Title
PEP-A TRIGGER ELECTRONICS

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Authors
Jackson, L.T.
Jared, Richard
Ronan, Michael.T.

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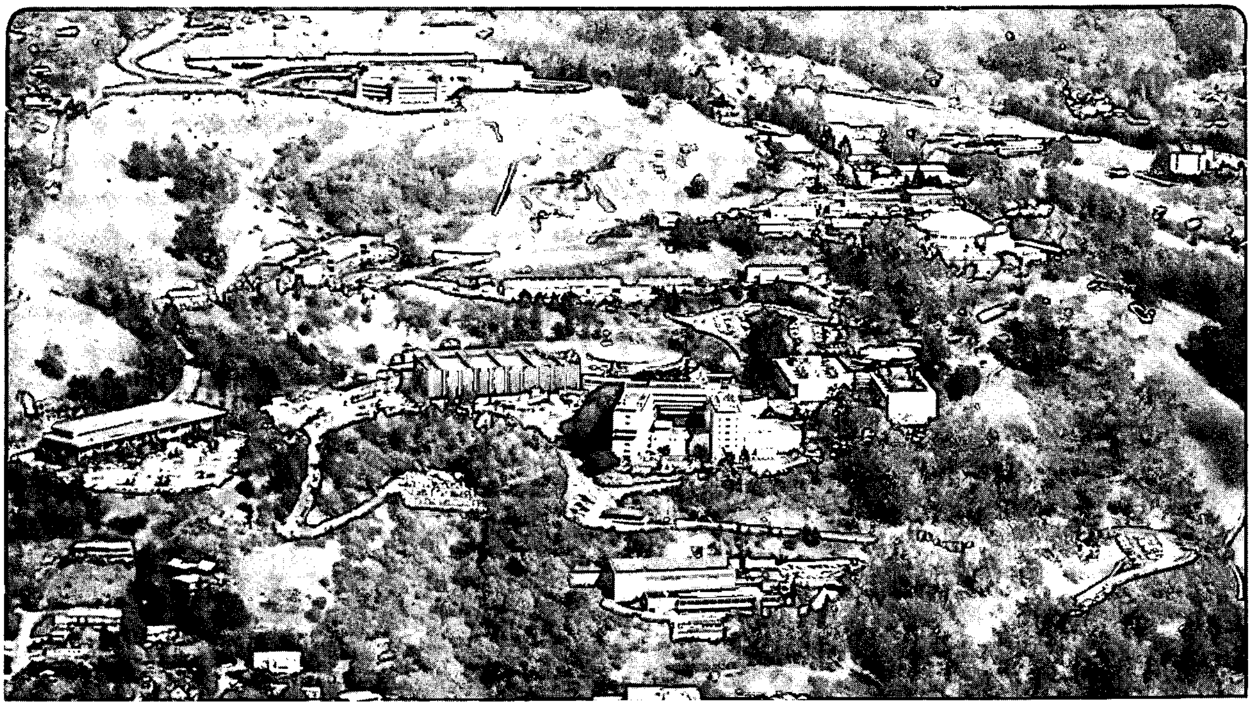
Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA, BERKELEY

Engineering & Technical Services Division



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ENGINEERING NOTE

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SUBJECT PEP-4 TRIGGER ELECTRONICS	NAME Jackson/Jared/Ronan	DATE October 31, 1977	

This note is the result of recent discussions on the PEP-4 Trigger Electronics. It is intended to give engineers and physicists a preliminary design criterion for use in simulation studies and for prototype development. The present design of the trigger differs from the original proposal in three respects:

1) A new trigger has been designed for the TPC itself. The suggestion now is to use the 192 dE/dx wires either individually or grouped together in majority circuits to define a straight line in wire number (r) vs. time. A track formed in the outer radius of the TPC will initiate a ripple in the trigger elements that will propagate to the inner radius elements to generate TPCS (the slow TPC trigger) in ~ 15 μs of the Beam Crossover (BCO) signal.

2) The endcap drift chambers have been eliminated. To generate a pretrigger for particles with $11^\circ < \theta < 45^\circ$, we intend to make use of the TPC ripple trigger to form TPCF (the fast TPC trigger) within ~ 2 μs of BCO.

3) The use of the cylindrical muon detector to form the dimuon trigger for $|\cos\theta| \leq 0.7$ has been superceded by the idea of using a coplanar 2-particle trigger, making use of the inner and outer drift chambers. The endcap muon detectors are still used in the 1 x 9 element coincidence array.

The main trigger is developed in two stages. In the first or pretrigger stage, within 2 μs of the beam crossover signal, a decision is made as to whether a possible interesting event was produced. Depending on this decision, the second stage is enabled, or the first stage is cleared for the next beam crossing. The pretrigger is given here as a Boolean expression:-

$$\mathrm{PT = IDC(ODC+TPCF)+LUMS+BHAB+LAD+DiM+PEP9}$$

(Each of these basic signals is discussed in more detail below).

In the second stage, sufficient time (15 μs) is given for single charged-particle tracks to form in the TPC. The main trigger is then identified as:-

$$\mathrm{T = PTD(TPCS+LUMS+BHAB+LAD+DiM)+PEP9}$$

It should be noted here that each of the basic signals and many of the logic decisions used to define them will be listed and stored in the Large Data Buffer (LDB) for later reference, if required. Also, the logic involving these basic signals is under the control of the computer.

BCO - A beam crossover signal is implicity assumed in the pretrigger definition. This signal is generated by beam pickup coils on either end of the detector and occurs every 2.45 μs. The timing of this signal relative to the actual beam crossing should be known to within a few tenths of a nanosecond. A 32 bit scaler will record the number of BCO triggers and will be read out with each event.

PT - This is the pretrigger for the TPC. If PT is not formed within 2 μs of BCO, then all latches and storage capacitors are cleared within 200 ns, and the system is primed for the next beam crossing. The rate for PT is expected to be ~ 10^3/s.

T - The main trigger is formed within 15 μs of BCO, and enables the readout of data from the TPC to the LDB. The trigger rate will be set to ~ 1/s. The trigger related dead time is 1.5% or less, depending on the slow TPC trigger (TPCS).

PTD - The delayed pretrigger is identical to PT, but is delayed by 15 μs. It is used to interrogate the status of the various triggers which enter into the definition of the main trigger (T).

IDC - The trigger from the Inner Drift Chamber requires that at least 1 charged track be radial within ± 4.75° ($p_{\perp} \geq \sim 500$ meV/c) and come within 25 ns of BCO. A double-pulse resolution of < 50 ns is required of the drift chamber electronics to ensure a high trigger efficiency for multiple tracks occurring within one cell. Both the bias level and the output pulse width of the discriminators (typically 28 ns) used for defining IDC will be computer controlled thus allowing changes in the $p_{\perp}$ (min) cutoff for different energies and background conditions.

ODC - At this time we anticipate there will be one layer of ~ 700 drift chamber cells between the magnet and the calorimeter. With a 5 cm/μs drift velocity, this implies a maximum drift time of 100 ns and that an ODC signal can be timed within ± 50 ns of BCO. The solid angle coverage of the ODC extends over $|\cos\theta| \geq 0.7$ or $45° < \theta < 135°$.

IDC · ODC - For this coincidence, we will section both the inner and outer drift chambers into 12 groups of 30° each (see Fig. 1). A coincidence will be required between $I_1\ (O_{12}+O_1+O_2)$ through $I_{12}\ (O_{11}+O_{12}+O_1)$ where I_n and O_n represent a logic OR of the signals within a 30° sector.

TPCF - For each endcap of the TPC, the dE/dx wires at a given radius in each sector will be OR'ed with wires of a similar radius in adjacent sectors to form 6 electronic "supersectors." In this way, tracks which cross sector boundaries will be contained within 1 supersector. One of the present TPC ripple trigger schemes assembles the 192 ORed dE/dx wires for each supersector into twenty-four 8-wire groups. A majority decision (5/8) in any of these groups will generate a fast TPC trigger (TPCF), provided that it occurs within 2 μs of BCO. Also note, a shift register under computer control is used to control the starting radius for this trigger. This is shown in a simplified logic diagram in Fig. 2. The TPCF trigger extends the single charged particle trigger to θ min $\gtrsim 11°$ depending on the exact scheme; e.g. using only one 8-wire unit to define TPCF gives θ min $\simeq 13°$. Note, the final value of θ min will be determined at PEP by the overall trigger rate.

IDC · TPCF - For this coincidence, we will require an angular coincidence between a 120° supersector and one of two 30° inner drift chamber sectors within ± 30° of the center of the supersector. As shown in Fig. 3, a coincidence will be required between SS1 $(I_1 + I_2)$ through SS6 $(I_{11} + I_{12})$.

TPCS - Also shown in Fig. 2, in elementary form, is the majority logic implementation of TPCS -- the slow TPC trigger. A charged track passing through the outer radius of the TPC (loading register R_n and generating TPCF) will sequentially trigger the register R_{n-1}, through R_1 and finally generate TPCS. A ripple in the R_n register can only be initiated during the first 2 μs pretrigger stage, or at R_{24} by ionization associated with a track which gave an ODC signal. TPCS must occur within 15 μs of BCO or the trigger will be aborted for charged tracks. (Note: due to propagation delays and possible race conditions, a special 90° track trigger will be implemented. This will require a positive decision from a number of majority units within a few microseconds of the expected time for the ionization due to a 90° track to be detected at the endcaps).

BHAB - In each of the endcap liquid argon detectors there are three sets of 3 cm wide collector strips (p, q and r) orientated at 0°, 120° and 240° to the vertical.

For each of these sets, we will form six 18 cm wide trigger elements arranged with one-half overlap and located on either side of the beam, beginning at the outer radius of the beam pipe as illustrated in Fig. 4. The Bhabha trigger is due to a Bhabha event that intersects diagonally opposite pairs of collector strips. To restrict the Bhabha trigger to those events that are ≥ 24° from the beam line, we use only the trigger elements C through F; thus,

$$\mathrm{BHAB} = \sum_{(i = p,q,r)} C_{1i}\, C_{3i} + C_{2i}\, C_{4i} + D_{1i}\, D_{3i} \,\cdots\cdots + F_{2i}\, F_{4i}$$

In addition to the angular requirements for this trigger, we require a minimum energy deposition in each endcap of approximately $\sqrt{s}/3$ and that BHAB occur within 1 μs of BCO. The choice of the minimum angle (as to which strips are enabled for the Bhabha trigger) and the discriminator thresholds for all trigger elements will be under computer control.

LUM - Small angle Bhabha scattering will be used for luminosity measurements. We define a LUM coincidence, using the strip arrangement given in Fig. 4 as

$$\mathrm{LUM} = \Big(\sum_{(i = p,q,r)} A_{1i}\, A_{3i} + A_{2i}\, A_{4i} + B_{1i}\, B_{3i} + B_{2i}\, B_{4i}\Big) \cdot \overline{\mathrm{BHAB}}$$

Using the A and B strips and BHAB as a veto restricts the scattering angle to $11° < \theta < 24°$. Consider the 2 hits (H1 and H2) shown in Fig. 4. H1 which corresponds to a scattering angle $\theta \simeq 37°$ will give (LUM)p, (BHAB)q and no coincidence for the r strips, resulting in BHAB = True, LUM = False. H2 corresponds to $\theta = 14°$, will give (LUM)p, no coincidence for the q strips and (LUM)r, resulting in BHAB = False, LUM = True. An energy deposition of approximately $\sqrt{s}/3$ and 1 μs timing relative to BCO are also required.

Three 16-bit scalers will be used to count the number of LUM coincidences. One scaler (LUM1) will be reset only at the beginning of each run, the other two will be stopped at each event trigger (T), but only one will be reset after the event is read. Thus, when T is enabled, one scaler (LUM2) will indicate the number of LUM coincidences (hence, livetime = LUM2/LUM1), and the other (LUM3) will read the number of LUM coincidences since the last event. The contents of all three scalers will be readout after each event.

LUMS - This is a scaled version of LUM which will trigger the system and will be used to study small angle Bhabha scattering events. The scale factor, which will be adjusted to give a LUMS rate of ~ 0.1/s, will be under computer control with a range of 8-bits, allowing 2 orders of magnitude variation in the scale factor.

LAD - This trigger requires a minimum energy deposition in any of the Liquid Argon Detectors (LAD). We will implement 7 different neutral energy triggers; one for each of the endcaps (EC1 and EC2), one for the total endcap energy deposition (TEC), one for each half of the cylindrical detector (CY1 and CY2), one for the total cylinder energy deposition (TCY) and one for the total LAD energy deposition (TLAD). The logic expression is then:

$$\mathrm{LAD} = \mathrm{EC1} + \mathrm{EC2} + \mathrm{TEC} + \mathrm{CY1} + \mathrm{CY2} + \mathrm{TCY} + \mathrm{LAD}$$

The discriminator threshold for each of the triggers will be computer controlled by an 8-bit DAC. Note: EC1, EC2 and TEC will not include the A and B strips, giving $\theta_{\min} \simeq 24°$.

DiM - The dimuon trigger (DiM) uses the endcap muon detectors to indicate a coincidence with $|\cos\theta| > 0.7$, and the inner and outer dirft chambers to record a coplanar 2-particle event for $|\cos\theta| \leq 0.7$. Hence,

$$\mathrm{DiM} = \mathrm{IDC}_L \cdot \mathrm{DiM}_{EC} + (\mathrm{IDC}_L \cdot \mathrm{ODC})_2$$

The endcap muon detectors are formed into 1 m x 1/3 m trigger elements and DiM_{EC} is a 1 x 9 element coincidence formed by a trigger element in each of the endcap detectors and 9 elements diagonally opposite opposite to it.

IDC_L indicates a loose coincidence between 2 layers of the inner drift chamber. The coincidence, $\mathrm{IDC}_L \cdot \mathrm{DiM}_{EC}$, does not include any angular coincidence. The $\mathrm{IDC}_L \cdot \mathrm{ODC}$ coincidence is similar to the IDC · ODC coincidence described previously, with the subscript 2 signifying that we will require two back-to-back $\mathrm{IDC}_L \cdot \mathrm{ODC}$ coincidences.

PEP9 - A trigger from PEP9 allows PT and T to develop independent of the PEP-4 trigger requirements. However, provision will also be made to allow inhibiting the PEP9 signal by computer control. It is anticipated that PEP9 will have a BCO scaler that will allow for synchronization of data with PEP-4. Development of the PEP9 trigger awaits further clarification, but will be included following future discussions.

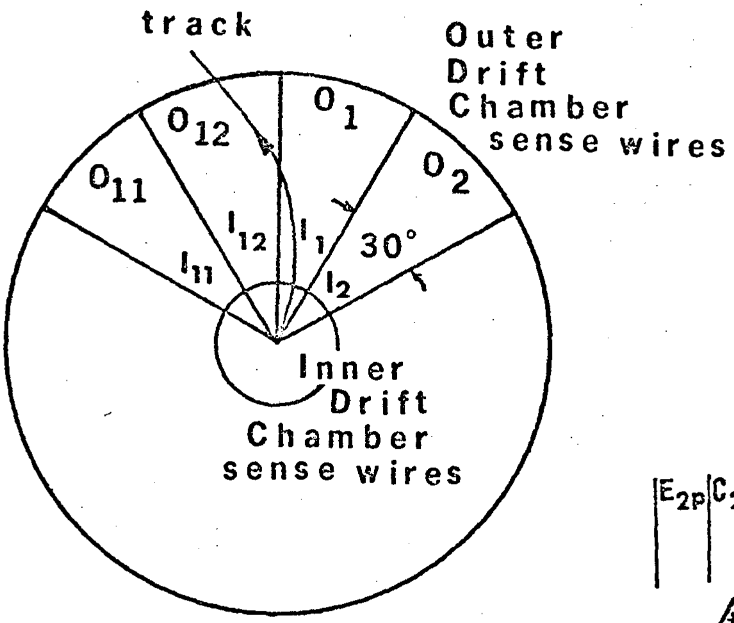

Figure 1. Geometry for IDC and ODC angular coincidence.

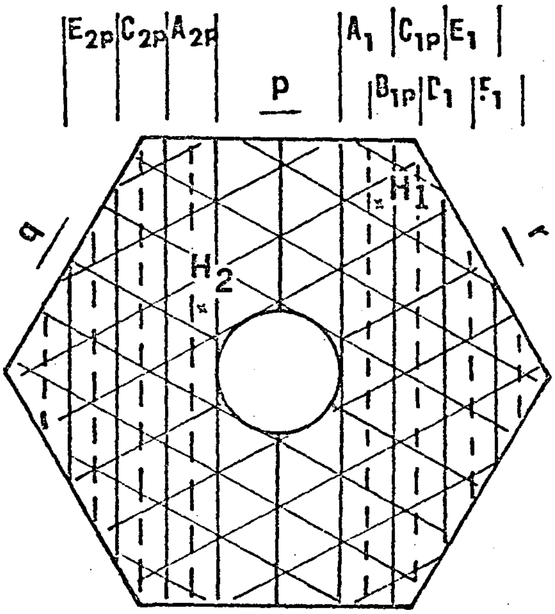

Figure 4. Diagram of collector strips in one endcap calorimeter. The other endcap is labeled A_{3i}, A_{4i}, etc.

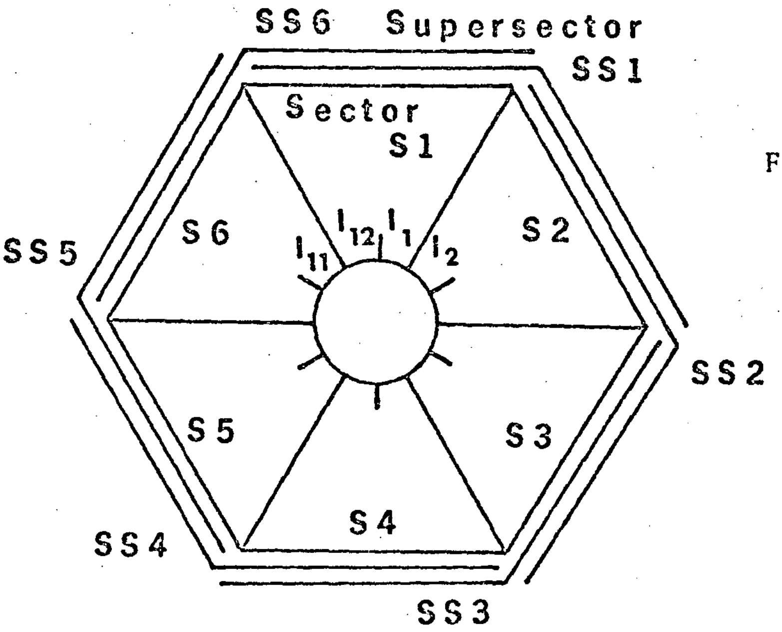

Figure 3. Illustration of the Supersector and Inner Drift Chamber alignment.

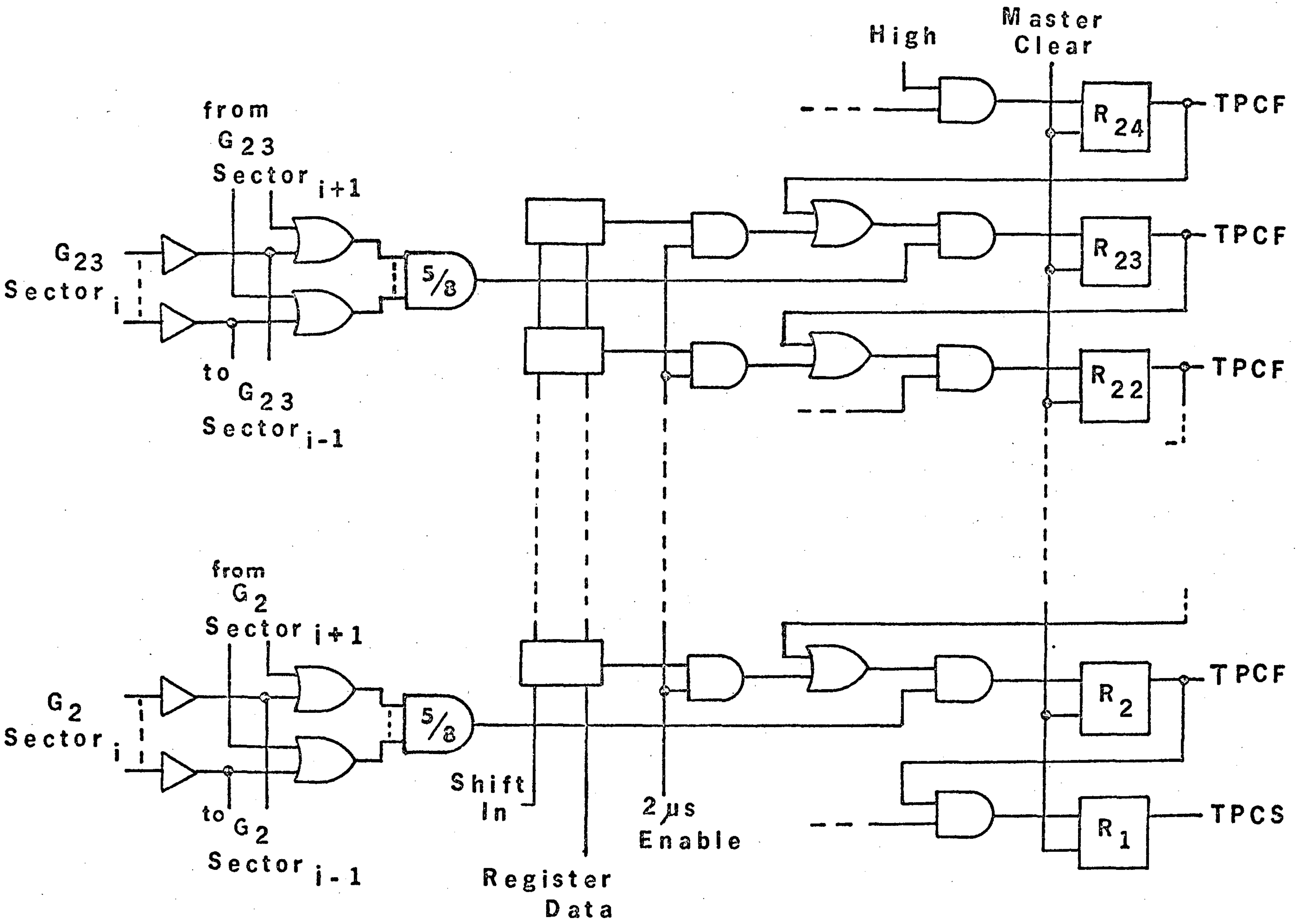

Figure 2. Simplified logic diagram for TPCF and TPCS.

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720