherit constructor
  ctk::ScalarInput<double> opSP{this, "opSP", "MV", "..."};
  ctk::ScalarOutput<double> curSP{this, "curSP", "MV", "..."};
  ctk::ScalarInput<int> trigger{this, "trigger", "", "..."};

  void mainLoop() {
    while(true) {
      trigger.read();
      opSP.readLatest();
      if(std::abs(opSP - curSP) > 0.01) {
        curSP += std::min( std::max(opSP - curSP, 0.1), -0.1);
        curSP.write();
      }
    }
  }
};
```

Excursus: Update modes

- Generalise the client/server concept



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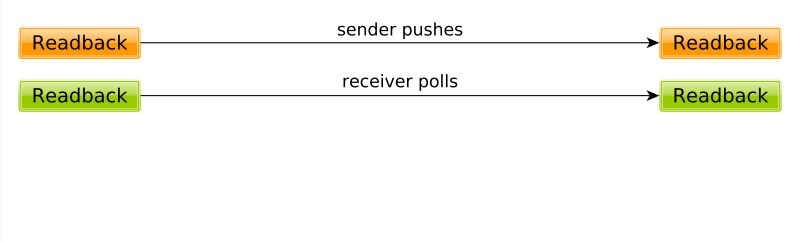

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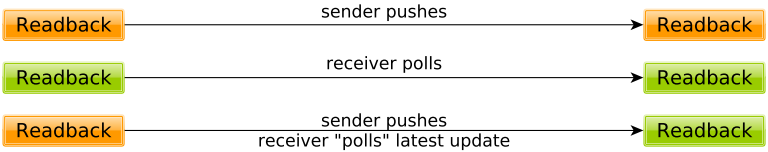

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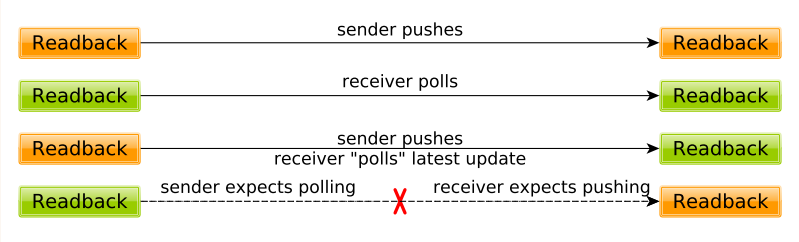

Application Module (actual code!)

```
struct Automation : public ctk::ApplicationModule {
  using ctk::ApplicationModule::ApplicationModule;
  ctk::ScalarPollInput<double> opSP{this, "opSP", "MV", "..."};
  ctk::ScalarOutput<double> curSP{this, "curSP", "MV", "..."};
  ctk::ScalarPushInput<int> trigger{this, "trigger", "", "..."};

  void mainLoop() {
    while(true) {
      trigger.read();
      opSP.readLatest();     // opSP.read() would be equivalent
      if(std::abs(opSP - curSP) > 0.01) {
        curSP += std::min( std::max(opSP - curSP, 0.1), -0.1);
        curSP.write();
      }
    }
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  }
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```

Interface from DeviceAccess

- ScalarPollInput / ScalarPushInput / ScalarOutput
  ⇒ ScalarRegisterAccessor
- ArrayPollInput / ArrayPushInput / ArrayOutput
  ⇒ OneDRegisterAccessor

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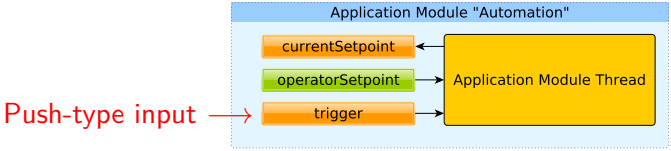
Interface from DeviceAccess

- ScalarPollInput / ScalarPushInput / ScalarOutput
  ⇒ ScalarRegisterAccessor
- ArrayPollInput / ArrayPushInput / ArrayOutput
  ⇒ OneDRegisterAccessor
- Actual inheritance!
- Only adds *inversion of control*

Application Module



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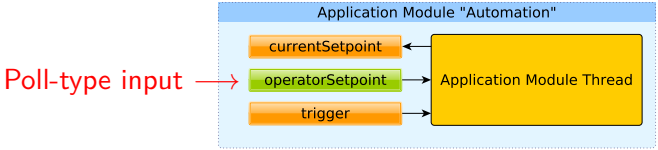

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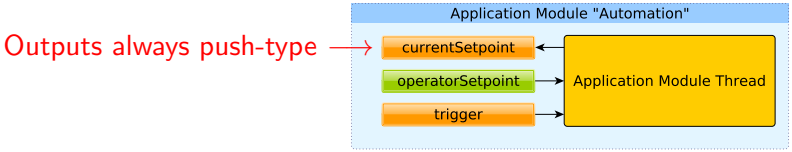
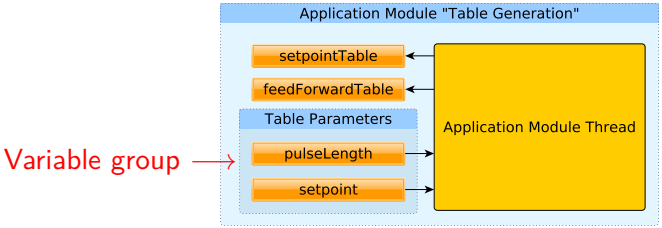


Group your variables



Group your variables

- An ApplicationModule can contain variables — and groups of variables

```
struct TableGeneration : public ctk::ApplicationModule {
  // ...
  struct TableParameters : public ctk::VariableGroup {
    using ctk::VariableGroup::VariableGroup;
    ctk::ScalarPushInput<double> pulseLength{this, "pulseLength", "us", "..."};
    ctk::ScalarPushInput<double> setpoint{this, "setpoint", "MV", "..."};
  };
  TableParameters tableParams{this, "tableParameters", "..."};









};
```

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  // ...
  struct TableParameters : public ctk::VariableGroup {
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    ctk::ScalarPushInput<double> setpoint{this, "setpoint", "MV", "..."};
  };
  TableParameters tableParams{this, "tableParameters", "..."};

  void mainLoop() {
    while(true) {
      // ...
      tableParams.readAll();    // blocks until *all* variables are changed
    }
  }
};
```

Group your variables

- An ApplicationModule can contain variables — and groups of variables

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struct TableGeneration : public ctk::ApplicationModule {
  // ...
  struct TableParameters : public ctk::VariableGroup {
    using ctk::VariableGroup::VariableGroup;
    ctk::ScalarPushInput<double> pulseLength{this, "pulseLength", "us", "..."};
    ctk::ScalarPushInput<double> setpoint{this, "setpoint", "MV", "..."};
  };
  TableParameters tableParams{this, "tableParameters", "..."};

  void mainLoop() {
    while(true) {
      // ...
      tableParams.readAny();    // block until *any* variable is changed
    }
  }
};
```

Defining the full application

Most code will go into those mainLoop() implementations!

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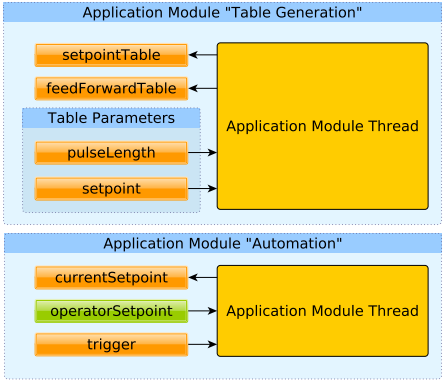
But some quite complicated concepts are still missing...

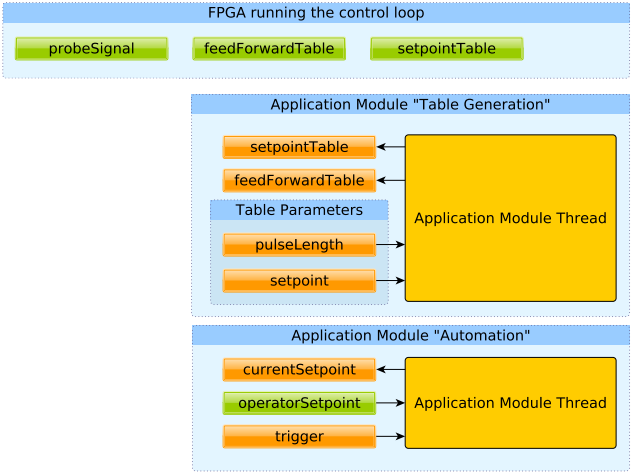
Defining the full application



Defining the full application (partial actual code)

```
struct LLRFServer : public ctk::Application {
    LLRFServer() : Application("demoApp") {}
    ~LLRFServer() { shutdown(); }

    Automation automation{this, "automation", "..."};
    TableGeneration tableGeneration{this, "tableGeneration", "..."};









};
```

Defining the full application



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    Automation automation{this, "automation", "..."};
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    ctk::DeviceModule dev{"Device0"};




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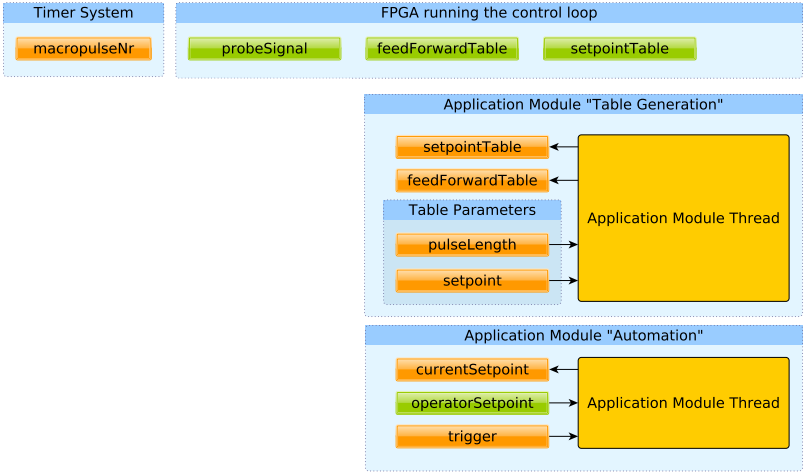

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    LLRFServer() : Application("demoApp") {}
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    Automation automation{this, "automation", "..."};
    TableGeneration tableGeneration{this, "tableGeneration", "..."};
    ctk::DeviceModule dev{"Device0"};
    ctk::DeviceModule timer{"Timer"};

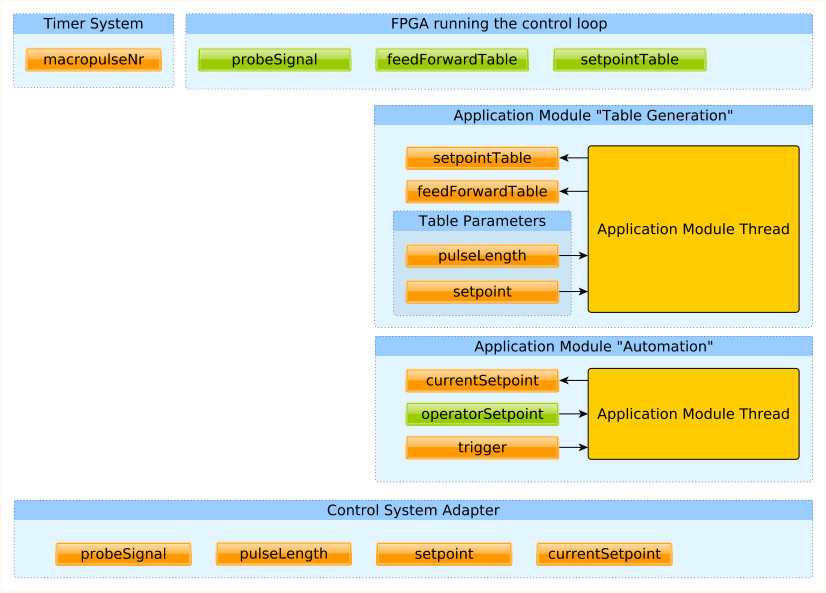



};
```

The .dmap file

```
@LOAD_LIB /usr/lib/libChimeraTK-DeviceAccess-DoocsBackend.so
ADC0      sdm://./pci:pcieunis4                    sincav_sis8300l_hzdr_srf_r2102.map
Device0   sdm://./logicalNameMap                   llrfserver.xlmap
Timer     sdm://./doocs=TEST.DOOCS,TIMER2_SRV,MTCACPU.0      none
```

Defining the full application



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    Automation automation{this, "automation", "..."};
    TableGeneration tableGeneration{this, "tableGeneration", "..."};
    ctk::DeviceModule dev{"Device0"};
    ctk::DeviceModule timer{"Timer"};
    ctk::ControlSystemModule cs;



};
```

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LLRFServer theLLRFServer;
```

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    ~LLRFServer() { shutdown(); }

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    TableGeneration tableGeneration{thi...eneration", "..."};
    ctk::DeviceModule dev{"Devic...
    ctk::DeviceModule time...
    ctk::ControlSys...s;

};
LLRFServer theLLRFServer;
```
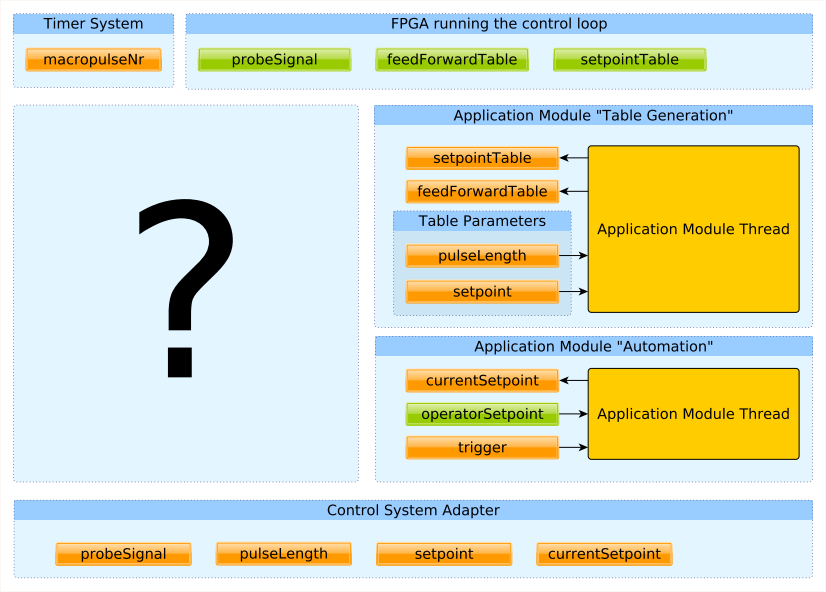

No main() function shall be defined, it is coming from the adapter!

Defining the full application



Defining the full application (actual code!)

```
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    LLRFServer() : Application("llrfServer") {}
    ~LLRFServer() { shutdown(); }

    Automation automation{this, "automation", "..."};
    TableGeneration tableGeneration{this, "tableGeneration", "..."};
    ctk::DeviceModule dev{"Device0"};
    ctk::DeviceModule timer{"Timer"};
    ctk::ControlSystemModule cs;

    void defineConnections();

};
LLRFServer theLLRFServer;
```
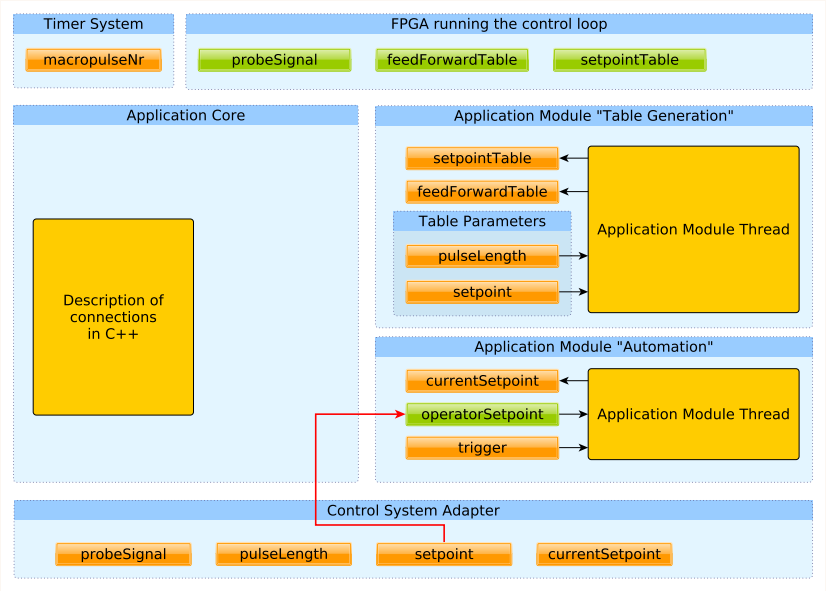

Defining the connections (partial code)

```
void LLRFServer::defineConnections() {
  mtca4u::setDMapFilePath("deviceMapFile.dmap");









}
```

Defining the connections



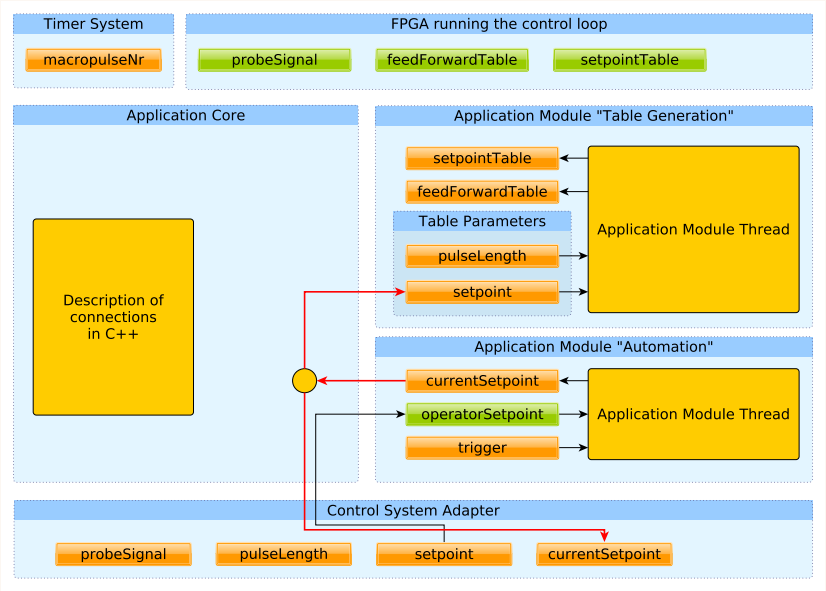
Defining the connections (partial code)

```
void LLRFServer::defineConnections() {
  mtca4u::setDMapFilePath("deviceMapFile.dmap");

  cs("setpoint") >> automation.opSP;









}
```

Defining the connections (partial code)

```
void LLRFServer::defineConnections() {
  mtca4u::setDMapFilePath("deviceMapFile.dmap");

  cs("setpoint") >> automation.opSP;

    ↑
    This will cause the creation of a ProcessVariable in the ControlSystemAdapter

}
```

Defining the connections



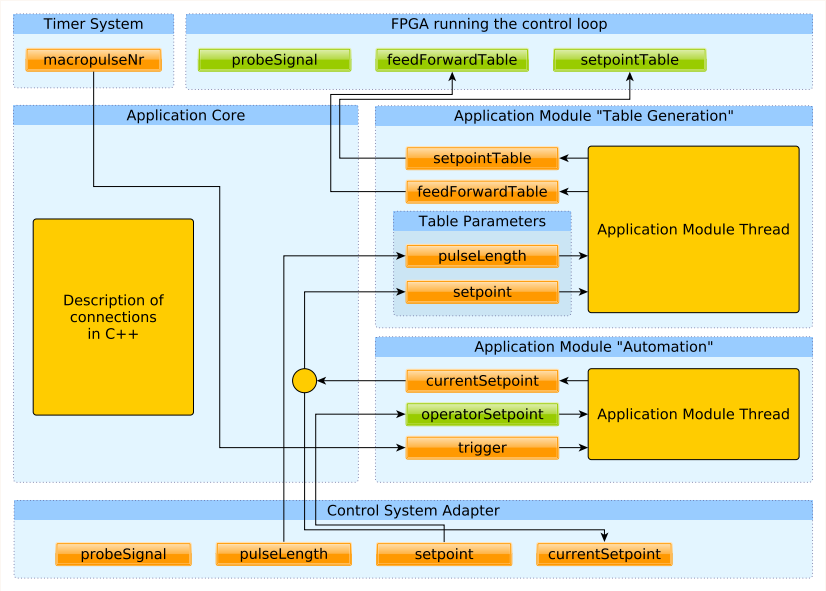
Defining the connections (partial code)

```
void LLRFServer::defineConnections() {
  mtca4u::setDMapFilePath("deviceMapFile.dmap");

  cs("setpoint") >> automation.opSP;
  automation.curSP >> tableGeneration.tableParams.setpoint >> cs("currentSetpoint");









}
```

Defining the connections (partial idealised code)

```
void LLRFServer::defineConnections() {
  mtca4u::setDMapFilePath("deviceMapFile.dmap");

  cs("setpoint") >> automation.opSP;
  automation.curSP >> tableGeneration.tableParams.setpoint >> cs("currentSetpoint");


  timer("macropulseNr") >> automation.trigger;

  cs("pulseLength") >> tableGeneration.tableParams.pulseLength;

  tableGeneration.setpointTable >> dev("setpointTable");
  tableGeneration.feedforwardTable >> dev("feedforwardTable");



}
```

Defining the connections



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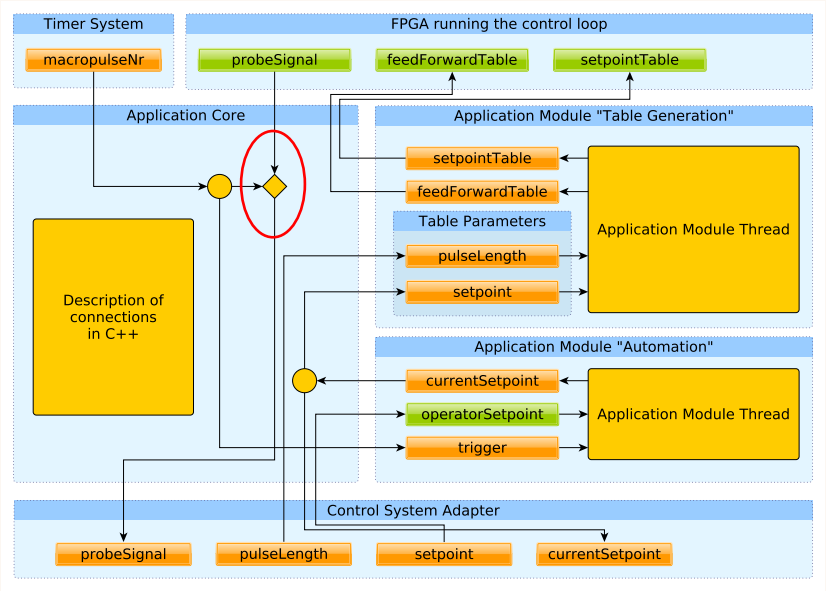
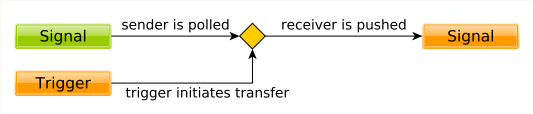


Triggers

- When connecting a poll-type output (e.g. a PCIe register) with a push-type input, a trigger for the transfer is needed



- Any push-type variable can be used as trigger, its value will be ignored

Defining the connections (idealised code)

```
void LLRFServer::defineConnections() {
  mtca4u::setDMapFilePath("deviceMapFile.dmap");

  cs("setpoint") >> automation.opSP;
  automation.curSP >> tableGeneration.tableParams.setpoint >> cs("currentSetpoint");


  timer("macropulseNr") >> automation.trigger;

  cs("pulseLength") >> tableGeneration.tableParams.pulseLength;

  tableGeneration.setpointTable >> dev("setpointTable");
  tableGeneration.feedforwardTable >> dev("feedforwardTable");

  dev("probeSignal") [ timer("macropulseNr") ] >> cs("probeSignal");

}
```

Defining the connections (idealised code)

```
void LLRFServer::defineConnections() {
  mtca4u::setDMapFilePath("deviceMapFile.dmap");

  cs("setpoint") >> automation.opSP;
  automation.curSP >> tableGeneration.tableParams.setpoint >> cs("currentSetpoint");
  tableGeneration.setpointTable >> dev("setpointTable");
  tableGeneration.feedforwardTable >> dev("feedforwardTable");

→ dev("probeSignal") [ timer("macropulseNr") ] >> cs("probeSignal");

}
```

- Neither DeviceModule nor ControlSystemModule define their variable types
- DeviceAccess allows to read a register as any type
- ControlSystemAdater variables are created on-the-fly
- We need to specify the type and array length here!

Defining the connections (idealised code)

```
void LLRFServer::defineConnections() {
  mtca4u::setDMapFilePath("deviceMapFile.dmap");

  cs("setpoint") >> automation.opSP;
  automation.curSP >> tableGeneration.tableParams.setpoint >> cs("currentSetpoint");
  tableGeneration.setpointTable >> dev("setpointTable");
  tableGeneration.feedforwardTable >> dev("feedforwardTable");

→ dev("probeSignal", typeid(int), 16384) [ timer("macropulseNr") ]
    >> cs("probeSignal");
}
```

- Neither DeviceModule nor ControlSystemModule define their variable types
- DeviceAccess allows to read a register as any type
- ControlSystemAdater variables are created on-the-fly
- We need to specify the type and array length here!

Defining the connections (actual code!)

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}
```

- Similar problem here, but this time the UpdateMode is wrong
- DeviceAccess variables are by default poll-type

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  cs("setpoint") >> automation.opSP;
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  auto macropulseNr = timer("macropulseNr", typeid(int), 1, ctk::UpdateMode::push);
  macropulseNr >> automation.trigger;

  cs("pulseLength") >> tableGeneration.tableParams.pulseLength;

}
```

- Similar problem here, but this time the UpdateMode is wrong
- DeviceAccess variables are by default poll-type
- Need to change this to push-type
- DOOCS backend: push-type means ZeroMQ subscription!

Defining the connections (actual code!)

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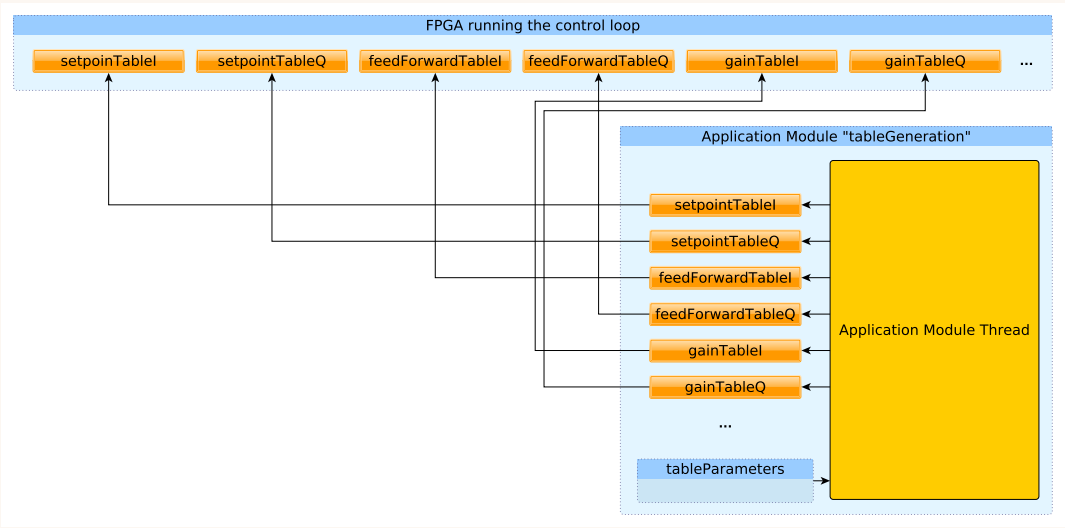
}
```

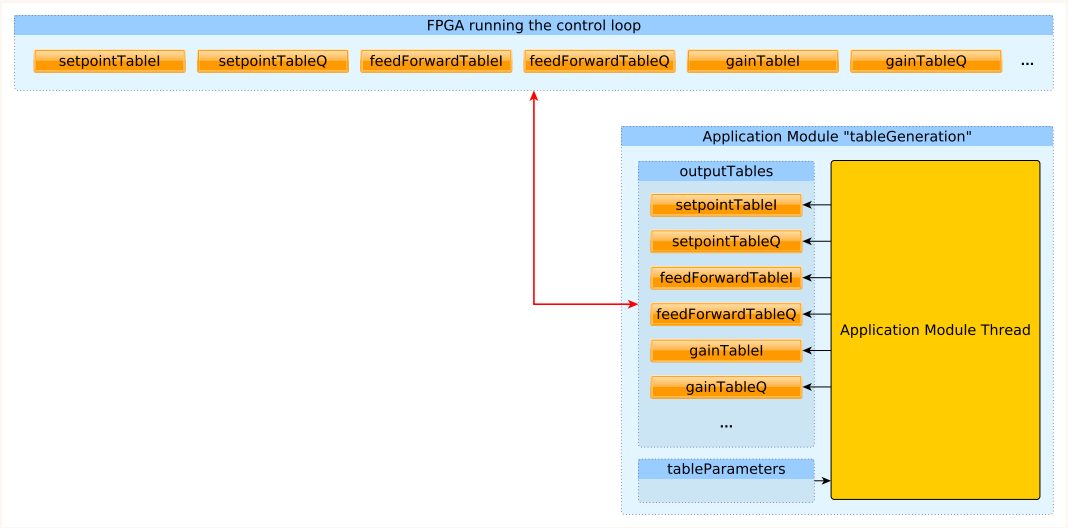
Too much code!

This would be way too much code for a big server.
One line of connection code per variable/register!

Group connections



Group connections



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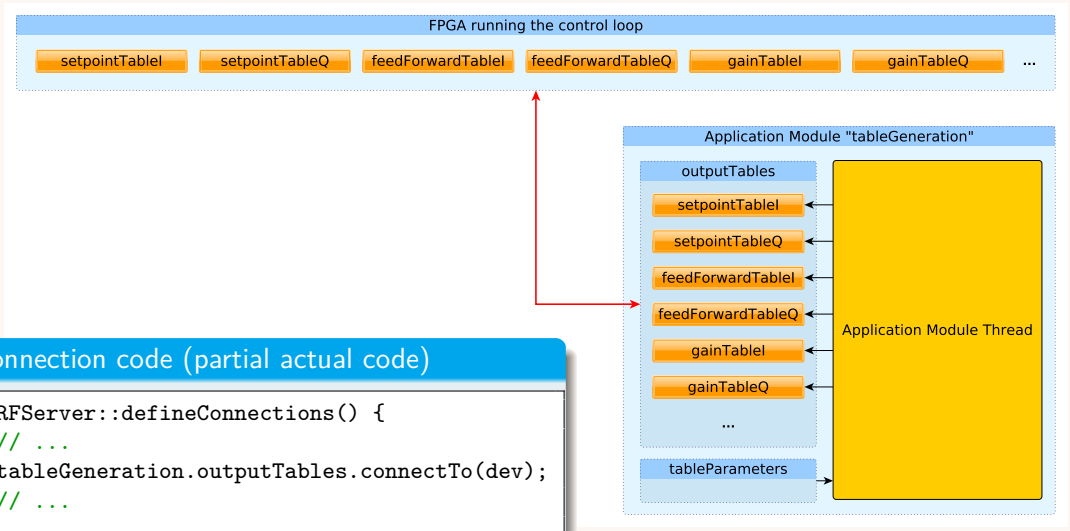

Connection code (partial actual code)

```
LLRFServer::defineConnections() {
  // ...
  tableGeneration.outputTables.connectTo(dev);
  // ...
}
```

connectTo()

- Connect all variables of module with variables of same name in other module
- Works the same way with VariableGroup

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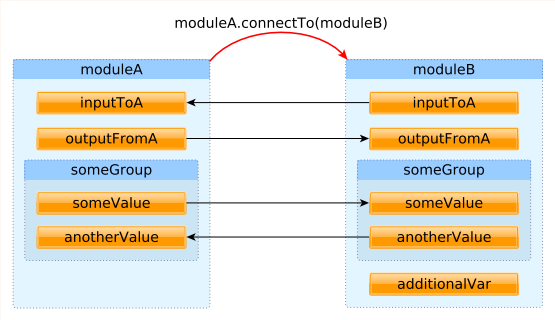

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- Add tags to variables (even to entire modules/groups)

Declaration of variable in module:

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ctk::ScalarOutput<double> curSP{this, "curSP", "MV", "...", {"TableGen"}};
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- Search for tag and connect by tags

  Connection code:

```
automation.findTag("TableGen").connectTo(tableGeneration);
```

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- Search for tag and connect by tags

  Connection code:

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automation.findTag("TableGen").connectTo(tableGeneration);
```
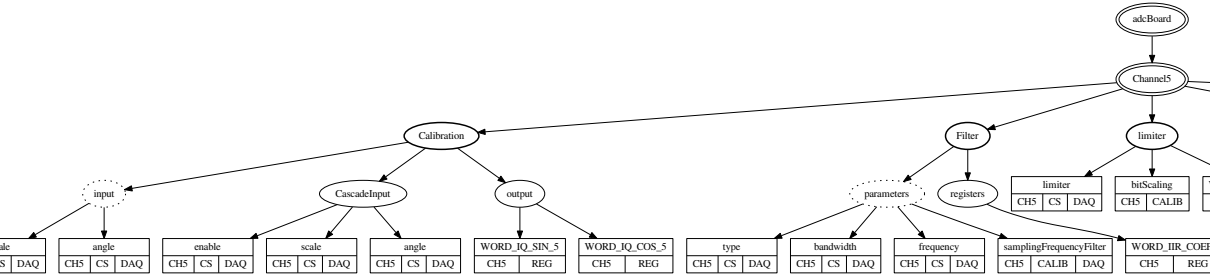

- Variables can have more than one tag
- findTag() can be nested (e.g. `someModule.findTag("tagA").findTag("tagB")`)

Example: LLRF server module adcBoard, Channel 5 (partial)



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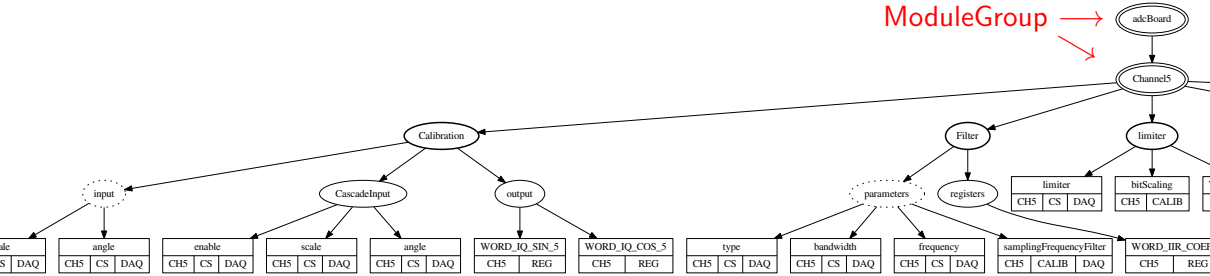

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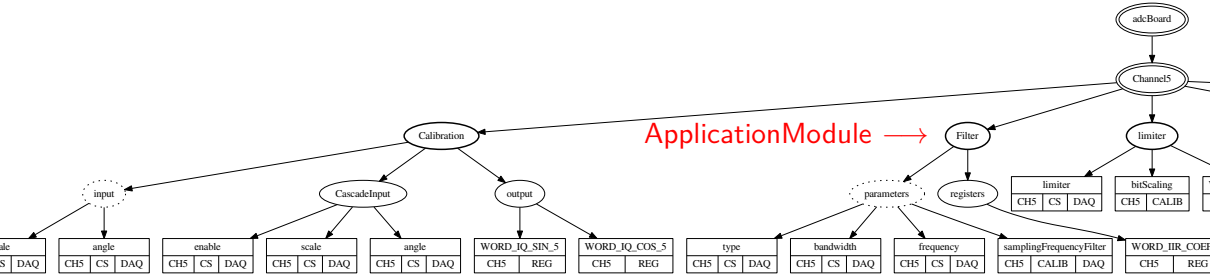

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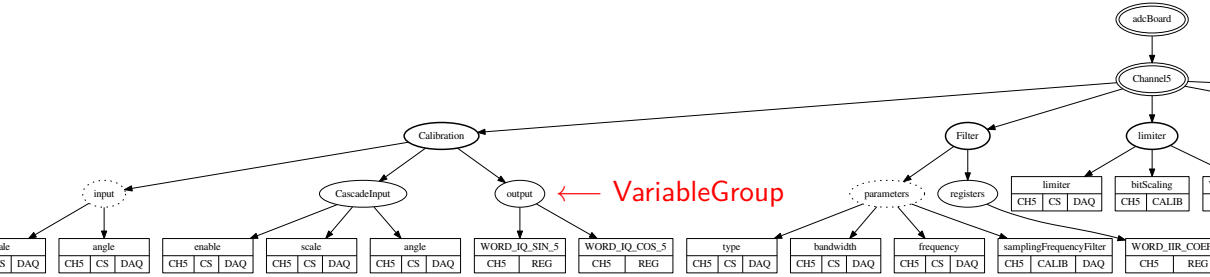

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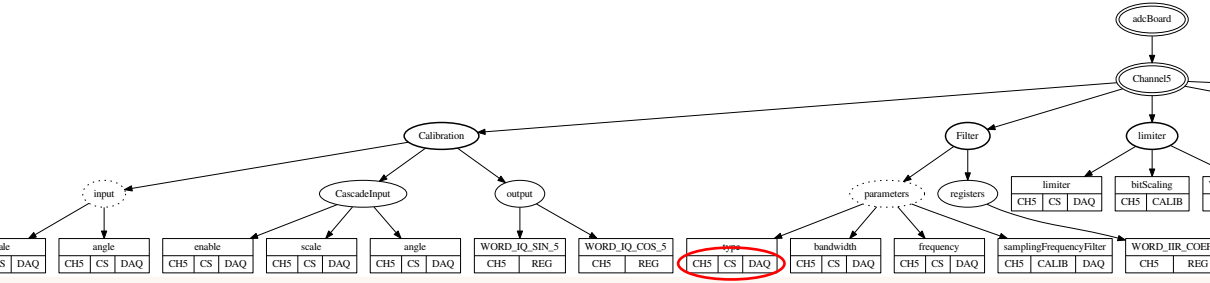
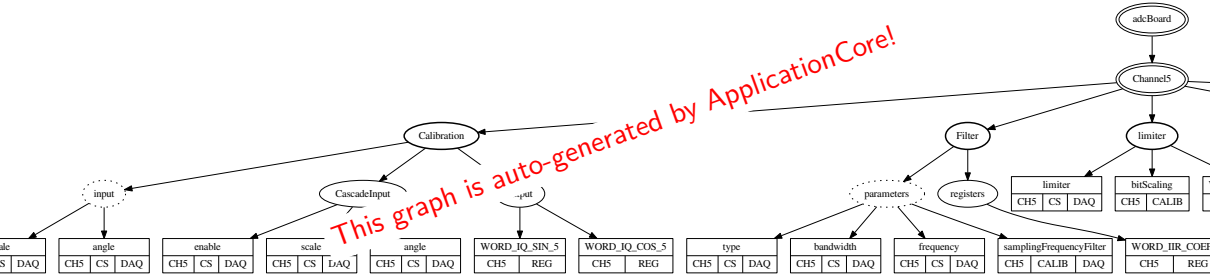


Tags

- Tag “CH5”: other modules also provide variables for Channel 5
- Tags “REG” and “CS”: device registers and control system variables
- Tag “CALIB”: global calibration values
- Tag “DAQ”: variables go into the internal DAQ system (if enabled)

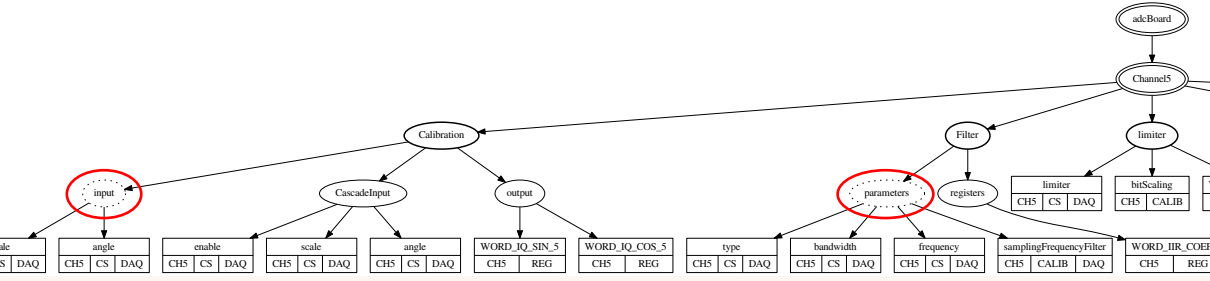
Example: LLRF server module adcBoard, Channel 5 (partial)



Tweak the model

In constructor of your ModuleGroup etc.:

- Eliminate hierarchy levels (`Module::setEliminateHierarchy()`)



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- Eliminate hierarchy levels (`Module::setEliminateHierarchy()`)
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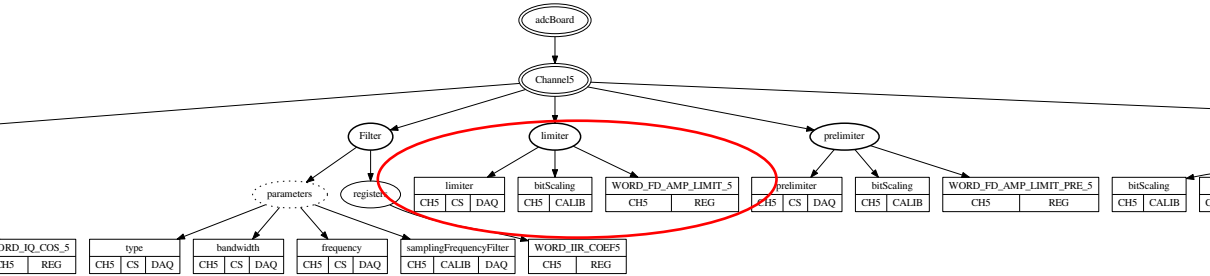


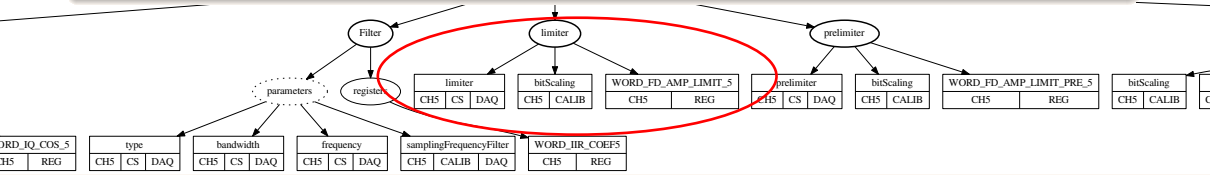
Tweak the model

Generic module

```
template<typename T>
struct MultiplierModule : public ctk::ApplicationModule {
  using ctk::ApplicationModule::ApplicationModule;

  ctk::ScalarPushInput<T> input{this, "input", "", "Input value to be scaled"};
  ctk::ScalarPushInput<T> factor{this, "factor", "", "Scaling factor"};
  ctk::ScalarOutput<T> output{this, "output", "", "Output value after scaling"};

  void mainLoop();
};
```



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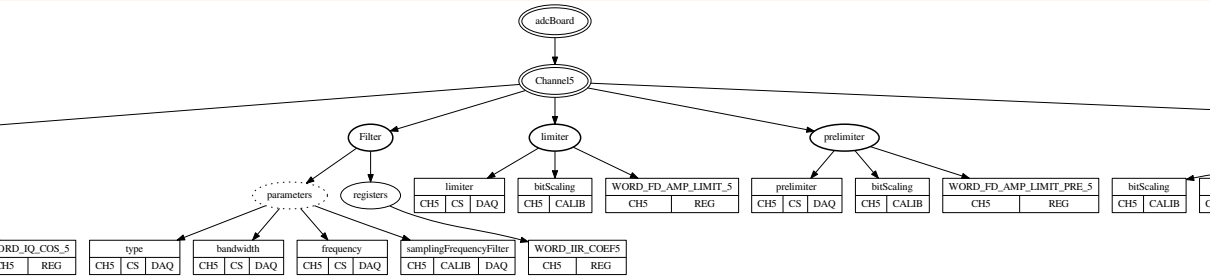
In your `defineConnections()`:

- Eliminate all hierarchy levels (`Module::flatten()`)



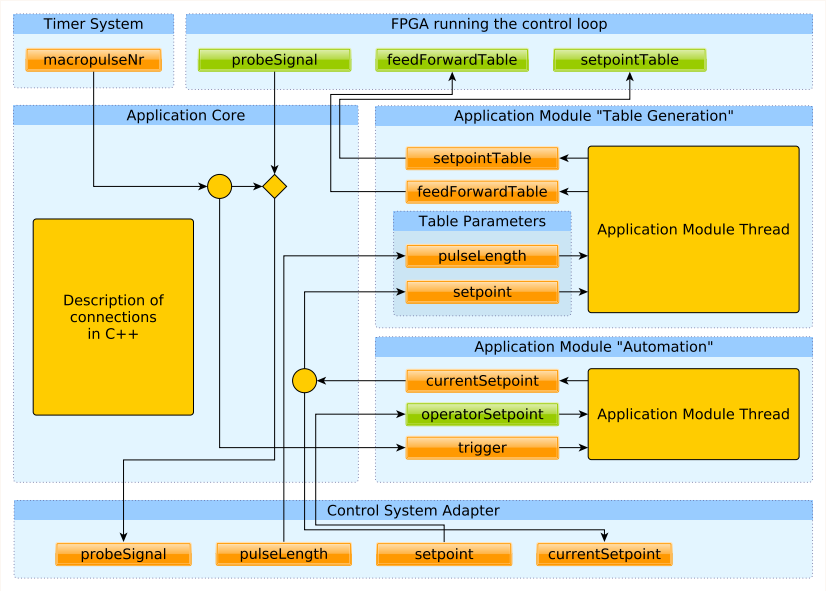
Arrays of modules

```
struct Channel : public ctk::ApplicationModule {
    // ...
};
struct AdcBoard : public ctk::ModuleGroup {
    // ...
    std::vector<Channel> channels;
    // ...
};
```

```
AdcBoard::AdcBoard(/* ... */) {
    for(size_t i = 0; i < numberOfChannels; ++i) {
      channels.emplace_back(this, "Channel"+std::to_string(i), /*...*/);
    }
}
```

- Similarly possible with variables (put e.g. `ctk::ScalarOuput` into `std::vector`)

The structure of ApplicationCore



Servers currently in development using ApplicationCore

- LLRF ctrl server: single cavity CW version for HZDR and CMTB
  - successfull tests at HZDR last week with full WinCC / OPC UA integration
  - long-term plan: extend for FLASH/XFEL and replace pure DOOCS server
- FRED server
- Watchdog for HZDR

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- Debian packages available for Ubuntu 16.04 (public DOOCS repository)

(backup)

Planned improvement (long term, not complete)

- Add types: bool and void (for triggers)
- "Blind" variables: add variable to information model, e.g. to publish a devie register to the control system despite not being used by the app
- "Tiny" application modules: save extra thread / context switches for small operation (e.g. just scaling a value)
- For documentation etc.: create more graphs showing the application structure in different views (actual realisation, ...)
- Enforce data consistency between variables in transfers
- Create library of generic modules (like the MultiplierModule)
- Allow defining the connections by XML file