Preface

This lecture covers the Insertion Device Control System (IDCS) at BESSY II.
IDCS is developed by:

Götz Pfeiffer

The EPICS-CAN bus interface is a joint work of the following people:

Jens Bergl
Bernhard Kuner
Ralf Lange
Ingo Müller
Götz Pfeiffer

BESSY II
Rudower Chaussee 5
12489 Berlin
GERMANY
+49 30 6392-2900
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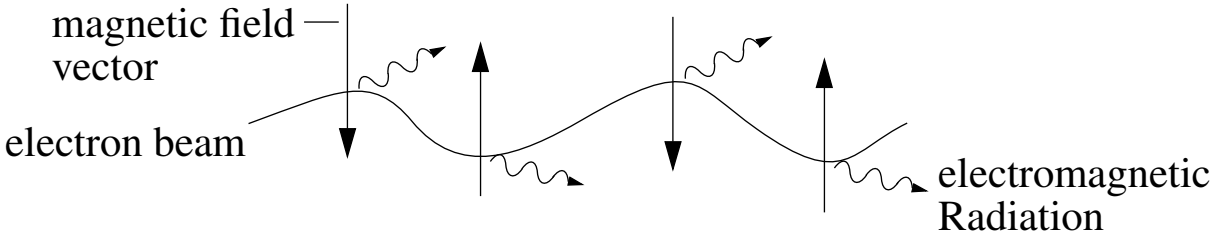
Insertion Devices

- **Purpose of Insertion Devices**
  Insertion Devices are periodic magnetic structures that lead the electrons of the storage ring on an undulatory trajectory. This causes the electrons to emit electromagnetic radiation.
  The changing of the magnetic field leads to a changing characteristic of the emitted radiation (wavelength and intensity).



- **How to change the magnetic field**
  Since the BESSY II Insertion Devices use permanent magnets, the magnetic field is altered by moving the magnets towards the electron beam.

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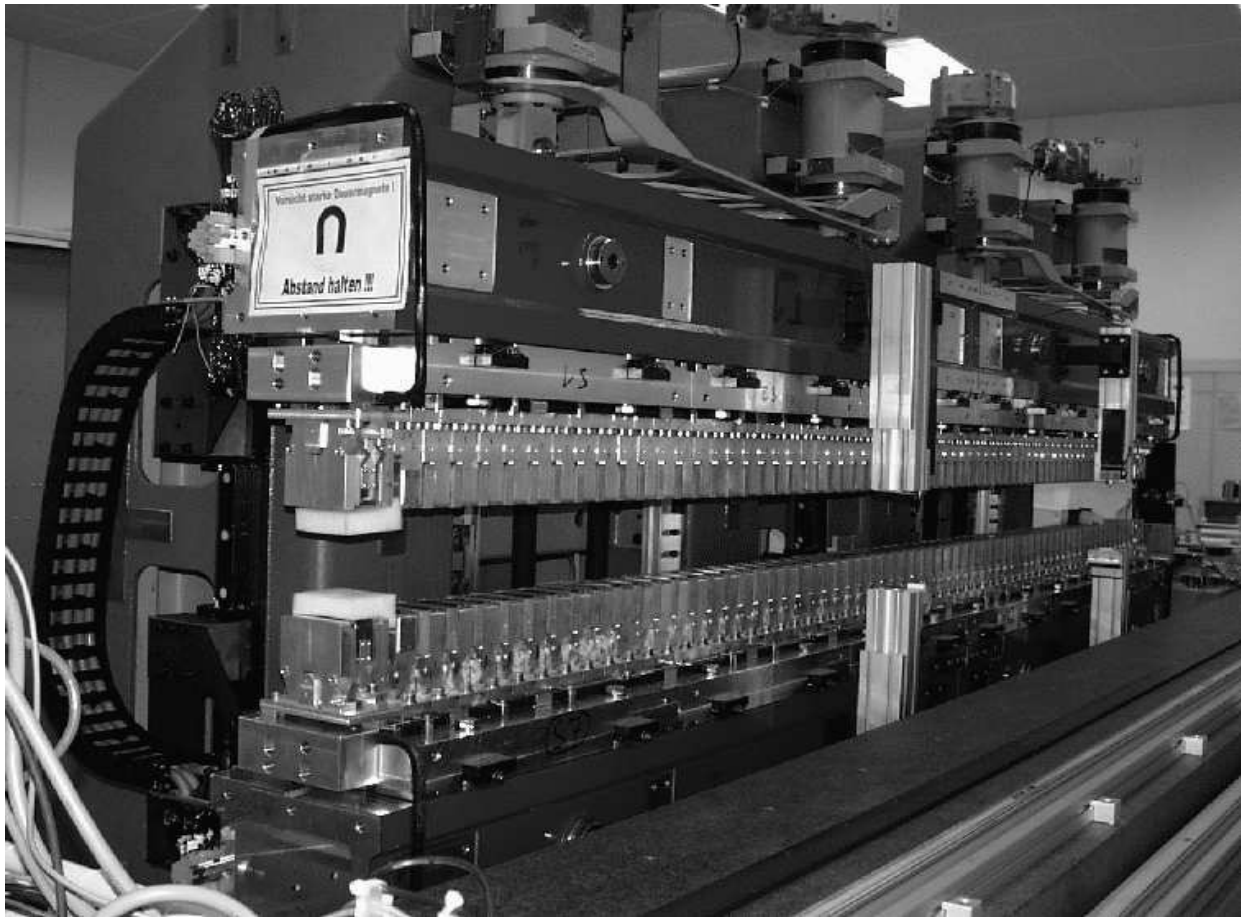
Picture of U125



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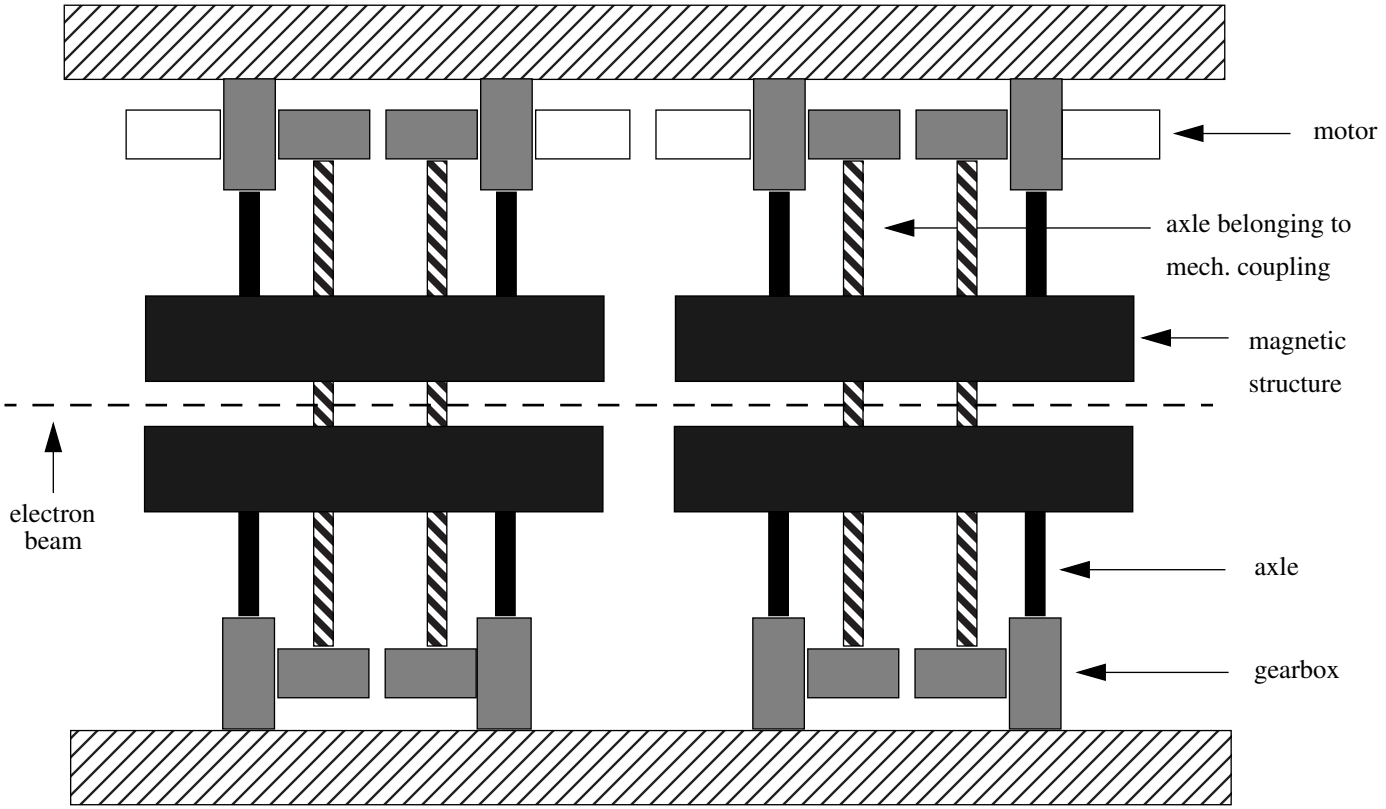
Insertion Device Structure



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Insertion Device Control System tasks

- **movement of the magnets**
- **control of correction coils for magnetic field fine-tuning during movement**
- **continuous real-time data feed to the beamline control**
- **continuous real-time data feed to the accelerator control system**
- **error-checking and emergency stop**

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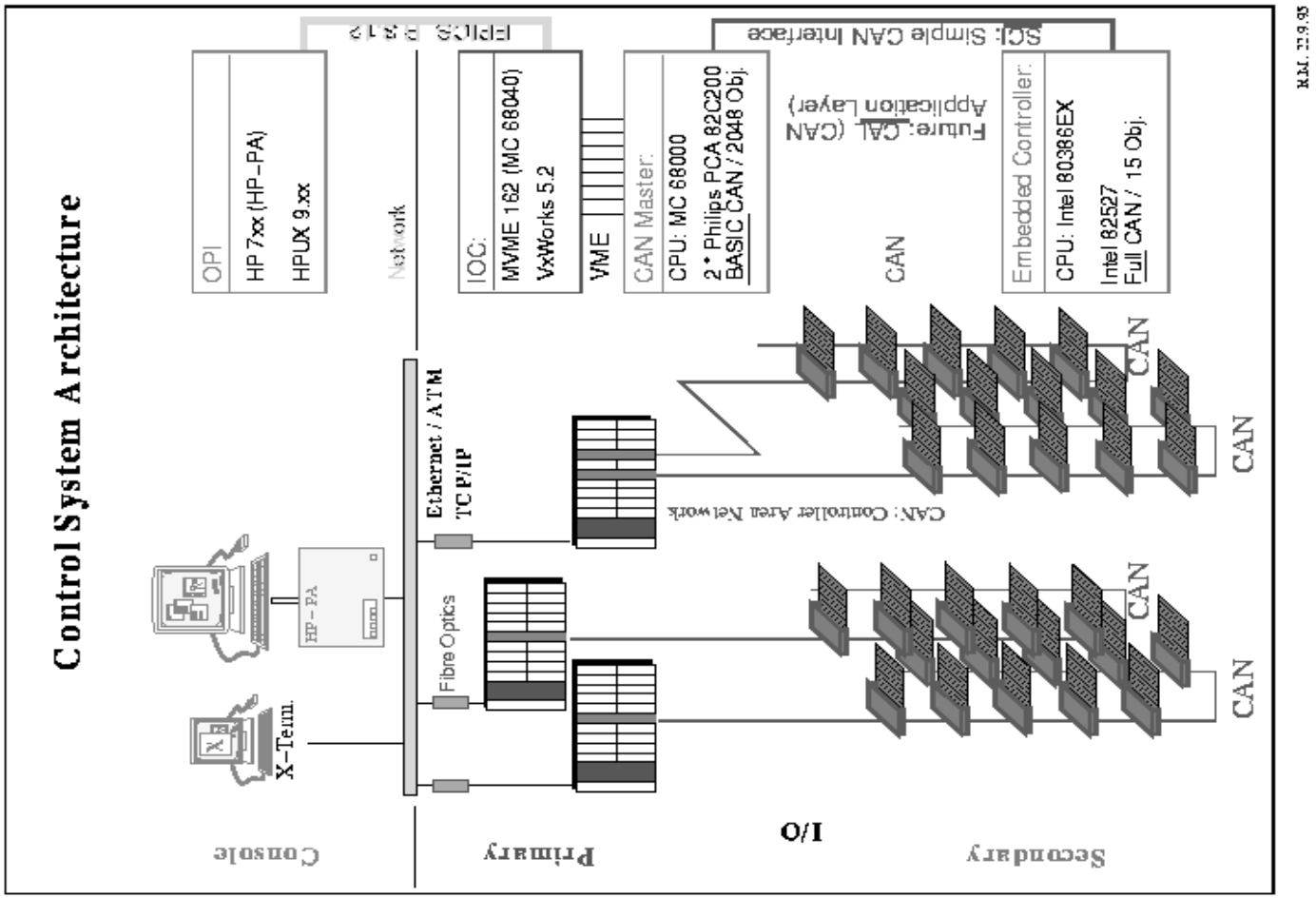

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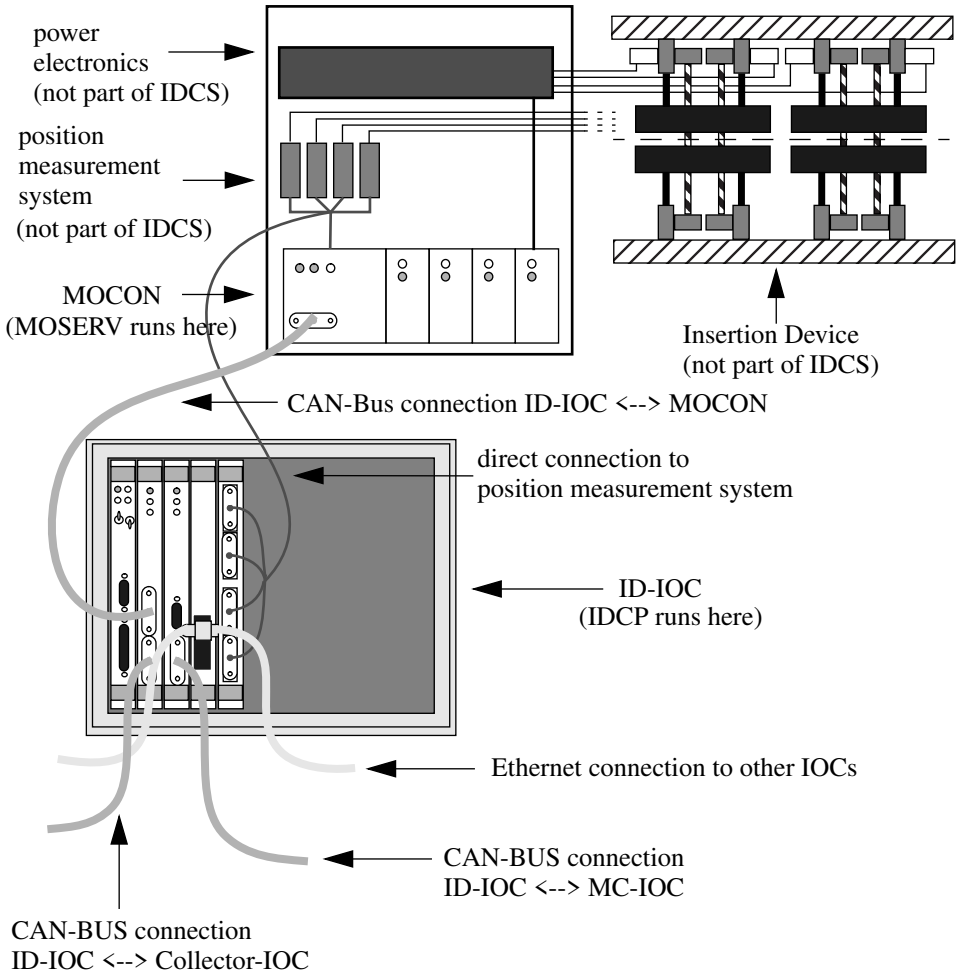
IDCS - Major Hardware Components



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Features of the motor control unit (MOCON)

- position feedback-control
- velocity feedback control
- direct connection to position measurement system
- CAN bus interface
- freely programmable in a BASIC-like language
- program execution speed: about 5ms per program line

Features of the MOCON program (MOSERV)

- server-application (waits for parameters and commands, executes commands)
- communication with the IOC via the CAN bus
- implements the LowCAL CAN bus protocol
- about 1900 lines of code

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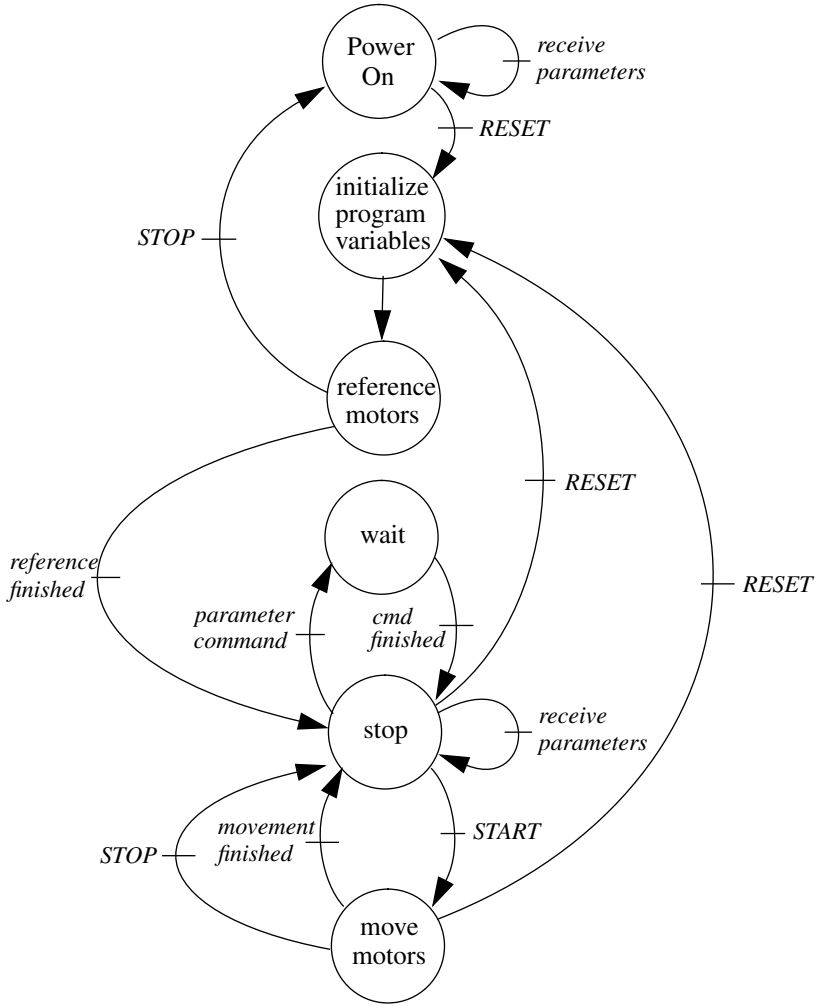
MOSERV State Transition Diagram



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IOC Communication with other Components

- **to the motor control unit (MOCON)**
  Communication via the CAN bus. The MOCON protocol (MOP) is based on CAN Application Layer (CAL).
- **to the Monochromator-IOC**
  Communication via the CAN bus. The Wiggler-Undulator protocol (WUP) is also based on the CAN Application Layer.
- **to the temperature measurement module**
  Communication via the CAN bus. The Selectron protocol (SEP) is also based on the CAN Application Layer.
- **to the position measurement system**
  Communication via VME bus and an arbitrary driver.
- **to the Operator-Workstation (for Insertion Device Maintenance only)**
  Communication via LAN (ethernet). The Channel-Access protocol is used.

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Properties of the CAN Bus

- **robustness against electrical interference**
- **real-time capability, maximum latency time can be predicted on an installed CAN-bus network, a collision avoidance mechanism is used.**
- **cheap bus-interface components are available**
- **long term availability of components due to wide usage in european and international car industry**
- **very low error-rate due to built in CRC check**
- **covers layer 1 and 2 in the ISO-OSI model**

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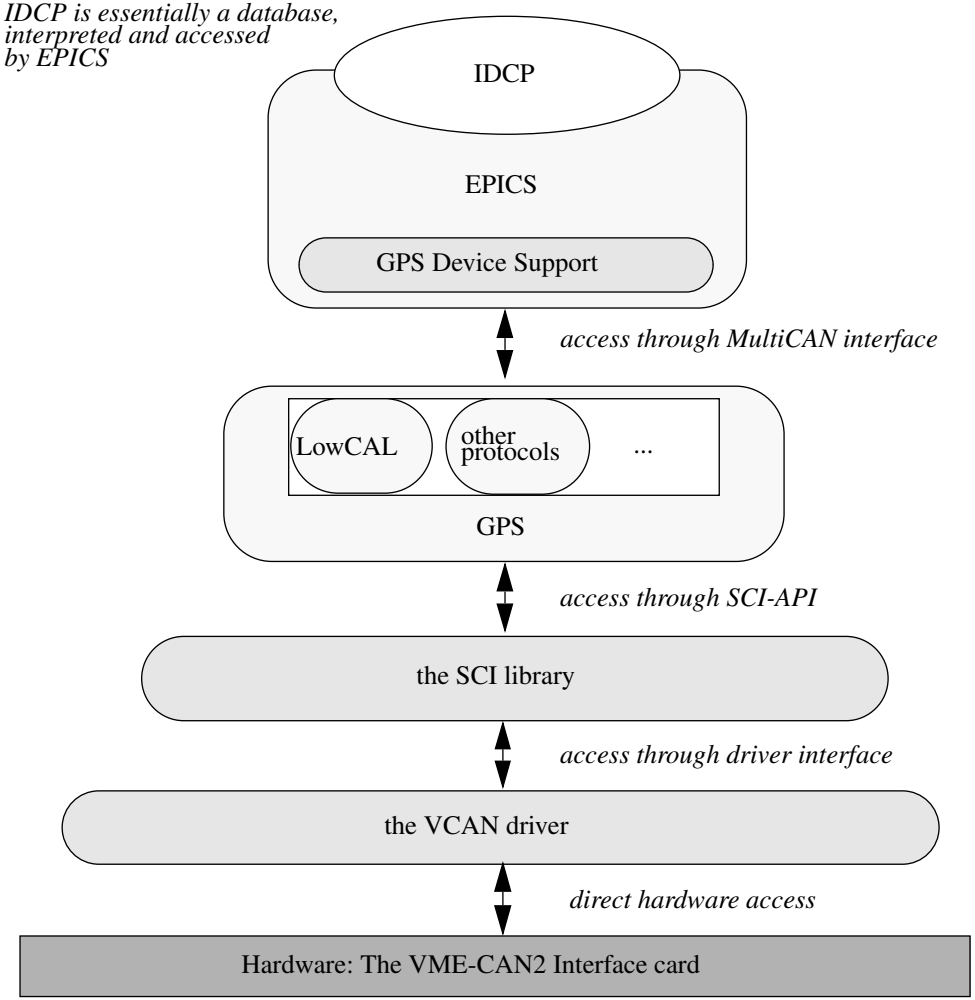
Implementation of the EPICS ↔ CAN Bus interface

IDCP is essentially a database, interpreted and accessed by EPICS



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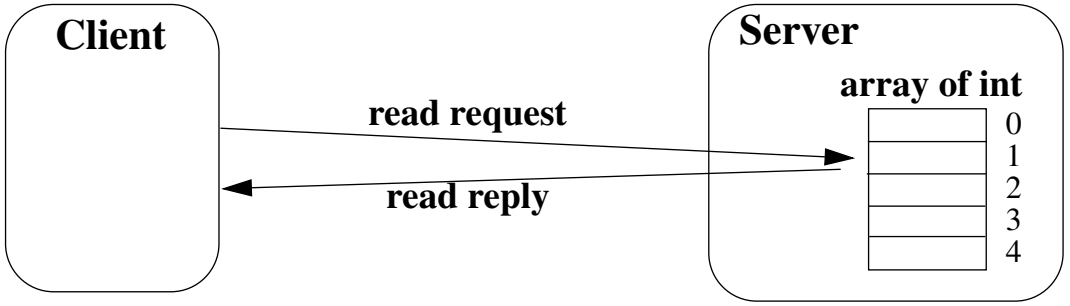
LowCAL

- **protocol for the CAN bus**
- **implements a sub-set of CAL (CAN application layer) which is a widely used protocol for the CAN bus**
- **variables are always stored on the server**
- **basic variable types are 1, 2, 3 and 4-byte integers, signed or unsigned**
- **multiplex variables which are arrays of elements of the basic data type with random access on each element**
- **access may be read-only, write-only or read-write (depending on the variable specification)**

Example of a read-access to a read-only multiplex variable



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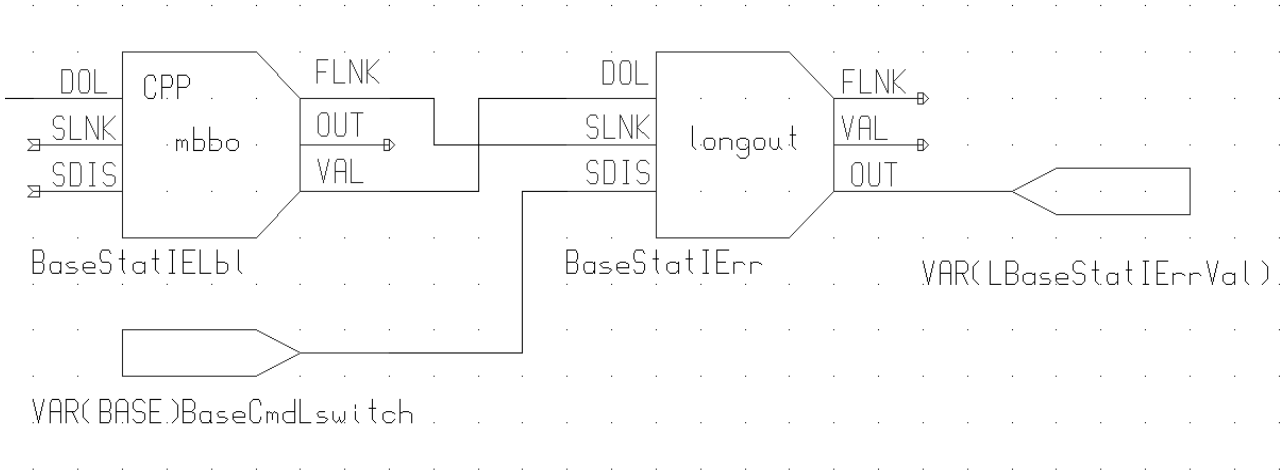
Example of a CAN Bus connection in EPICS



The macro `LBaseStatIErrVal` is substituted by dbLoadTemplate. The substitutions-file for dbLoadTemplate is created by a perl-script which evaluates a protocol definition-file (here *wup.def*) and a macro definition file which contains lines like:

```
CAN  LBaseStatIErrVal   WUP ID_IOC CONFMESSAGE ERR
```

Such a line contains the protocol-name (`WUP`), the server-name(`ID_IOC`), the multiplex-variable-name (`CONFMESSAGE`) and the variable field name (`ERR`). At run-time, the hardware-link will have the following value:

```
@f 1 5 2 2d4 294 1 5 5dc 0
```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Example of Protocol definition file

```
%PROTOCOL= (NAME=> WUP, VERSION=>1,
            PROJECT=> IDCP,
            COMMENT=> "basic definitions for the Wiggler/Undulator Protocol");

%NODES= ( ID_IOC => { NID    =>    10,
                      INHIBIT=>   500,
                      TIMEOUT=>  1500
                    },
          MC_IOC => { NID    =>    20,
                      INHIBIT=>   500,
                      TIMEOUT=>  1500
                    },
        );

%CONNECTIONS =
  ( PARAMETER  => { SERVER => ID_IOC,
                    TYPE   => "RW,MULTIPLEX,LONG,SIGNED",
                    INDEX  => 4,
                    FIELDS => { CMD => 0, VER => 1, TICE => 2 }
                  },
    CONFMESSAGE=> { SERVER => MC_IOC,
                    TYPE   => "RW,MULTIPLEX,LONG,SIGNED",
                    INDEX  => 5,
                    FIELDS => { STAT=> 0, ERR=> 1 }
                  },
```


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Example of Protcol definition File (continued)

```
    FASTMESSAGE=> { SERVER => MC_IOC,
                    TYPE   => "WO,MULTIPLEX,LONG,SIGNED",
                    INDEX  => 6,
                    FIELDS => { CICE=>0 }
                  }
  );

%FIELD_CONSTANTS=
  ( CONFMESSAGE => { STAT  => { STOP  => 0, PWON    => 1, RESET  => 2,
                                RUN   => 3, SCAN    => 4
                              },
                     ERR   => { NONE  => 0, PAR_INIT=> 1, PAR_VAL=> 2,
                                SWITCH=> 3, HW      => 4, DECL   => 5
                              }
                   },
    PARAMETER   => { CMD  => { RESET=> 1, STOP=> 10, START=>11, GETPOS=>22 } },
  );
```


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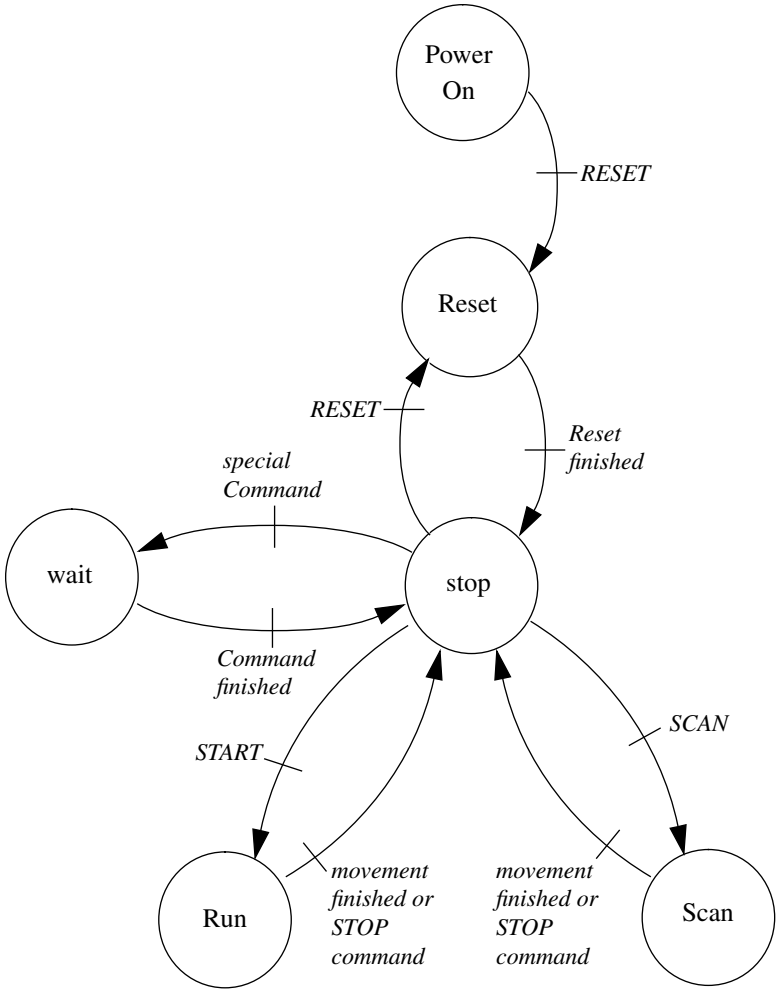
State Transition Model of IDCP



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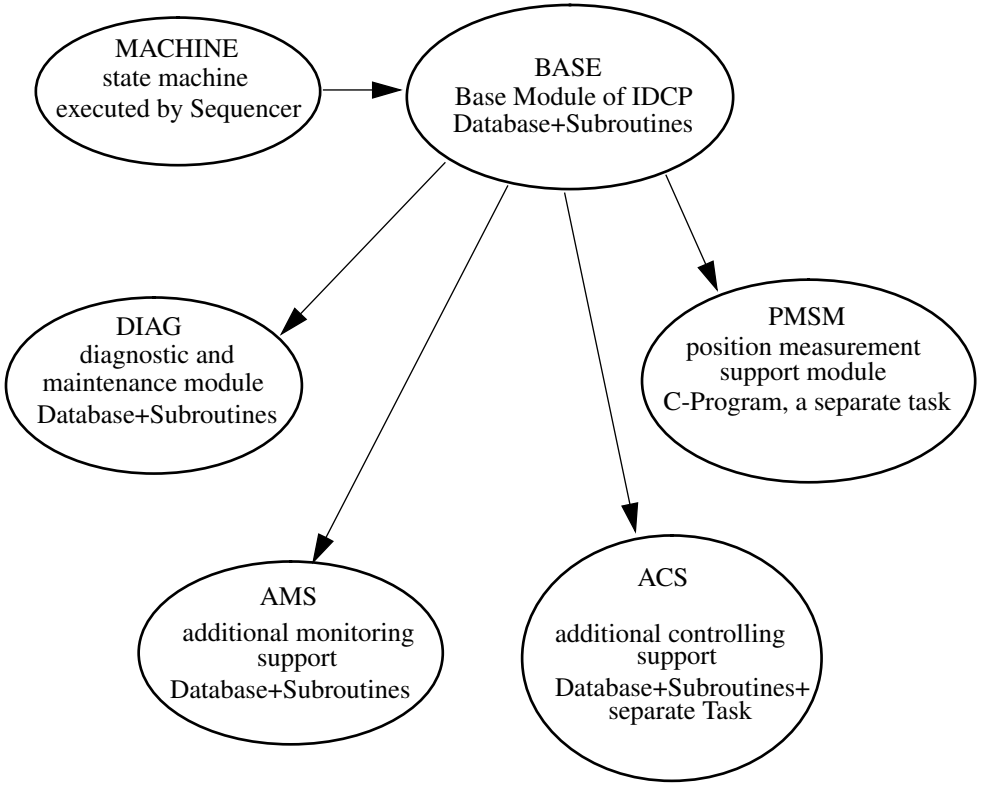
IDCP Basic Software Modules



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IDCP Statistics

- **number of records: 105**
- **number of subroutines: 27**
- **number of state-sets: 2**
- **number of separate tasks (not including EPICS): 5**
- **number of CAN hardware links in the database: 22**
- **lines of c-code excluding header-files: about 9000**

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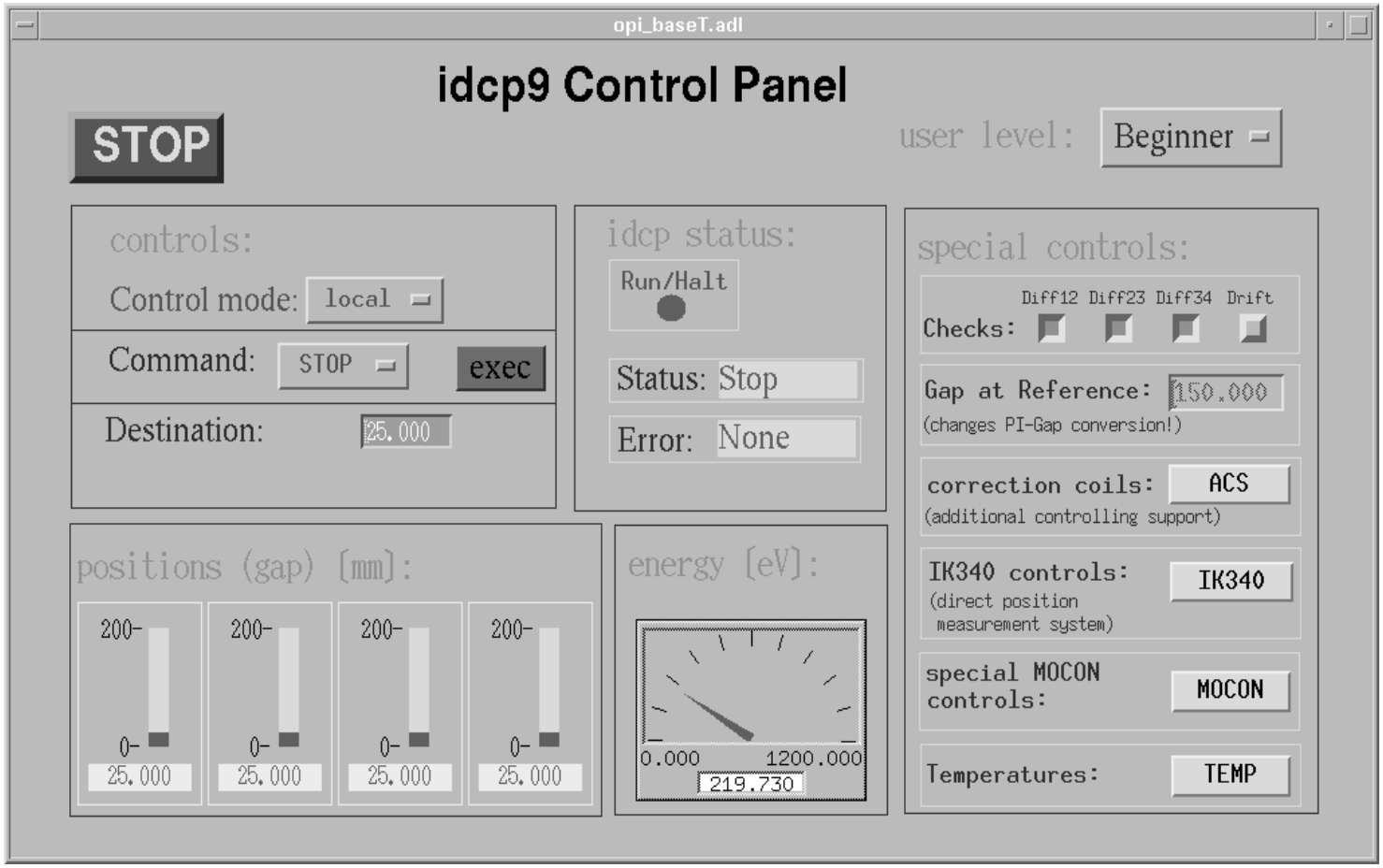
Insertion Device Main Control Panel



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Current State of IDCP (Nov. 1998)

- **EPICS-CAN bus interface: implemented and tested, this was a joint work of the experts in the BESSY accelerator-group and me and is only used by IDCP**
- **MOCON - IOC Protocol (MOP): implemented and tested**
- **MOCON Program: implemented and tested**
- **Wiggler-Undulator Protocol (WUP): a preliminary version was tested**
- **Maintenance User Interface (via MEDM): implemented and tested**
- **IDCP: all functions for point-to-point movement are implemented for the undulators U49 and U125. These undulators have been placed in the storage ring and the emitted radiation is used to test components of the beamline. The undulators are currently operated via the maintenance user interface.**

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implemented functions of IDCP:

- **Reset and Position-Reference (uses end-position switches, accuracy about 1μm)**
- **detect reference-marks of position measurement system, which increases determination of the absolute position to 0.1μm**
- **move to a destination position**
- **possibility to move all 4 axles independently**
- **display and check positions by a MOCON-independent position measurement system**
- **provide the current position with via the CAN bus to the Monochromator-IOC (10Hz)**
- **control the coils for magnetic field correction during movement according to a given table (10Hz)**
- **test of several error conditions (motor-drift, end-position switch, declination exceeded, position measurement system failure, CAN bus communication failure, MOCON failure detection via CAN-watchdog)**

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Things to come

- **for Ue56: control of 12 additional axles via PMAC controller**
- **for Ue56: control of 4 additional axles by a second MOCON unit**
- **integration-test of the Monochromator-IOC - Insertion Device IOC communication (wiggler-undulator protocol, WUP)**
- **transmission of the current gap to the accelerator control system via the CAN bus**
- **continuous mode: move the magnets to a destination position while varying the velocity according to a given table**

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