

# EPICS BASED BEAM ORBIT MEASUREMENT SYSTEM FOR KEK PF-AR

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## Abstract

A new beam position measurement system for KEK PF-AR was constructed employing EPICS (Experimental Physics and Industrial Control system). Two new record types were developed for this system. The EPICS database includes more than 3,500 records and SNL programs are used to operate electric relay switching beam position monitors (BPMs). Measured orbit data is agreed with the data which is taken by the existing HIDIC mini computer system. The measurement time is improved with the new system.

## 1 INTRODUCTION

The PF-AR (Advanced Ring), 6.5 GeV electron storage ring for pulsed X-rays, was originally constructed as an injection booster to TRISTAN [1] main ring, and had also been used as a synchrotron radiation source during the intervals of injection to the TRISTAN. The upgrading project of PF-AR [2, 3] which intend to reconstruct the ring as the SR light source, is under way.

Replacement of the control system with the system reliable and easy for machine operation is the part of the project. In order to minimize costs and loads of the replacement, device interface layer under CAMAC has not changed. We only replace the existing HIDIC mini-computer system with EPICS IOC (VME computer, CPU: Power PC 750, CAMAC Serial Driver: VSD 2992). In this study, an auxiliary crate controller, which is controlled from IOC, was installed on each CAMAC crate to ensure simultaneous controls from HIDIC and EPICS.

## 2 HARDWARE SETUP

The PF-AR has 83 sets of electrostatic beam position monitors (BPMs), each of which consists of 4 electrodes [4]. Electric signal of each electrode is selected by coaxial relay placed in the AR tunnel. And the output from the relay is fed to one of four local control rooms located on east, west, south and north part of the ring. Signals are processed by the detector located in each local control room and digitized by 12-bit CAMAC ADC for beam position calculation. Several kind of CAMAC modules are used to measure the beam position: AIO (Active Input/Output register) module to control the coaxial relay, SIG (Status Input Gate) to monitor the hardware status.

## 3 SOFTWARE DEVELOPMENT

### 3.1 New record type

Two new record types were created, one is to calculate the horizontal and vertical (X and Y) positions and a standard deviation of each electrodes, the other is to concatenate the single position values into a big array to be displayed in MEDM (Motif-based Editor and Display Manager). Both records are designed so that they can be applicable to the other EPICS based system easily.

**bpmArRecord** Then main purpose of the new record type bpmArRecord is to calculate out the beam position (X, Y). The CNAM field is used to specify a user defined conversion function name. The default conversion function implements the following algorithm:

- Apply correction factors for cable loss to each signal from four electrodes.
- Check the consistency
  - Calculate (X,Y) with picking up only three signals out of four for all possible combinations (abc/bcd/cda/dab) by using a fourth order polynomial for its own.
  - Calculate variances of result in the previous step,  $\sigma_x$  and  $\sigma_y$ .
  - compare the variance with the standard variance to check the consistency.
- Return the final beam position (X, Y) when status is normal, otherwise returns error code.

The record was created based on bpmKekRecord by adding about 60 fields, such as the fields of signal values from the four electrodes of a BPM, the correction ratios of the cable loss, size of elements for each set of coefficients, maximum variance,  $\sigma$ , specified by user, etc.

Values of these coefficients (mapping data and setting error of beam duct) is taken from the data stored in HIDIC system. We transferred these data on HIDIC system to the ascii file on UNIX workstation, then converted them to the form which can be directly downloaded to the IOC using a program written for it.

**aConcatRecord** In order to display all the calculated beam positions, X and Y, for each station and also for all stations, a new record type aConcatRecord was created. It has up to 12 input links to get input data and concatenate them into an array pointed by VAL field. The input links

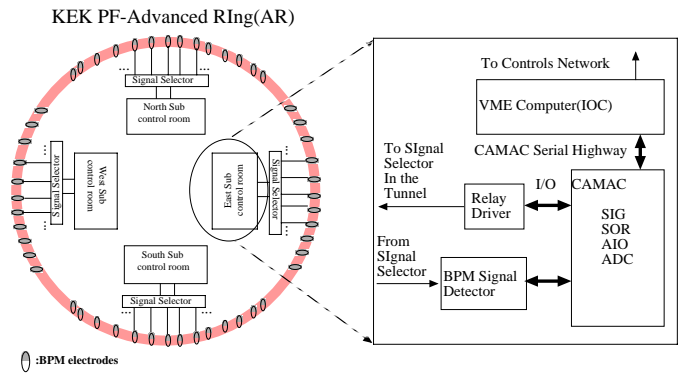


Figure 1: A block diagram of EPICS based beam position measuring system.

can be any record type of EPICS database including aConcat record, so data which has more than 12 elements can be concatenated using two or more aConcat records. The NELM field must be specified correctly when an aConcat record in the database is created.

### 3.2 Database

CapFast<sup>1</sup> is used to create most of the database logics for the AR BPM measurement system. Some logics are created by editing the ascii files of database.

The database logic of AR BPM measurement system can be classified into 4 types: 1) IOC read/write logics, 2) relay logics, 3) timestamp logics and 4) data concatenation logics. Four template files, bpm1.db, bpmrelay.db, time.db and wf.db, have been created corresponding these four kinds of logics.

The IOC read/write logic (bpm1.db) is the largest one, which contains the logic for each BPM to clear BPM\_DONE and BPM\_ERR flags, to enable CAMAC AIO module, to set time delay, and to get input data from the four electrodes one by one. Figure 2 shows a CapFast schematics for this logic. The four database parameter files for the BPM read/write logic of AR east, west, north and south were created from some parameter files of HIDIC control system.

For each station, four database parameter files were created. Taking AR east station as an example, the parameter files are bpmArEast.dbprm, relayArEast.dbprm, timeArEast.dbprm and wfArEast.dbprm. The EPICS command "dbLoadTemplate" is applied to create run-time database from the template and parameter files. For example, bpmArEast.dbprm gives parameters for read/write logics of 20 BPMs in AR east station. By using the command "dbLoadTemplate bpmArEast.dbprm > bpmArEast.db" the final run-time database file for AR east "bpmArEast.db" is generated. In the similar way other database files for AR west, north and south stations are also created.

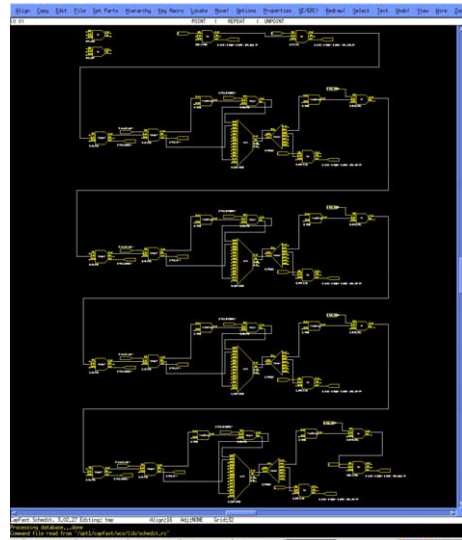


Figure 2: CapFast schematics for 1 BPM (4 electrodes).

Besides, there is a parameter file containing the parameters for timestamp records to get the timestamp information for all BPMs. And there is a run-time database "wfArAll.db" to trigger the measurement of four stations concurrently, to concatenate all the X and Y position data from four stations into two arrays separately to be displayed graphically. So altogether there are 4 database template files, 17 database parameter files, and 18 final run-time database files which can be loaded into IOC memory.

### 3.3 SNL

The layers of SNL logic are used to achieve the measurement. One is for the measurement in a single station. The other manages the concurrent measurement over the four stations. In each station, a SNL program is used to do the following tasks:

- start the measurement,
- switch the measurement from one BPM to the next one,
- set the starting and ending timestamps,

<sup>1</sup>Capfast<sup>TM</sup> is the name of schematic editor, developed and sold by Phase Three Logic, Inc., Beaverton, Oregon, USA.

- reset relay drivers when all BPMs in one station have been tested,
- trigger the aConcat records to be processed when all bpmAr records in one station have been processed.

The BPM\_DONE and BPM\_ERR flags are monitored in the SNL programs for each BPM. In the database logic, BPM\_DONE is set to "1" when the four electrodes of the BPM have been read, and BPM\_ERR is set if something wrong. Therefore when any of them is set to "1" the SNL programs switches the measurement to next BPM.

Another layer of SNL logic is to deal with all BPMs of the four stations. These logics are running on AR east IOC.

### 3.4 Display

MEDM is used to create graphical user interfaces to control the measurement and monitor interested results for this measurement system as shown in Fig. 3. For each station there are two kinds of MEDM adl files created, one is to enable the measurement, display some key information. The contents are summarized as:

- buttons to enable the power and start the measurement
- label to display the status of the relay power: "enabled" or "disabled"
- labels to display the start\_measuring timestamp, the end\_measuring timestamp and the time "elapsed"
- labels to monitor the BPM\_DONE flag, BPM\_ERR flag and the four electrodes' write-out, read-in for each BPM
- labels to display the calculated X position and Y position for each BPM

Another kind of adl file is to plot sets of values of the calculated X and Y positions in a graph, for the east, west, north, south stations separately and for all BPMs, too. The button to start the measurement of all BPMs in the four stations is created in the bpmArEast.adl, which is also used to control and monitor BPMs for the east station.

BPM TEST SYSTEM FOR EAST	Electrode B	Electrode C	Electrode D	x / y	BPM_DONE
M01	AMPH01E0100 RD ADI	AMPH01E0101 RD ADI	AMPH01E0102 RD ADI	AMPH01E0103 RD ADI	AMPH01E0104 RD ADI
M02	AMPH01E0105 RD ADI	AMPH01E0106 RD ADI	AMPH01E0107 RD ADI	AMPH01E0108 RD ADI	AMPH01E0109 RD ADI
M03	AMPH01E0110 RD ADI	AMPH01E0111 RD ADI	AMPH01E0112 RD ADI	AMPH01E0113 RD ADI	AMPH01E0114 RD ADI
M04	AMPH01E0115 RD ADI	AMPH01E0116 RD ADI	AMPH01E0117 RD ADI	AMPH01E0118 RD ADI	AMPH01E0119 RD ADI
M05	AMPH01E0120 RD ADI	AMPH01E0121 RD ADI	AMPH01E0122 RD ADI	AMPH01E0123 RD ADI	AMPH01E0124 RD ADI
M06	AMPH01E0125 RD ADI	AMPH01E0126 RD ADI	AMPH01E0127 RD ADI	AMPH01E0128 RD ADI	AMPH01E0129 RD ADI
M07	AMPH01E0130 RD ADI	AMPH01E0131 RD ADI	AMPH01E0132 RD ADI	AMPH01E0133 RD ADI	AMPH01E0134 RD ADI
M08	AMPH01E0135 RD ADI	AMPH01E0136 RD ADI	AMPH01E0137 RD ADI	AMPH01E0138 RD ADI	AMPH01E0139 RD ADI
M09	AMPH01E0140 RD ADI	AMPH01E0141 RD ADI	AMPH01E0142 RD ADI	AMPH01E0143 RD ADI	AMPH01E0144 RD ADI
M10	AMPH01E0145 RD ADI	AMPH01E0146 RD ADI	AMPH01E0147 RD ADI	AMPH01E0148 RD ADI	AMPH01E0149 RD ADI
M11	AMPH01E0150 RD ADI	AMPH01E0151 RD ADI	AMPH01E0152 RD ADI	AMPH01E0153 RD ADI	AMPH01E0154 RD ADI
M12	AMPH01E0155 RD ADI	AMPH01E0156 RD ADI	AMPH01E0157 RD ADI	AMPH01E0158 RD ADI	AMPH01E0159 RD ADI
M13	AMPH01E0160 RD ADI	AMPH01E0161 RD ADI	AMPH01E0162 RD ADI	AMPH01E0163 RD ADI	AMPH01E0164 RD ADI
M14	AMPH01E0165 RD ADI	AMPH01E0166 RD ADI	AMPH01E0167 RD ADI	AMPH01E0168 RD ADI	AMPH01E0169 RD ADI
M15	AMPH01E0170 RD ADI	AMPH01E0171 RD ADI	AMPH01E0172 RD ADI	AMPH01E0173 RD ADI	AMPH01E0174 RD ADI
M16	AMPH01E0175 RD ADI	AMPH01E0176 RD ADI	AMPH01E0177 RD ADI	AMPH01E0178 RD ADI	AMPH01E0179 RD ADI
M17	AMPH01E0180 RD ADI	AMPH01E0181 RD ADI	AMPH01E0182 RD ADI	AMPH01E0183 RD ADI	AMPH01E0184 RD ADI
M18	AMPH01E0185 RD ADI	AMPH01E0186 RD ADI	AMPH01E0187 RD ADI	AMPH01E0188 RD ADI	AMPH01E0189 RD ADI
M19	AMPH01E0190 RD ADI	AMPH01E0191 RD ADI	AMPH01E0192 RD ADI	AMPH01E0193 RD ADI	AMPH01E0194 RD ADI
M20	AMPH01E0195 RD ADI	AMPH01E0196 RD ADI	AMPH01E0197 RD ADI	AMPH01E0198 RD ADI	AMPH01E0199 RD ADI
M21	AMPH01E0200 RD ADI	AMPH01E0201 RD ADI	AMPH01E0202 RD ADI	AMPH01E0203 RD ADI	AMPH01E0204 RD ADI
M22	AMPH01E0205 RD ADI	AMPH01E0206 RD ADI	AMPH01E0207 RD ADI	AMPH01E0208 RD ADI	AMPH01E0209 RD ADI
M23	AMPH01E0210 RD ADI	AMPH01E0211 RD ADI	AMPH01E0212 RD ADI	AMPH01E0213 RD ADI	AMPH01E0214 RD ADI
M24	AMPH01E0215 RD ADI	AMPH01E0216 RD ADI	AMPH01E0217 RD ADI	AMPH01E0218 RD ADI	AMPH01E0219 RD ADI
M25	AMPH01E0220 RD ADI	AMPH01E0221 RD ADI	AMPH01E0222 RD ADI	AMPH01E0223 RD ADI	AMPH01E0224 RD ADI
M26	AMPH01E0225 RD ADI	AMPH01E0226 RD ADI	AMPH01E0227 RD ADI	AMPH01E0228 RD ADI	AMPH01E0229 RD ADI
M27	AMPH01E0230 RD ADI	AMPH01E0231 RD ADI	AMPH01E0232 RD ADI	AMPH01E0233 RD ADI	AMPH01E0234 RD ADI
M28	AMPH01E0235 RD ADI	AMPH01E0236 RD ADI	AMPH01E0237 RD ADI	AMPH01E0238 RD ADI	AMPH01E0239 RD ADI
M29	AMPH01E0240 RD ADI	AMPH01E0241 RD ADI	AMPH01E0242 RD ADI	AMPH01E0243 RD ADI	AMPH01E0244 RD ADI
M30	AMPH01E0245 RD ADI	AMPH01E0246 RD ADI	AMPH01E0247 RD ADI	AMPH01E0248 RD ADI	AMPH01E0249 RD ADI
M31	AMPH01E0250 RD ADI	AMPH01E0251 RD ADI	AMPH01E0252 RD ADI	AMPH01E0253 RD ADI	AMPH01E0254 RD ADI
M32	AMPH01E0255 RD ADI	AMPH01E0256 RD ADI	AMPH01E0257 RD ADI	AMPH01E0258 RD ADI	AMPH01E0259 RD ADI
M33	AMPH01E0260 RD ADI	AMPH01E0261 RD ADI	AMPH01E0262 RD ADI	AMPH01E0263 RD ADI	AMPH01E0264 RD ADI
M34	AMPH01E0265 RD ADI	AMPH01E0266 RD ADI	AMPH01E0267 RD ADI	AMPH01E0268 RD ADI	AMPH01E0269 RD ADI
M35	AMPH01E0270 RD ADI	AMPH01E0271 RD ADI	AMPH01E0272 RD ADI	AMPH01E0273 RD ADI	AMPH01E0274 RD ADI
M36	AMPH01E0275 RD ADI	AMPH01E0276 RD ADI	AMPH01E0277 RD ADI	AMPH01E0278 RD ADI	AMPH01E0279 RD ADI
M37	AMPH01E0280 RD ADI	AMPH01E0281 RD ADI	AMPH01E0282 RD ADI	AMPH01E0283 RD ADI	AMPH01E0284 RD ADI
M38	AMPH01E0285 RD ADI	AMPH01E0286 RD ADI	AMPH01E0287 RD ADI	AMPH01E0288 RD ADI	AMPH01E0289 RD ADI
M39	AMPH01E0290 RD ADI	AMPH01E0291 RD ADI	AMPH01E0292 RD ADI	AMPH01E0293 RD ADI	AMPH01E0294 RD ADI
M40	AMPH01E0295 RD ADI	AMPH01E0296 RD ADI	AMPH01E0297 RD ADI	AMPH01E0298 RD ADI	AMPH01E0299 RD ADI
M41	AMPH01E0300 RD ADI	AMPH01E0301 RD ADI	AMPH01E0302 RD ADI	AMPH01E0303 RD ADI	AMPH01E0304 RD ADI
M42	AMPH01E0305 RD ADI	AMPH01E0306 RD ADI	AMPH01E0307 RD ADI	AMPH01E0308 RD ADI	AMPH01E0309 RD ADI
M43	AMPH01E0310 RD ADI	AMPH01E0311 RD ADI	AMPH01E0312 RD ADI	AMPH01E0313 RD ADI	AMPH01E0314 RD ADI
M44	AMPH01E0315 RD ADI	AMPH01E0316 RD ADI	AMPH01E0317 RD ADI	AMPH01E0318 RD ADI	AMPH01E0319 RD ADI
M45	AMPH01E0320 RD ADI	AMPH01E0321 RD ADI	AMPH01E0322 RD ADI	AMPH01E0323 RD ADI	AMPH01E0324 RD ADI
M46	AMPH01E0325 RD ADI	AMPH01E0326 RD ADI	AMPH01E0327 RD ADI	AMPH01E0328 RD ADI	AMPH01E0329 RD ADI
M47	AMPH01E0330 RD ADI	AMPH01E0331 RD ADI	AMPH01E0332 RD ADI	AMPH01E0333 RD ADI	AMPH01E0334 RD ADI
M48	AMPH01E0335 RD ADI	AMPH01E0336 RD ADI	AMPH01E0337 RD ADI	AMPH01E0338 RD ADI	AMPH01E0339 RD ADI
M49	AMPH01E0340 RD ADI	AMPH01E0341 RD ADI	AMPH01E0342 RD ADI	AMPH01E0343 RD ADI	AMPH01E0344 RD ADI
M50	AMPH01E0345 RD ADI	AMPH01E0346 RD ADI	AMPH01E0347 RD ADI	AMPH01E0348 RD ADI	AMPH01E0349 RD ADI
M51	AMPH01E0350 RD ADI	AMPH01E0351 RD ADI	AMPH01E0352 RD ADI	AMPH01E0353 RD ADI	AMPH01E0354 RD ADI
M52	AMPH01E0355 RD ADI	AMPH01E0356 RD ADI	AMPH01E0357 RD ADI	AMPH01E0358 RD ADI	AMPH01E0359 RD ADI
M53	AMPH01E0360 RD ADI	AMPH01E0361 RD ADI	AMPH01E0362 RD ADI	AMPH01E0363 RD ADI	AMPH01E0364 RD ADI
M54	AMPH01E0365 RD ADI	AMPH01E0366 RD ADI	AMPH01E0367 RD ADI	AMPH01E0368 RD ADI	AMPH01E0369 RD ADI
M55	AMPH01E0370 RD ADI	AMPH01E0371 RD ADI	AMPH01E0372 RD ADI	AMPH01E0373 RD ADI	AMPH01E0374 RD ADI
M56	AMPH01E0375 RD ADI	AMPH01E0376 RD ADI	AMPH01E0377 RD ADI	AMPH01E0378 RD ADI	AMPH01E0379 RD ADI
M57	AMPH01E0380 RD ADI	AMPH01E0381 RD ADI	AMPH01E0382 RD ADI	AMPH01E0383 RD ADI	AMPH01E0384 RD ADI
M58	AMPH01E0385 RD ADI	AMPH01E0386 RD ADI	AMPH01E0387 RD ADI	AMPH01E0388 RD ADI	AMPH01E0389 RD ADI
M59	AMPH01E0390 RD ADI	AMPH01E0391 RD ADI	AMPH01E0392 RD ADI	AMPH01E0393 RD ADI	AMPH01E0394 RD ADI
M60	AMPH01E0395 RD ADI	AMPH01E0396 RD ADI	AMPH01E0397 RD ADI	AMPH01E0398 RD ADI	AMPH01E0399 RD ADI

Figure 3: Editing the panel for one local control room.

## 4 RESULTS AND CONCLUSION

All the measurement can be done in 12 seconds, including getting signals from the four electrodes of each BPM and

calculating X/Y positions and SIGMAs of BPMs and concatenating them into 10 arrays (2 arrays for each station, and 2 arrays for all BPMs). Most of measurement time is spent to wait ready signal from relay switch. This was mainly achieved by doing the measurements for the four stations concurrently.

Python scripts and MatLab are used to plot and compare 15 sets of data from the HIDIC system (the original one) and the result from the new BPM measurement system using EPICS as shown in Fig. 4. Measured data seems to

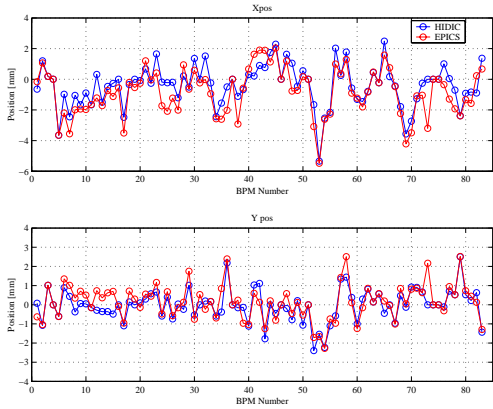


Figure 4: Beam position measured by HIDIC and EPICS.

agree with each other, however, there is a slight difference between two systems. The possible reasons are a reliability of coaxial relay or a difference of average function. HIDIC system use 8 channels of scanning ADC, whereas EPICS used only one channel at this time. Because the coaxial relay (mechanical switch) will be replaced by mercury relay switches during the shutdown period, reliability of the relay will remarkably be improved.

Commissioning with the electron beam will start at the beginning of January 2002. We will investigate the system further before commissioning. In order to achieve the more fast data acquisition, we are planning to build a new detector circuits and switching system.

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## 6 REFERENCES

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