5.3 SPS Controls: A Part of Touch Screen History

Bent Stumpe

The choice of a distributed computer network for controlling the SPS had profound consequences for the interaction of the accelerator operator with the equipment. No direct (hard) wiring would connect the control centre to the equipment to change settings and observe signals. Every control action or piece of information would transit through the computer network via a limited number of operator consoles. The issue was to develop an "intelligent" system based on minicomputers, which would replace the thousands of buttons, switches and oscilloscopes a conventional control system would need for a machine of the size and complexity of the SPS [Highlight 5.2]. Three programmable devices were either newly designed or improved for the machine controls project: a programmable knob which could mimic a variety of hardware knobs and two devices to point at an image on a screen: a trackball, and a transparent touch screen [25]. The operator would need only a few devices to interact with the accelerator and would observe its status and performance on at most half a dozen displays. The devices and displays could be redefined quickly to select accelerator subsystems for control and monitoring, and choose from hundreds of analogue signals those to be displayed at any given time.

The trackball was invented in the 1940s for a British military research project and remained classified for a long time. The CERN design of the track ball had incremental optical encoders, working on the same principle as the ball mouse that became popular in the 1980s. Buttons with labels programmable by a computer [26] could easily be generated on a cathode-ray tube (CRT) display. How the computer would detect which button was being selected, was the question to be answered. The existing rather complicated mechanical designs were unsuitable for the SPS control system. This prompted the development at CERN of one of the world's earliest operational capacitive transparent touch screens, and the first to be used to control a machine of the complexity of the SPS.

The transparent Touch Screen [25,27] consisted of a set of capacitors etched into a film of copper on a sheet of glass, each capacitor being constructed so that a touching finger would change the capacitance by a significant amount. In the final device, a simple lacquer coating prevented the fingers from actually touching the capacitors. The two conductors of the capacity were two interleaved flat copper combs (Fig. 5.9). The fineness of the lines, which constituted the teeth of the combs, and their pitch required a great deal of care in producing the screen, but could be achieved with techniques used to make printed circuit boards. At first, using vacuum deposition of the copper layer on the glass did not result in films

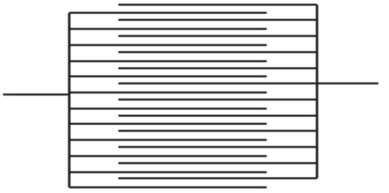

Fig. 5.9. Schematic layout of the transparent double-comb capacitor sputtered on the glass, matching the location of a button.

with reliable adherence. Ion sputtering gave better results. Ensuring that the glass was scrupulously clean and depositing the copper slowly provided films with adherence strong enough to solder connections to the sputtered layers.

The capacitance of each button was about 200 pF, increasing by about 10% under the touch of a finger. The change in capacitance was detected with a phase-locked oscillator circuit, which had become available as a single integrated circuit chip. One circuit acted as a reference oscillator, while each button had a similar circuit. The oscillator attached to a button locked into the frequency of the reference oscillator (120 kHz), so that a change in capacity altered the phase but not the frequency. The phase shift was converted into a voltage shift, indicating that the button had been touched. The circuit was very immune to noise and transients. Changing conditions would be common to all 16 “touch circuits”, so that good thermal stability could be obtained with commercial components.

A simple computer algorithm detected a “touch”: the computer could handle 16 simultaneous touches. The touch screen developed in 1972, nowadays called a self-capacitance screen, was therefore a “Multi Touch” screen and was able to react to simple gestures. The “Touch” information was then used by the software to execute the desired operation. By 1974 industry was capable of producing robust 16-button glass screens with low surface reflections. In a further development an X/Y touch screen (nowadays called a mutual capacitance screen) was constructed in 1978. When the SPS started operation in 1976 its control room was fully equipped with touch screens. Touch screens later took their place in modernized control systems for the PS, in the Antiproton Accumulator (AA) control room (Fig. 5.10), and subsequently for the much bigger LEP collider. Some of these screens continued to operate until the new CERN Control Centre took over operations in 2006. CERN touch screens were also adopted by other laboratories around the world. The commercial breakthrough for touch screens came some 25 years later, thanks to the technological progress in electronics which led to powerful microchips replacing the electronic circuits of the 1970s.

Fig. 5.10. The “Touch Terminal”, equipped with a CRT and driven by a 16-bit microprocessor.

The present CERN Control Centre (CCC), which oversees the control of CERN’s entire accelerator complex, including the PS, SPS and LHC, has no touch screens for accelerator control: the use of the ubiquitous mouse as a pointing device provides the same function. However, touch screens still play a role in the CCC, as the operators frequently communicate with colleagues by mobile phones with their capacitive touch screens and, if needed, can even control the accelerator!

The details of the practical Touch Screen, as applied in 1972 to accelerator control at CERN, were published, and following CERN policy, no patent was taken. The concept has since conquered the world with a multitude of applications, from vending machines to rail and airline ticket machines, and after further development to the ubiquitous multifunction smartphone.

5.4 The SPS Muon Beam: Energy, Intensity and Precision

Niels Doble and Lau Gatignon

The high energy muon beam M2 was designed for the NA2 (EMC) and NA4 experiments, located in experimental hall EHN2 in the SPS North Area (Fig. 5.5). These experiments required a high intensity muon flux at beam momenta up to 280 GeV/c. Muons are dominantly produced by two-body in-flight decays of pions and kaons. The lifetime of pions in the laboratory, proportional to their momentum, is about 55 m per GeV/c,[a] so that pions in the 100 to 300 GeV/c range have average decay lengths of from 5 to16 km. This led to the concept of the M2 beam design [28], which consists of a pion and a muon section (Fig. 5.11).

[a] Kaons have a shorter average decay length of about 7.5 m per GeV/c.