Timing System and Low Level RF Distribution for the Injector of the Tesla Test Facility Linac

M. Bernard, J.C. Bourdon, T. Garvey, J.C. Jumel and P. Roudier
LAL, Orsay

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Introduction

This note describes a proposed timing and low-level RF distribution network for the TTF linac injector. As the proposed injection scheme is based on that of the linac for the CLIO free electron laser we propose a timing system based on that of CLIO. Consequently this note leans heavily on the system described in the CLIO design report (LAL/RT-89/04) to which many of our colleagues at LAL contributed.

1 Synchronisation

The triggering and the duration of the different pulsed elements of the machine are synchronised by a collection of pulse generators whose width and delay (or advance) with respect to a reference clock are programmable from the control room. The pulse generators are distributed close to each synchronised sub-assembly in a fashion intended to minimise the cabling between the control room and the machine.

1.1 Reference Clock

The delays and widths of the pulses are defined with respect to the period of the eigth sub-harmonic of a 216.7 MHz oscillator i.e. 37 nanoseconds; the beginning of each cycle of the machine is determined by the zero-crossing of the mains supply voltage. The composite signal sent to each programmable pulse generator consists of a train of pulses at 27 MHz and of constant amplitude with the exception of the pulse immediately following the zero-crossing, which has an amplitude twice that of the others, as shown in figure 1. The principle of the reference clock is illustrated schematically in figure 2.

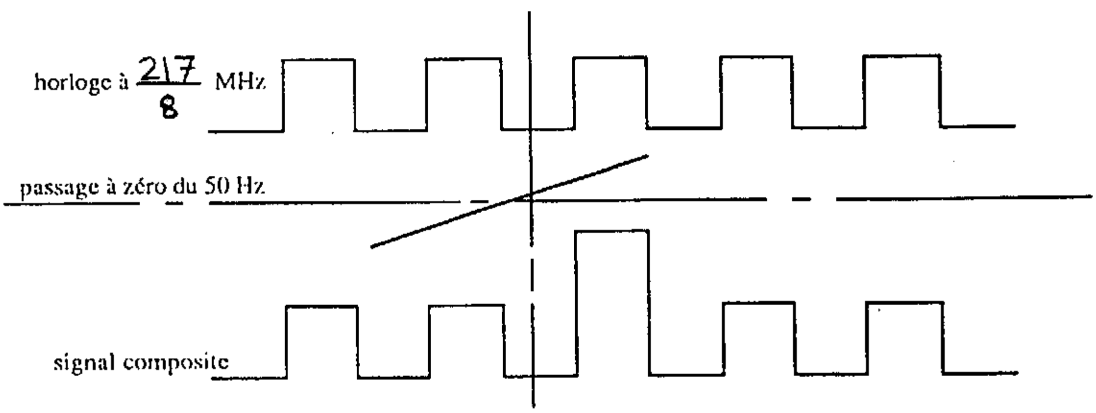


Figure 1. Entry and exit signals of the composite signal generator

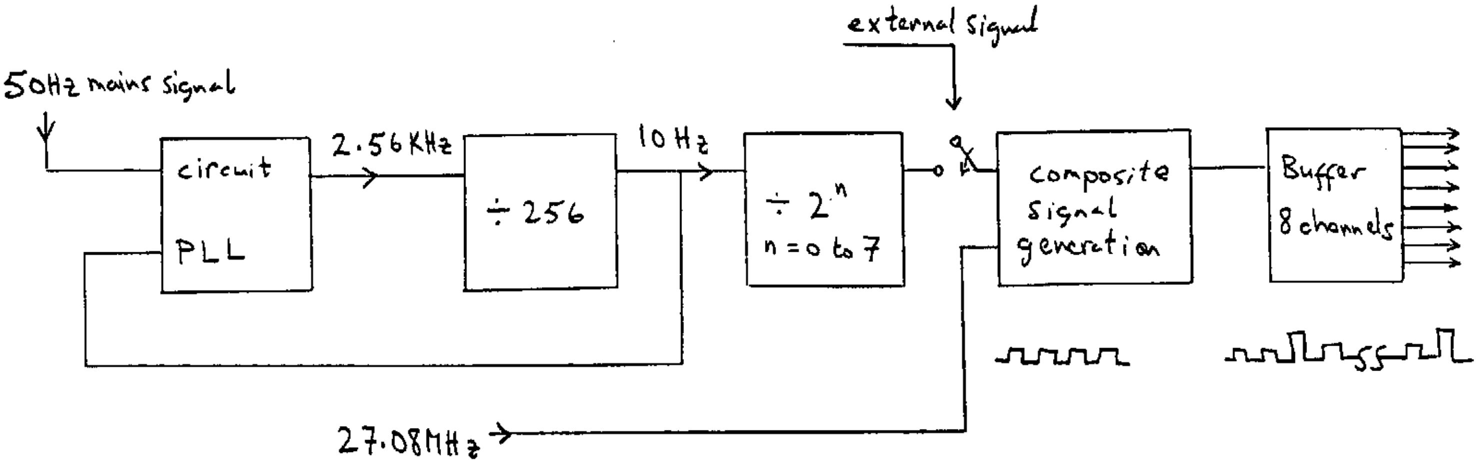


Figure 2. Schematic of the principle of composite signal generation

1.2 Programmable Pulse Generation

The pulse generators, synchronised by the reference clock, are modules placed close to each sub-assembly to be synchronised and computer controlled. They consist of programmable counting circuits, driven by the composite 27 MHz clock signal. The principal is shown schematically in figure 3.

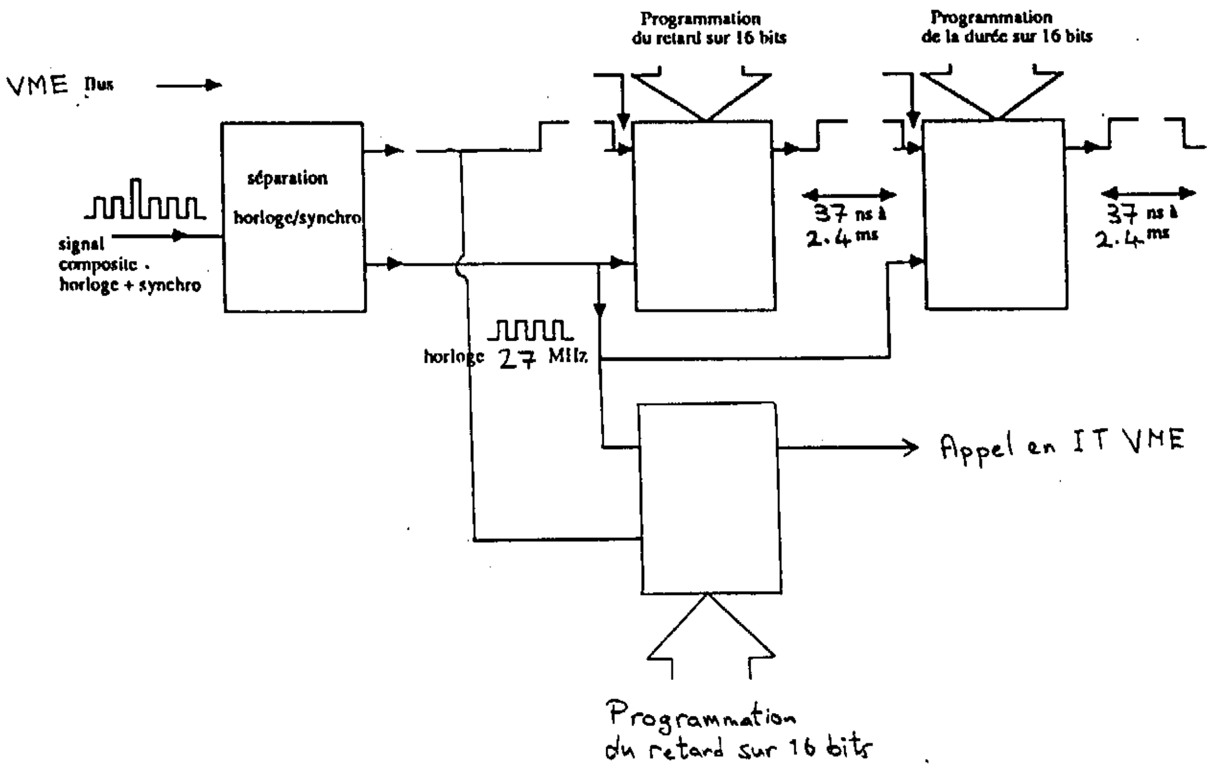


Figure 3. Schematic of programmable pulse generation

With 16 bit control for the delay and width one can regulate each parameter in the range from 37 ns to 2.4 ms in 37 ns steps. The detection of the reference clock's synchronisation pulse activates the 'count-down'. If the duration of 2.4 ms is insufficient one can use 17 or 18 bits. The circuits will be constructed in the form of VME cards. Each card will control two generators if single EUROPE format is used, or four generators if double EUROPE format is adopted.

If neccesary, the input frequency to the card can be divided by powers of two (in particular if one wishes the gun macropulses to have a repetition frequency different from that of the RF sources)

In addition each card will be able to generate an interrupt signal on the VME bus, the call to IT can be delayed from 37 ns to 2.4 ms in steps of 37 ns with respect to synchronisation. The purpose of this signal is to start up the programme reading the ADC cards.

1.3 Interconnections

The connections between the pulse generator cards and the composite signal generators, on one hand, and the pulse generator cards and the local VME chassis, on the other, are represented in figure 4. They consist of a compromise to minimise the cable lengths.

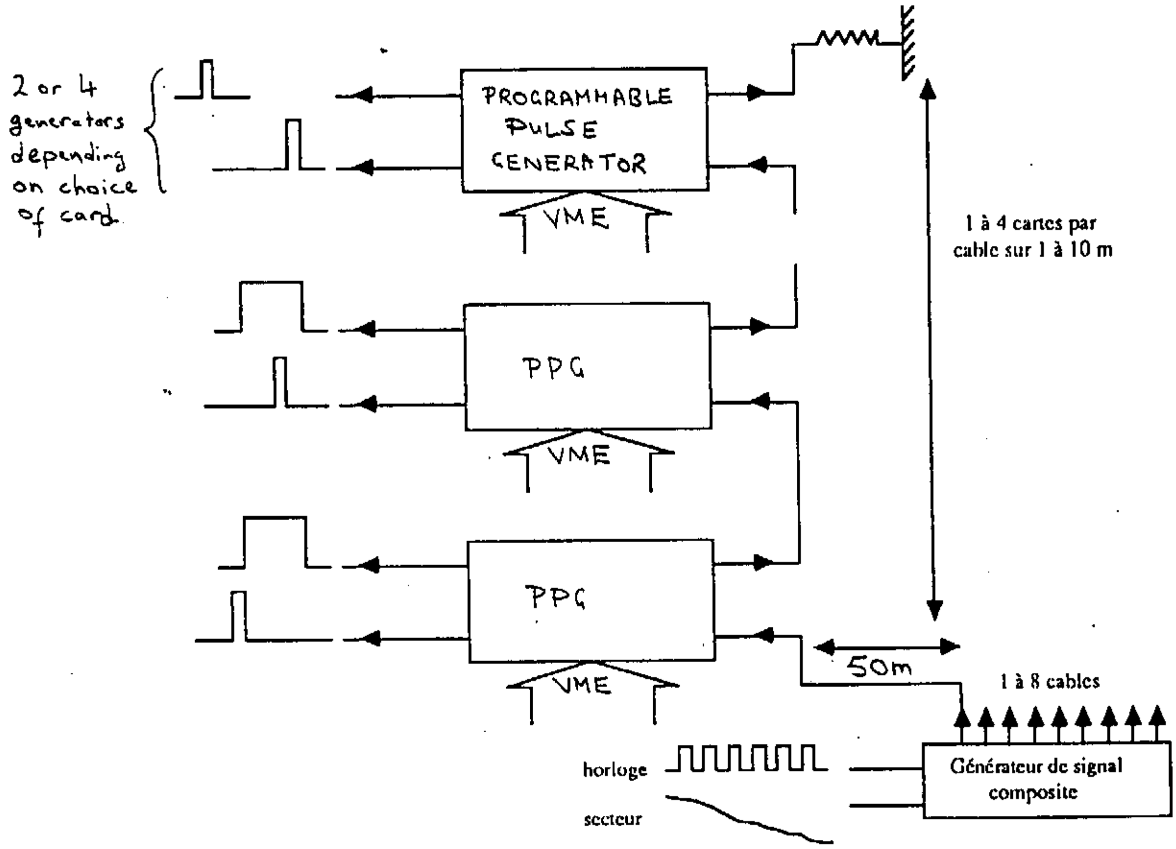


Figure 4 Layout of components of synchronisation stystem

1.4 Proposed Synchronisation of the TTF injector

Figure 5 is a schematic of the proposed synchronisation which takes into account the adjustments needed for the different modes of operation of the gun. It is neccessary to ensure that this proposal is compatible with the synchronisation of other sub-assemblies of the TTFL, particularly the modulators.

2 Low Level RF Distribution, Diagnostics and Tuning.

2.1 Components of the low level RF distribution system

The different components of the low level RF distrubution system are shown in figure 6. The 216.7 MHz and 1.3 GHz generators are, respectively, ceramic resonator and metallic cavity oscillators phase-locked, to the second and twelth harmonic respectively, of a high stability quartz master oscillator at a frequency of 108.33333 MHz.

2.2 Measurements and adjusments of the RF system

Directional couplers extract a part of the incident or reflected RF power at the following locations;

- output of the pulsed 216.7 MHz and 1.3 GHz oscillators
- output of the 1.3 GHz pre-amplifier
- output of 1.3 GHz klystron
- inputs of the sub-harmonic (216.7 MHz) cavity and the capture cavity (1.3 GHz)
- interior of the 216.7 MHz cavity (loop coupling to the standing-wave field)
- input to 1.3 GHz accelerating cavities

The signals are treated by electronic circuits for amplitude and phase detection.

2.3 Amplitude Detection

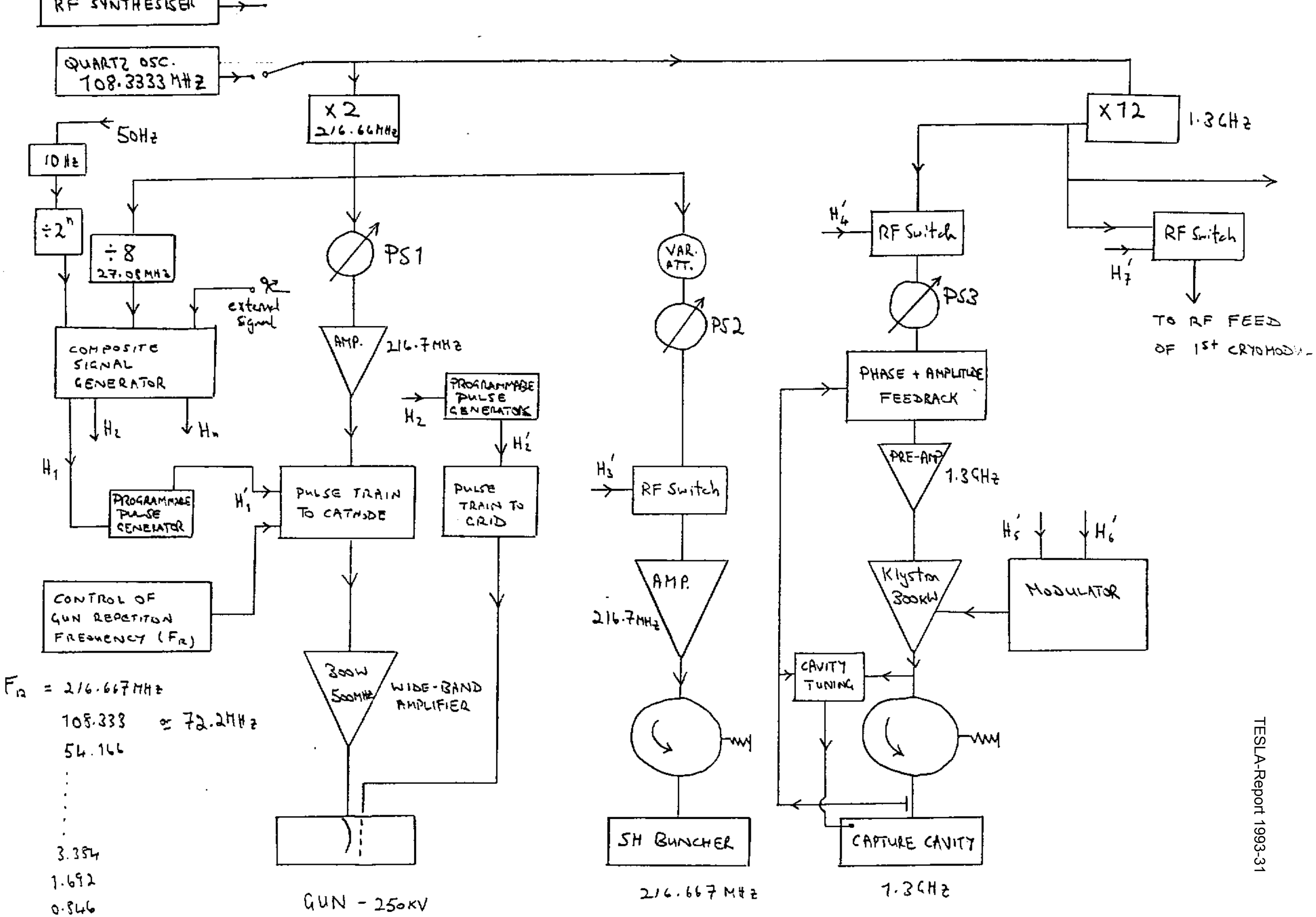
This is done in modules mounted in the 19" EUROPE drawers, which include a pass-band filter (for the measurements at 1.3 GHz), a polarised Schottky diode (placed behind a directional coupler) and a video amplifier for the detected signal) The dynamic range of linear detection is 20 dB and the signal level at the video output is 5 V into 50 Ω for 100 mW input power level.

2.4 Phase Measurements

The phase detection circuits permit the measurement of relative phase differences with respect to the 1.3 GHz master oscillator; the signals coming from the inputs to the 216.7 Mhz cavity, the 1.3 GHz capture cavity, the coupling loops of the 216.7 MHz and 1.3 GHz cavities, as well as for the input or the coupling loops of the accelerating cavities. The circuits are shown schematically in figure 7.

Heterodyning to 70 MHz before phase phase detection allows one to obtain, under the best conditions, the amplitude limit and the phase detection without parasitic amplitude

Figure 5. SCHEMATIC OF TIMING SYSTEM FOR TTF INJECTOR



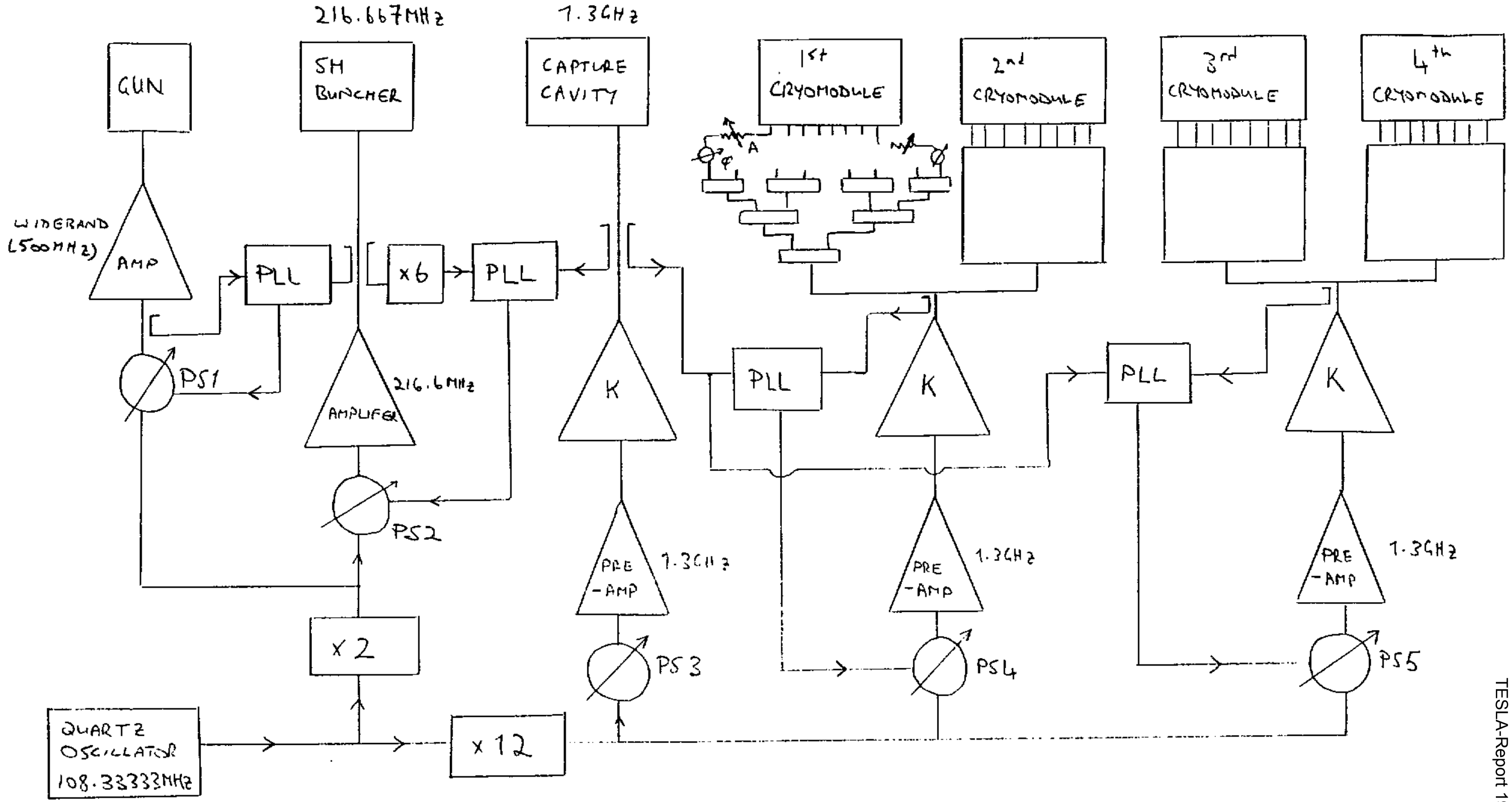


FIGURE 6. RF DISTRIBUTION AND PHASE REGULATION

detection. The sample and hold units allow the measured signals to be memorised, thus one can envisage remote control of the phases assisted by a local micro-controler on the bus.

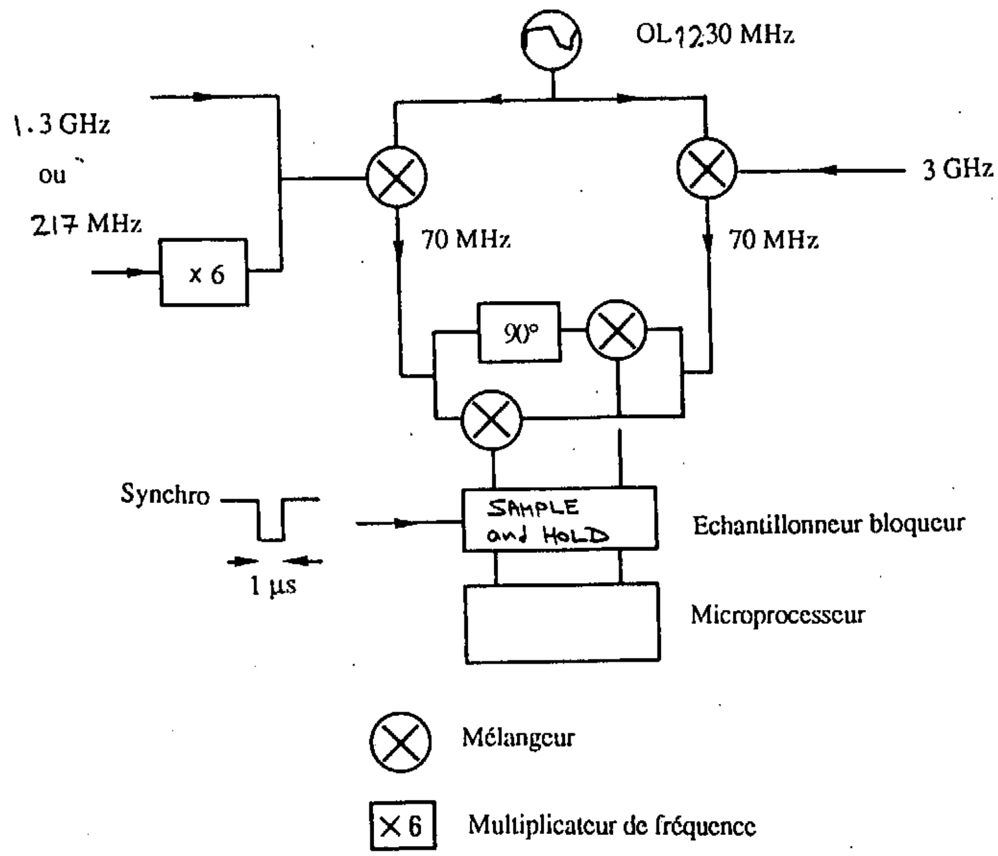


Figure 7. Phase measurement electronics and phase feedback circuit (PLL)

2.5 Phase Adjusments

Bearing in mind the small number of RF sources to regulate (216.7 MHz cavity, 1.3 GHz capture cavity and 1.3 GHz accelerating cavities), the determination of the correct phases for the sources can be done in an empirical fashion by measurement of the energies and phase-widths of the bunches.

On the other hand, it will be possible to store, and to recall in a precise fashion, the working points of the machine. In effect a local microproccesor which controls, through a VME bus, digital to analog convertors will be used. It will be programmed to determine, from the output voltages of the phase-measuring sample and hold units, the relative phases of the RF signals at the input to the wide-band amplifier of the gun, the inputs to the 216.7 MHz and 1.3 GHz cavities with respect to the phase of the input signal of the 1.3 GHz capture cavity, taken as a reference.

The working points, thus memorised, can be recalled automatically by the microprocessor which will regulate the phase-shifters between the gun and the cavities at 216.7 MHz and 1.3 GHz.