RF Note #10
by J. Riedel

MSU SCC RF SYSTEM

June 29, 77

214-0011-01-01_00

Conceptual PLAN for the RF System

Introduction

It seems that, after thinking about the rf system for a year, and before we concentrate ~~in th~~ too much in the details of the various parts it is desireable to document a complete overall plan. Now it turns out that there are many possible plans all of equal merit, and also for any plan, difficult to justify a specific way of doing a part of it over another way. Still, in order to build a system one must have a specific plan, even if some of the chosen ways of doing things are arbitrary. The purpose in presenting this plan at this time is to give others a chance to suggest modification or alternatives to it. This is especially true in regard to the synthesizer and adder-buffer arrangement described herin. Very likely some talks should be arranged with synthesizer manufacturers to decide how much of all this should be a part of the synthesizer and how much separate from it.

Then also, right away, we should add to this plan whatever is necessary to make it compatable with the r f system for the second cyclotron.

— —

~~The~~

Symbols and Specifications

F ~~F~~ is a 5 volt r.m.s sine wave of ~~frequency F between~~ 15 and 90 mHz

F is a 5 volt rms sine wave of the exact same frequency as F but is in quadrature (+ 90° phase shifted).

F+ is the upper single side band of F, i.e., it is 2 ± .01 MHz higher in frequency than F and has good spectral purity. It is a sine wave of 5 V rms amp.

$\overline{F+}$ is ~~the~~ in quadrature with F+, i.e., phase shifted by + 90°.

Buffers are for the purpose of providing terminated independent outputs, i.e., reflected power into one output does not affect the others; also all outputs are short circuit proof.

<u>adders + buffers</u> permit, by ~~vector~~ passive vector addition of F, $-F$, $\bar{F}$, $-\bar{F}$ any possible output phase. It is hoped that after once setting the amplitude and phase knobs that the outputs: ±120° phase shifted sine waves of 5 V rms will remain so over the frequency range without further adjustment. However monitor outputs are available so that a little tweaking can be made if necessary.

φ Det stands for phase detector


stands for an operational amplifier including transfer function determining networks.

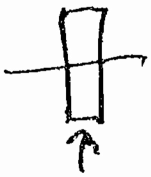
Δφ means phase shifter

SPDT means single pole double throw

L1 is a commercially available motor operated variable inductor.

Ref. means amplitude command. Provision will be made for local and remote command.

is a solid state 50 watt 90 mHz bandwidth amplifier, accepting a 1 volt rms input signal. Maybe we can afford an existing commercial version of this



1 KW absorber is a ~~powdered~~ water cooled powdered iron core or cores thru which the grid rf current will pass, à la FNAL.

the rest of the symbols are, hopefully, obvious.

The Grand Plan

Refer to the large dwg. Fig. 1 labelled "Block Diagram". It is presumed ~~that~~ the drawing speaks for itself and no commentary is necessary. There is nothing unique or fancy here, the plan being much the same as elsewhere.

Perhaps, however, the purpose of the electronic + manual phase shifter should be explained. First, note the dashed lines ~~l~~ l_1 and l_2. These must have the same time delay, which means that l_2 will probably be a 200 to 500 feet stored roll of cable. The time delay through the attenuator and amplifier chain should be constant and independent of frequency or amplitude. Thus phase detector φ1A gives a true picture of a ~~#~~ dee phase error due to whatever cause, and servoe Sc 2A will correct for it. Thus, in case there is a slight amplitude or frequency dependence on time delays, this will be corrected. But the main reason for this servo is to add high frequency regulation possibility to the dee phase servoe. It is unlikely that we will achieve better than 5 Hz response with the dee fine tuner, yet if, due to mechanical motion, thermal induced motion or otherwise phase variations of less than ±20° occur at frequencys larger than 1 Hz the fast phase servoe Se 2A will correct for this, even for frequencies above the 10 KHz or so break frequency of the dee system. At GANIL this provision turned out to be very usefull, and at FNAL it is absolutely necessary.

Phase Detectors

Fig 2 shows a phase detector. I'm sure some will ask: "why all this folderol with F+ and F+ instead of the simple ring modulator scheme employed on the existing MSU cyclotron"? There are three reasons. The most important reason is that it ~~not~~ is desireable to have the phase detectors give full ~~out~~ output signals for input signal amplitude variations of 1000 to 1, so that, for example, the dee can be tuned with 100 volts on the dee, below the multifactoring level.

This means limiting amplifiers. Now it is difficult enough to build ~~[illegible]~~ ~~unity~~ constant frequency amplifiers that do not introduce phase shifts with varying amplitude input. But to ask, in addition, for 90 mHz bandwidth is too much. In these phase detectors the limiting amplifiers and phase ~~sh~~ detector work at a constant 2 mHz.

The second reason for choosing this method is that by using F+ or $\bar{F}$+ mixed signals one can build phase ~~detors~~ detectors with null output for either in phase or out of phase inputs. Thus ϕ4A det. with Quadrature inputs provides a null signal when each is mixed with F+, but ϕ3A detector, where the grid and plate signals are 180° out of phase at resonance, provides a null output when mixed with F+ & $\bar{F}$+. Now ~~th~~ to achieve this desireable feature over a large frequency range is impossible using the simple phase detector scheme. Some means must be found to phase shift one of the inputs by 90°, the usual method being to take the derivitive of the plate signal. This enhances harmonic problems which are already bad enough. The third reason is not so important. It is that the ϕ det outputs will be linear with $\Delta\phi$.

Synthesizer

It seems that for the first cyclotron the synthesizer, adder, buffer arrangement shown in Fig. 1 would be adequate. F would be settable in 10 Hz steps from 4 to 90 mHz, with drift less than 1 ppm. Thus the synthesizer would have 9 – 1/2 watt outputs (2 for monitors) and the buffers would have a total of 37 – 1/2 watt outputs. Or the synthesizer could combine all these into 39 outputs.

However, consideration should be given to permitting this same synthesizer to be used for the 800 MEV cyclotron to follow. Now if both cyclotrons always work on the same frequency then it would be sufficient to double the number of buffered outputs. But if they will be operating on different harmonics then we should ask that the synthesizer provide for this. Someone should be assigned to develope a chart or whatnot deleniating all the possible harmonic relationships between the beam in each machine and the r f systems, specifying absolute frequencies for each. (3).

Computer Control — and other control.

At the moment, it is visualized that the computer will do only 3 things:

1. control the reference voltage for amplitude, naturally with protection override. On each line going to the box labelled Ref in fig 1 will be a 2 position switch, one for local, the other for remote. Then at the console another 2 position switch for manual and computer.
2. At each newly selected frequency the computer, via a look up table, will set the tuning of the dee stems and the ~~anno~~ final anode stems.
3. Remember and display on command status information.

The turn on controls and protective interlocks will be similar to those on the existing cyclotron.

Power Supplies

Power supplies for the finals, drivers and preamplifiers will be common to the three chains. This means we must make or buy magnetic type current transducers.

Phase Det.

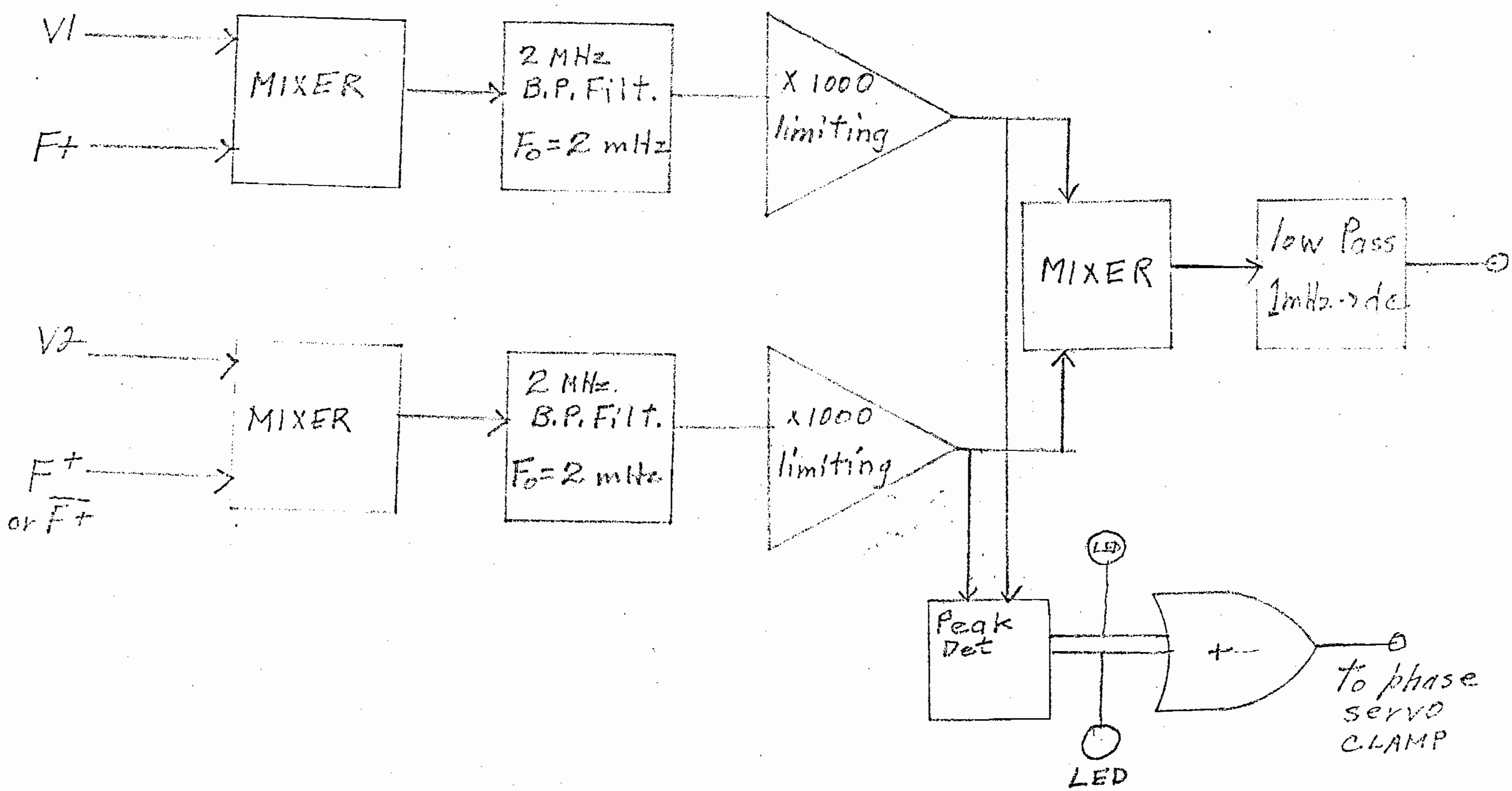


FIG. 2