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NEUTRAL BEAM TIMING

Real Time Systems Group

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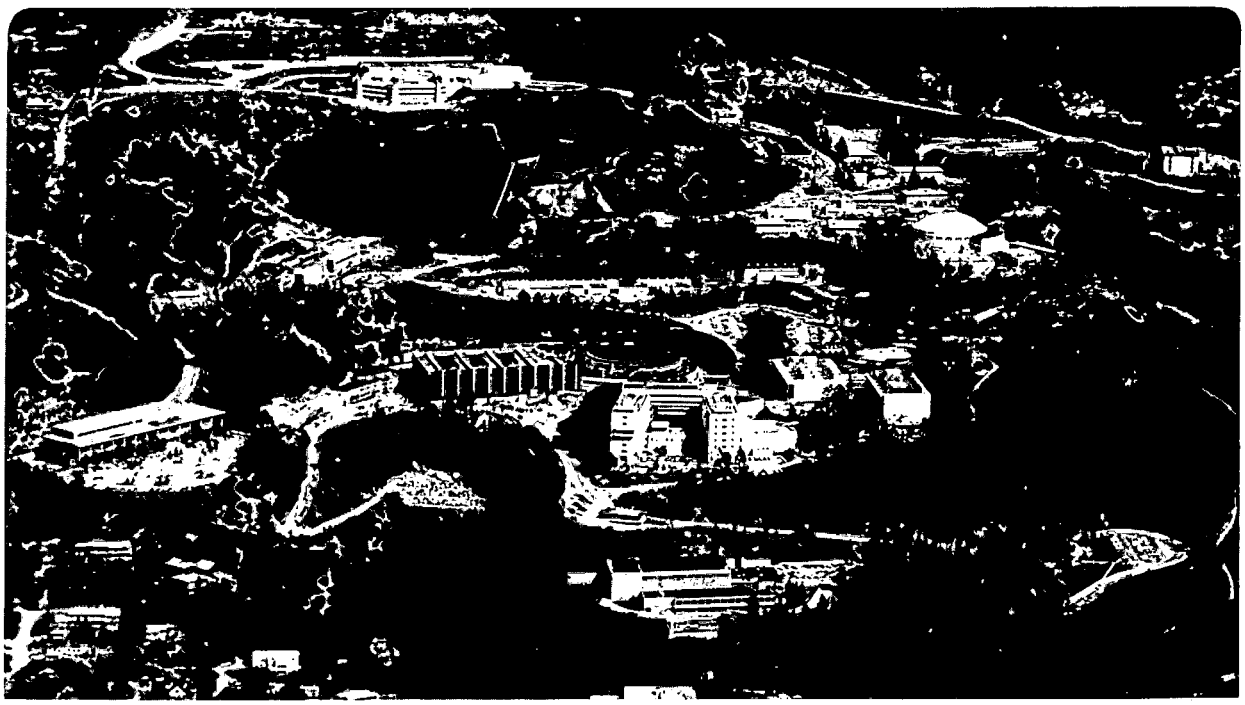

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Neutral Beam Timing

Real Time Systems Group

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Neutral Beam Timing

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This note is a general discussion of neutral beam timing. Although the timing details are largely a result of the power system, the general sequence of events is due to the source and independent of the particular power system. We describe this general source timing.

We have found it useful to view the entire neutral beam system as having a single timing diagram which applys to all shots, then we accommodate different operating modes by enabling or disabling various components of the hardware and software. E.g., the timing for an arc-only shot is identical to the timing of a beam shot but the accel primary is disabled for arc-only.

Also, the words "on" and "off" in the following description should not be construed as the sequence of actions necessary to bring a power supply to the armed and ready state. Remember that all of the neutral beam power supplies are pulsed and, thus, "on" and "off" are always used to refer to the leading and trailing edges of a supply's gate pulse.

1. Shot Sequence Timing

The overall timing sequence can be derived by the following thought process: Assume that you are going to turn on the beam at some time and call it time zero. Working

backwards from zero to fill in the prerequisites for beam we see we need arc and accel. To get accel, we only need to turn on the accel primary. To get arc, we must have gas and filament. Thus the sequence of events must look like:

```
Filament on\
           |->Arc on\
     Gas on/          \
                      |-->Beam on
        Accel Prim on-/
```

Given this sequence of events, the following help to determine the relative times:

- The accel primary has to be turned on early enough for its contactor to take up (20-60 ms) and to allow any turn-on transients to dissipate (100-200 ms). Thus, it should be turned on about -120 to -260 ms relative to Beam on. It should not be turned on much earlier than it has to be since a load is put on the regulator as soon as the Accel primary is turned on.

- The arc contactor will take 20-60 ms to take up and the arc will take about 200 ms to strike and settle. Thus, the arc should be turned on about -220 to -260 ms relative to beam on.

- The gas valve will take 20-50 ms to open, then the gas will take another 100-150 ms to fill the gas line and arc chamber. Thus the gas should be turned on about -120 to -200 ms relative to <u>arc on</u>.

- The filaments will take about 3 sec. to reach thermal equilibrium. Thus the filaments need to be turned on about -3 sec relative to <u>arc on</u>.

The timing at Beam Off is essentially the mirror image of the Beam On timing: turn off the beam (modreg), turn off the accel primary and arc then turn off the gas and filament. It takes about 100ms for the Arc contactor to open and the arc to go out. Thus, if the Arc is turned off at Beam Off, Gas and Filament can be turned off 100ms later.

The discussion above has covered the power supply timing. There also needs to be some computer data acquisition timing as part of the same sequence: Before Beam On, one must

- Read the 'reference' (pre-shot) thermocouple temperatures. To avoid errors due to conduction and radiation cooling, these should be read as close to Beam On as possible. However, not so close that there's any possibility of the read overlapping beam.

- Read the pre-shot vacuum. Since the tank is being continuously pumped, this should be read as close to Gas On as possible but, again, not so close that there's any possibility of the read overlapping with the gas.

- Set up the transient digitizers' clock rates and start them scanning. The slow (~1 KHz) digitizers should be set to 'cover' everything from Arc On to Beam Off. Thus, they need to be set up before Arc On. To keep the window for a spurious digitizer trigger small, they should not be set up much before Arc On.

After Beam Off one must

- Read the 'final' (post-shot) thermocouple temperatures. These must be read after the heat has had a chance to diffuse from the front to back surface of the dump but before it can diffuse laterally (otherwise the beam shape information needed to find the divergence is lost). This read time is about 1 - 2 sec for the apertures and beam dump (the exact time depends on the type of ADC being used) and 3 - 4 sec for the Ion Dump (since it is much thicker).

- Read the digitizers, scalars, fault detector, etc. This can be done anytime after Beam Off since the data is captured in local storage in the device.

One ends up with a timing diagram much like Fig. 1. Time zero could be moved to the 'Fire' command to make the negative times disappear but one should keep the dependencies in mind. E.g., the operator may have to give the arc more time to stabilize. Conceptually, one is simply moving Arc On earlier relative to Beam On. Since Filament and Gas are relative to Arc On, their timing need not change. Operationally, unless your timing software is similar to LBL's, the operator would probably have to lengthen Filament, Gas and Arc, then delay Beam On to give the arc more warmup time.

2. Other Timing Sequences

The preceding section covered what we call the "Shot Sequence" timing. There are actually 3 independent timing sequences for a neutral beam:

(1) The Shot Sequence which covers the overall timing of a shot (power supply pulsing, data acquisition, etc.). This sequence is initiated by the Fire button or Tokamak Fire command. All of the timing in this sequence has fairly gross resolution (±1 ms).

(2) The Interrupt Sequence which concerns actions which must be performed during a fault. This sequence is initiated by the Fault Detector and things must happen on a micro-second scale (see below).

(3) The Turn-On Sequence which concerns actions which must be performed when applying high voltage to the source. This sequence is initiated either by the Shot Sequence, when everything is ready to make beam, or by the Interrupt Sequence, at the end of the interrupt. Everything in this sequence must happen on a micro-second scale (see below).

2.1. The Interrupt Sequence

The interrupt sequence consists of 2 timers triggered by the fault detector. One timer controls the interrupt duration. It inhibits the "Strobe" for 10-20ms then triggers a 'turn-on' sequence at its end of time. The other timer causes the arc to be 'diverted' (via the arc modulator) for about 5ms to keep the fault from triggering an anode spot. Both of these timers must turn on within 5 micro-seconds of the trigger. Fig.2 illustrates the interrupt sequence.

2.2. The Turn-On Sequence

The turn-on sequence consists of 3 or 4 timers triggered by a 'turn-on' command (which is generated by both the shot sequence and the interrupt sequence). One timer is a fast digitizer (the 1 MHz digitizer) or scope trigger (to allow the operator to view the turn-on so that the arc and accel can be matched). Another timer triggers the arc notch. Another triggers the accel (modreg) turn on. The timing between the arc notch and accel turn on is probably the most crucial in the entire neutral beam system. The time between these 2 events is typically 100-200 micro-seconds and must be stable and repeatable to 1-5 micro-seconds. At LBL, a 4th timer is used as a pre-trigger for the suppressor supply to make sure that the suppressor is up when the accel is turned on. Fig. 3 illustrates the turn on sequence.

3. The LBL Timing Displays

The LBL timing displays reflect the preceding discussion but are complicated by having to accomodate both 'manual' and 'computer' timing. I.e., when the system was brought on line, the shot timing was controlled by the 'manual' timers but the computer data acquisition was controlled by PPPL timing modules. This resulted in the shot sequence being broken into a number of sub-sequences (called SHOTSTART, LARC, BEAMOFF on the displays) so that manual timer settings could trigger the appropriate data acquisition timer. Hopefully, the TFTR timing system can do without this complication.

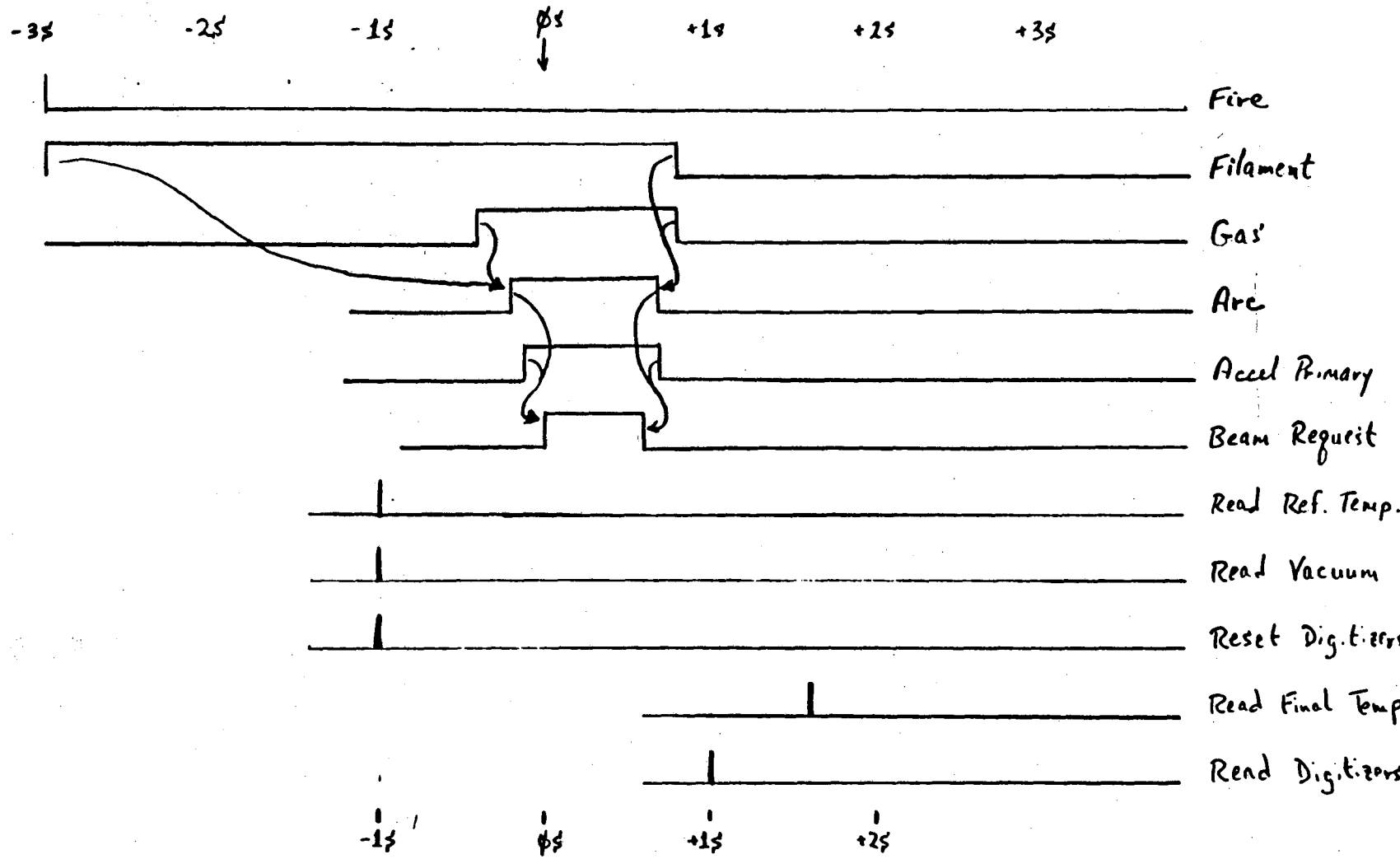

Fig. 1 - Shot Sequence Timing

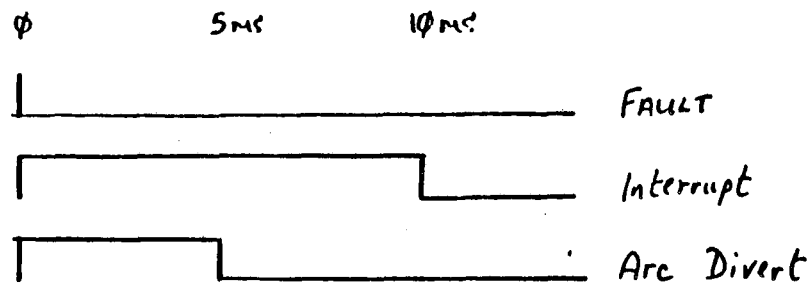

Fig. 2 - Interrupt Timing

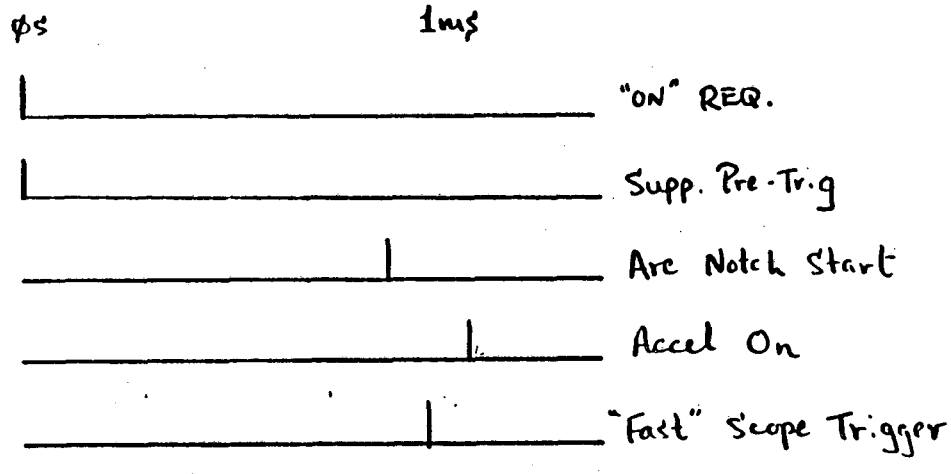

Fig. 3 - Turn-On Timing

Also, the LBL software implements various minimum time constraints (like contactor delays or warm-up times) via "imaginary" timers, i.e., timing signals with no associated hardware timer whose function is to enforce a non-adjustable minimum time for some operation. These signals usually have names ending in ".MIN" or ".WARM". See the Timing Writeup (nbs.4.1) for a description of these signals and their purpose.

NBSTF Computer Controlled Timing System

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November 12, 1981

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Table of Contents

1. System Overview 1

2. Timing Signal Definition 1

3. Menus 2

4. Timing Display Characteristics 2

    4.1. Signal Names 2

    4.2. Reference Names 3

    4.3. Delay Times 3

    4.4. Graphic Display Area 3

    4.5. Control Buttons 4

    4.6. Other Display Information 5

5. Timing Display Descriptions 5

    5.1. Operations Display 5

    5.2. Fil & Arc Display 6

    5.3. Accel Display 8

    5.4. Interrupt Display 9

    5.5. Data Acquisition Display 10

    5.6. Misc.1 Display 11

    5.7. Misc.2 Display 12

NBSTF Computer Controlled Timing System

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1. System Overview

The NBSTF computer controlled timing system consists of a collection of CAMAC based hardware timing modules, the CAMAC highway (which provides communication between the computer and the hardware), the operator console system (which provides communication between the operator and the computer) and software in the Modcomp computer.

The computer does not perform real time control of the timing system. Once the timing hardware has been programmed by the computer, it will generate timing signals independent of the status of the computer.

The timing system provides timing signals to data acquisition hardware, the power supplies and the computer. Timing sequences are fixed by a combination of hardware and software, and are not adjustable by the operator. Some timing values are operator adjustable, others are not. The non-adjustable values have been empirically determined to be a minimum safe operating set, constrained mostly by power supply considerations. Non-adjustable values can only be changed by requesting a change from the RTSG Software Group.

2. Timing Signal Definition

Timing signals in this system are defined in terms of a delay from some reference point to a change of state or "edge" of the signal. A signal can then be defined in terms of four parameters: the leading edge reference, leading edge delay, trailing edge reference and trailing edge delay. A leading edge reference can be either an external hardware event (like pushing the FIRE button on the fire control panel) or some other signal's leading or trailing edge. A trailing edge reference can be any leading or trailing edge.

The ability to reference one signal edge to some other signal edge allows us to enforce timing sequences and "slave" certain signals to others.

In general, delays can be positive or negative. A positive delay is conventional enough. A negative delay means that you want a signal edge to change a certain time before its reference occurs.

The four parameter definition just described is artificial in the sense that the hardware timers do not directly correspond. A hardware timer consists of 2 CAMAC modules: a delay unit which produces a pulse delayed from some hardware external event and a gate unit, triggered by the delay pulse, which produces the proper width gate. Thus the hardware requires three parameters to generate a timing signal. The computer converts the four parameter software definition to the three parameter hardware definition automatically.

3. Menus

To interact with a timing display, the operator must first select the "TIMING" menu on the main menu. The button labelled "TIMING" will light up and shortly thereafter a "TIMING DISPLAYS" menu will appear on the console (see figures 1 and 1A).

4. Timing Display Characteristics

4.1. Signal Names

Signal names appear enclosed in rectangles on the right side of a display. To adjust a signal, touch its signal. The rectangle will light up around your selection. The leftmost two knobs on the central console just below the display screen will be labeled "LEADING DELAY" AND "TRAILING DELAY" and will connected by the computer to the signal name you have selected.

4.2. Reference Names

Immediately above a group of signal names will be reference name. These are not enclosed in a rectangle, and are not adjustable. A reference name is the hardware reference point for the signals listed below it.

4.3. Delay Times

Immediately to the left of the signal names is another rectangle enclosing two numbers. The leftmost number is the signal's leading edge delay; the rightmost number is the signal's trailing edge delay. Non-adjustable delays are dimmed on the screen and show the built in default values used to insure a safe set of minimum delays.

The rectangle enclosing the delay times will light up if you adjust a delay time. It will stay lit up until you either press the CANCEL button (lower right on screen) or the CHANGE TIMERS button (upper right on screen).

4.4. Graphic Display Area

The left central portion of any display is used to graphically portray timing signals. The horizontal axis is time. The vertical axis shows leading and trailing edges. Two numbers appear above the graphic display area. The leftmost number is the time from the hardware reference point (which may or may not appear on the screen) to the left edge of the display area. The rightmost number is the time per division (tick mark) of the horizontal axis. The leading and trailing edges of a signal will be connected by a dim or bright horizontal line. A dim connection indicates that the signal trailing edge is referenced to an edge of some other signal. A bright connection indicates that a trailing edge is referenced to its own leading edge. The symbols "<" or ">" at the left or right edge of a display indicate that a signal edge cannot be displayed on the currently selected display "window" and points in the direction that the edge is off the screen.

4.5. Control Buttons

CHANGE TIMERS (upper right corner) is the only control button that has any direct effect on changing the hardware timers. Any changes made on the display screen are imaginary until you push CHANGE TIMERS. At that time, whatever changes you have made are processed and sent to the hardware timers. CHANGE TIMERS, when pushed, will light up into a split button labeled REALLY and NO CHANGE. Touching REALLY will change the hardware timers, "NO CHANGE" allows you to take back your request.

CANCEL (lower right corner of screen) resets all of the delay times back to whatever they were at the last time CHANGE TIMERS/ REALLY was pushed.

EXPAND DISPLAY and SHRINK DISPLAY are alternate action push buttons. Touching either button will light it up and enable the expanding or shrinking function. To actually change the display, touch the point in the graphic display area you want to expand/shrink around. The display will be redrawn with the area you have touched centered in the graphic display area. Repetitive touches will continue expansion/shrinkage in a 1, 2, 5 sequence like an oscilloscope time base. These two buttons are alternate action so the expansion/ shrinkage function can be turned off (otherwise inadvertent touching of the screen will cause more expansion/shrinkage).

In addition to adjusting the time base of the graphic display area, expansion/shrinkage also changes the "gain" of the LEADING EDGE and TRAILING EDGE control knobs. Rotation of these knobs is always interpreted as a percentage of the full scale time being displayed.

For example, on the OPERATIONS display (Fig. 2) RECYCLE (shot repetition time) is normally set to about 90 seconds. The normal full scale time base of this display is 10 divisions times 100m(S) per division or 1 sec. If you select RECYCLE to adjust, you will have to spin the TRAILING EDGE control knob a lot to get RECYCLE to change very much. To get the proper "gain" between the TRAILING EDGE KNOB and RECYCLE, you need to get the edges of RECYCLE visible in the graphic display area. To do this, turn on the DISPLAY function and repeatedly touch the screen on the right edge of the graphic display area until the trailing edge of RECYCLE becomes visible. Now spin the TRAILING EDGE control knob and you will see a much higher "gain" between the control

knob and the delay time. A general rule is: to have finer resolution of a time delay--expand the display; for coarser resolution--shrink the display.

EXIT makes the timing display go away and returns you to the main menu. You may EXIT at any time; it is not necessary to restore the display to any particular condition before you EXIT.

4.6. Other Display Information

In the upper left hand corner of each display is a running real time calendar clock. Directly below the clock is the last shot number and the time at which it occurred.

5. Timing Display Descriptions

The following sections give a detailed description of each of the NBSTF timing displays.

5.1. Operations Display

BEAMRQST — Trailing edge is adjustable to vary the requested beam on time.

Leading edge reference = trailing edge of BEAMDEL. Trailing edge reference = leading edge of BEAMRQST.

BEAMDEL — Trailing edge is adjustable to vary the delay from the arc notch to the application of accel voltage.

Leading edge reference = trailing edge of AME. Trailing edge reference = leading edge of FASTSCOPE.

INT — Trailing edge adjustable to increase the interrupt duration time. This timer is slaved to a non-adjustable timer named INT.MIN. To see what INT.MIN is set to, look at the INTERRUPT display. The actual interrupt duration will be

the sum of INT.MIN and whatever you have dialed into the trailing edge delay of INT.

Leading edge reference = FAULT (from Fault Detector). Trailing edge reference = trailing edge of INT.MIN.

RECYCLE — Trailing edge adjustable to allow control of the machine repitition rate in the AUTO firing mode. This timer is interlocked with the manual timing systems rep rate lockout EAGLE timer, so the machine recycle time will be the longer of the two timers.

Leading edge reference = SHOTSTART. Trailing edge reference = leading edge of RECYCLE.

5.2. Fil & Arc Display

FIL — Leading edge adjustable to allow delaying the whole shot sequence from SHOTSTART. Trailing edge control is automatic. This signal is the command to turn the filament power supply on and off.

Leading edge reference = SHOTSTART. Trailing edge reference = trailing edge of ARC.HANG.

FIL.MIN — Non-adjustable imaginary timer that is used to set a lower limit on the amount of filament warm up time.

Leading edge reference = leading edge of FIL. Trailing edge reference = leading edge of FIL.MIN.

FIL.WARM — Trailing edge adjustable to allow you to increase the amount of filament warm up time. The sum of FIL.MIN and FIL.WARM will be the time from first turning on the filament power supply until the first extraction of beam.

Leading edge reference = trailing edge of FIL.MIN. Trailing edge reference = leading edge of FIL.WARM.

GAS — Nonadjustable timer that controls the gas valve. Automatically adjusted.

Leading edge reference = leading edge of GASVALV.DL. Trailing edge reference = trailing edge of ARC.HANG.

GASVALV.DL — Nonadjustable imaginary timer that delays the command to the arc power supply to allow the gas valve to operate.

Leading edge reference = trailing edge of GASVALV.DL Trailing edge reference = leading edge of ARC.

ARC — Leading edge adjustable to allow you to increase the time the arc is on before first beam extraction. The total time the arc will be on before first beam will be the sum of ARC.WARM and whatever you have set in ARC.

Leading edge reference = leading edge of ARC.WARM. Trailing edge reference = trailing edge of BEAMROST.

ARC.MIN — Nonadjustable imaginary timer used to enforce a minimum amount of warm up time for the arc.

Leading edge reference = trailing edge of ARC.MIN. Trailing edge reference = trailing edge of FIL.WARM.

BEAMRQST — Trailing edge adjustable to vary the request beam on time. Fiddle this timer and you will see FIL, GAS, and ARC follow it around.

Leading edge reference = trailing edge of BEAM-DEL. Trailing edge reference = leading edge of BEAMRQST.

ARC.HANG — Nonadjustable imaginary timer used to keep the filament and gas on for the arc power supply contactor drop out time.

Leading edge reference = trailing edge of ARC. Trailing edge reference = leading edge of ARC.HANG.

ARCSCOPE Leading edge adjustable to vary the delay from the request to turn on the arc power supply to the ARCSCOPE trigger.

Leading edge reference = leading edge of ARC. Trailing edge reference = leading edge of ARC-SCOPE.

5.3. Accel Display

ACLPERM Nonadjustable timer. This signal is required to bracket any request to turn on the accel power supply

Leading edge reference = leading edge of ACLPRI.1. Trailing edge reference = trailing edge of ACLHANG.

ACLPRI.MIN Nonadjustable imaginary timer used to enforce the minimum on command required of the accel power supply contactor system.

Leading edge reference = trailing edge of ACLPRI.MIN. Trailing edge reference = trailing edge of AME.

ACLPRI.1 Leading edge adjustable to allow you to turn the accel power supply on earlier, relative to the time of first beam extraction. ACLPRI.1 and ACLPRI.2 are or'ed together to form the on command to the accel power supply

Leading edge reference = leading edge of ACLPRI.MIN. Trailing edge reference = trailing edge of ACLPRI.MIN.

ACLPRI.2 Trailing edge adjustable to allow additional accel power supply ontime after the end of beam. ACLPRI.2 is or'ed with ACLPRI.1 to form the on command to the accel power supply. You will notice that when BEAMRQST is less than 50mS ACLPRI.2 is displayed as a vertical line with a left going hook on the top. This indicates that ACLPRI.2 is negative. No real timer can be negative so ACLPRI.2 will be set to zero in this case. The significance of all this is

that the accel power supply contactor system provides a minimum of 50mS of useable accel power regardless of how the power supply is commanded. When BEAMRQST is increased past 50mS, ACLPRI.2 will become positive and automatically add additional command time to the power supply.

Leading edge reference = trailing edge of ACLPRI.1. Trailing edge reference = leading edge of ACLHANG.

ACLHANG — Nonadjustable imaginary timer used to account for the contactor drop out time of the accel power supply. The accel power supply is commanded off this much time before the end of beam.

Leading edge reference = trailing edge of ACLHANG. Trailing edge reference = trailing edge of BEAMRQST.

BEAMRQST — Trailing edge adjustable to allow you to vary the request beam on time. Fiddle with this and note how ACLPRI.2 automatically follows.

Leading edge reference = trailing edge of BEAMDEL. Trailing edge reference= leading edge of BEAMRQST.

SLOWSCOPE — Leading edge adjustable to allow you to vary the delay from on command to the accel power supply and the SLOWSCOPE trigger.

Leading edge reference = leading edge of ACLPRI.1 Trailing edge reference = leading edge of SLOWSCOPE.

5.4. Interrupt Display

INT — Trailing edge adjustable to allow you to increase the interrupt duration time. Actual interrupt duration will be the sum of INT.MIN and whatever you have set INT to.

Leading edge reference = FAULT (from Fault

Detector). Trailing edge reference = leading edge OF INT.MIN.

INT.MIN — Nonadjustable imaginary timer used to enforce a minimum interrupt duration time

Leading edge reference = leading edge of INT. Trailing edge reference = leading edge of INT.MIN.

AME1 — Nonadjustable timer that provides the Arc Modulator Enable signal. Trailing edge of AME1 signals the arc modulator to begin the arc notch.

Leading edge reference = leading edge of INT. Trailing edge reference = leading edge of DIVERT

5.5. Data Acquisition Display

RDREF — Read References. This signal interrupts the computer so it will read the preshot thermocouple temperatures.

Leading edge reference = SHOTSTART. Trailing edge reference = leading edge of RDREF.

SDIG — Stop trigger to the 32 channel slow waveform digitizer. The digitizer will trap the waveforms for 1 second following the trigger.

Leading edge reference = leading edge of ARC. Trailing edge reference = leading edge of SDIG.

RDDIG — Read Digitizer. This signal interrupts the computer so it will read in the waveforms trapped by the slow digitizer.

Leading edge reference = trailing edge of BEAMOFF2. Trailing edge reference = leading edge of RDDIG.

OMATRIGGER — Stop trigger to the OMA.TRIGGER will trap data following this trigger.

Leading edge reference = leading edge of ARC. Trailing edge reference = leading edge of OMA-TRIGGER.

RDCAL — Read Calorimetry. Interrupts the computer so that post shot thermocouple temperature data can be taken.

Leading edge reference = trailing edge of BEAMOFF2. Trailing edge reference = leading edge of RDCAL.

5.6. Misc.1 Display

PREWATEROFF — Shuts off the water to the calorimeter from the beginning of the shot until a few seconds after the shot. It is or'ed with POSTWATEROFF to keep calorimeter cooling water off until temperatures have been acquired.

Leading edge reference = SHOTSTART. Trailing edge reference = leading edge of PREWATEROFF.

RESETFD — Resets the fault detector system just before each shot.

Leading edge reference = leading edge of FIL. Trailing edge reference = leading edge of ACLPERM.

AME — Signal to the arc modulator to have it go into full series mode. Warms up the arc chamber. The arc modulator times its notch and recovery from the trailing edge of AME. Or'ed with AME1.

Leading edge reference = leading edge of ARC. Trailing edge reference = trailing edge of FIL.WARM.

LASTOFF — Signal that fires the commutating crowbar at the end of BEAMRQST.

Leading edge reference = trailing edge of BEAMRQST. Trailing edge reference = leading edge of LASTOFF.

DTREAD Signal to the Delta T system to read the energy for the current shot.

Leading edge reference = trailing edge of RECYCLE. Trailing edge reference = leading edge of DTREAD.

DTSTART Signal to the Delta T system to start a new shot.

Leading edge reference = trailing edge of BEAMOFF2. Trailing edge reference = leading edge of DTSTART.

POSTWATEROFF Keeps the calorimeter cooling water off until the calorimeter temperatures have been read by the computer.

Leading edge reference = leading edge of BEAMOFF2. Trailing edge reference = leading edge of RDCAL.

5.7. Misc.2 Display

ABORT Signal that interrupts the computer whenever the operator pushes the ABORT or CRASHOFF buttons.

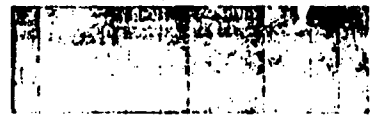
Leading edge reference = ABORT or CRASHOFF BUTTONS. Trailing edge reference = leading edge of ABORT.

GO Signal that interrupts the computer whenever the operator pushed the FIRE button (or when the AUTO mode does it for him).

Leading edge reference = FIRE. Trailing edge reference = leading edge of GO.

PSEUDO.INT Leading edge reference = SCR.TRIG. Trailing edge reference = leading edge of PSEUDO.INT.

SHOT 65931 OPERATIONS TIMING 02/30/81 11:32



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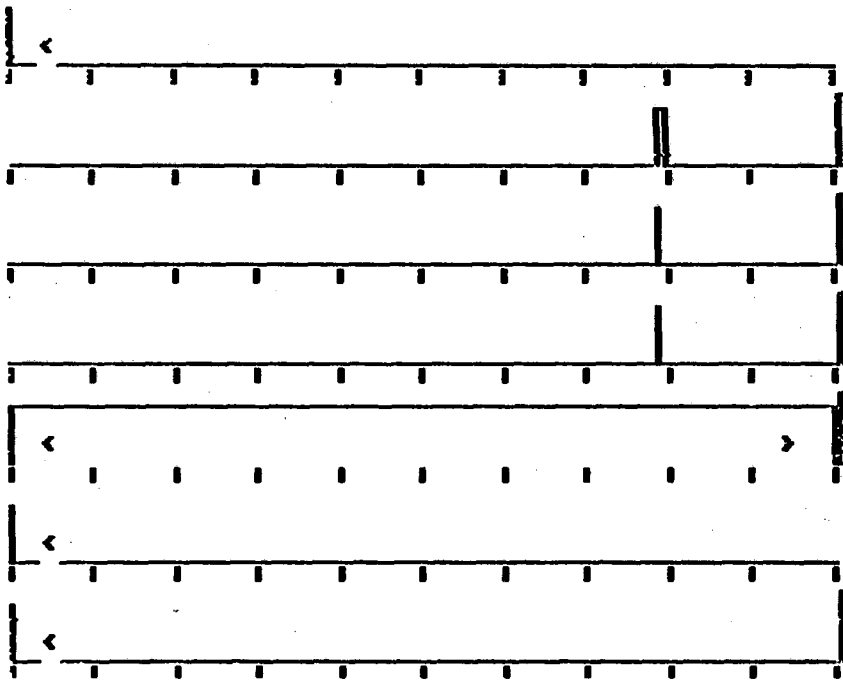

SHOTSTART		
0s	10.0as	BEAMRAST
0s	200us	BEAMDEL
190us	100us	FASTSCOPE
50.0ms	15.1s	RECYCLE
FAULT		
0s	10.0as	INT

EXIT	DEFAULT DISPLAY	EXPAND DISPLAY	SHRINK DISPLAY	CANCEL

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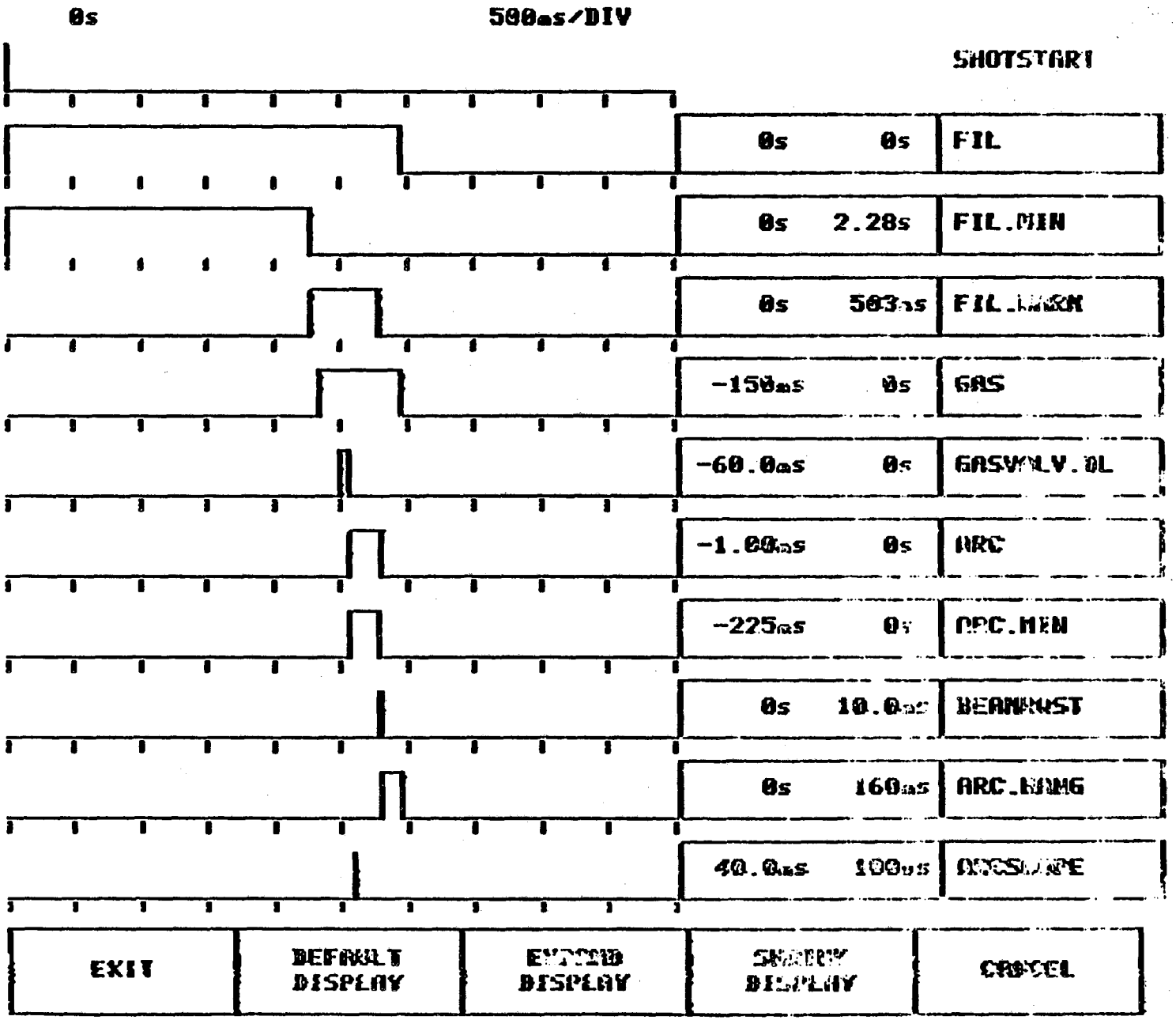

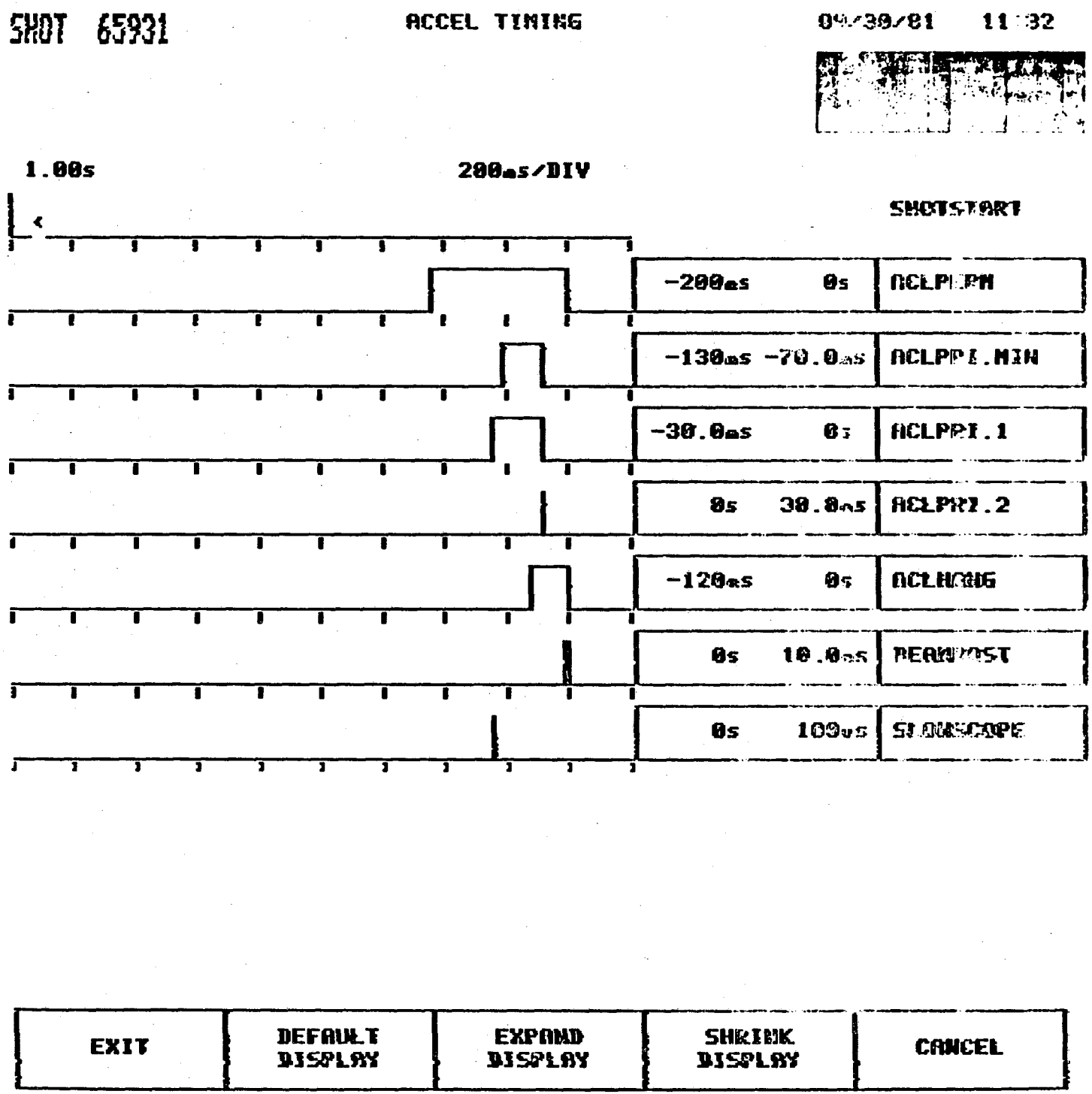
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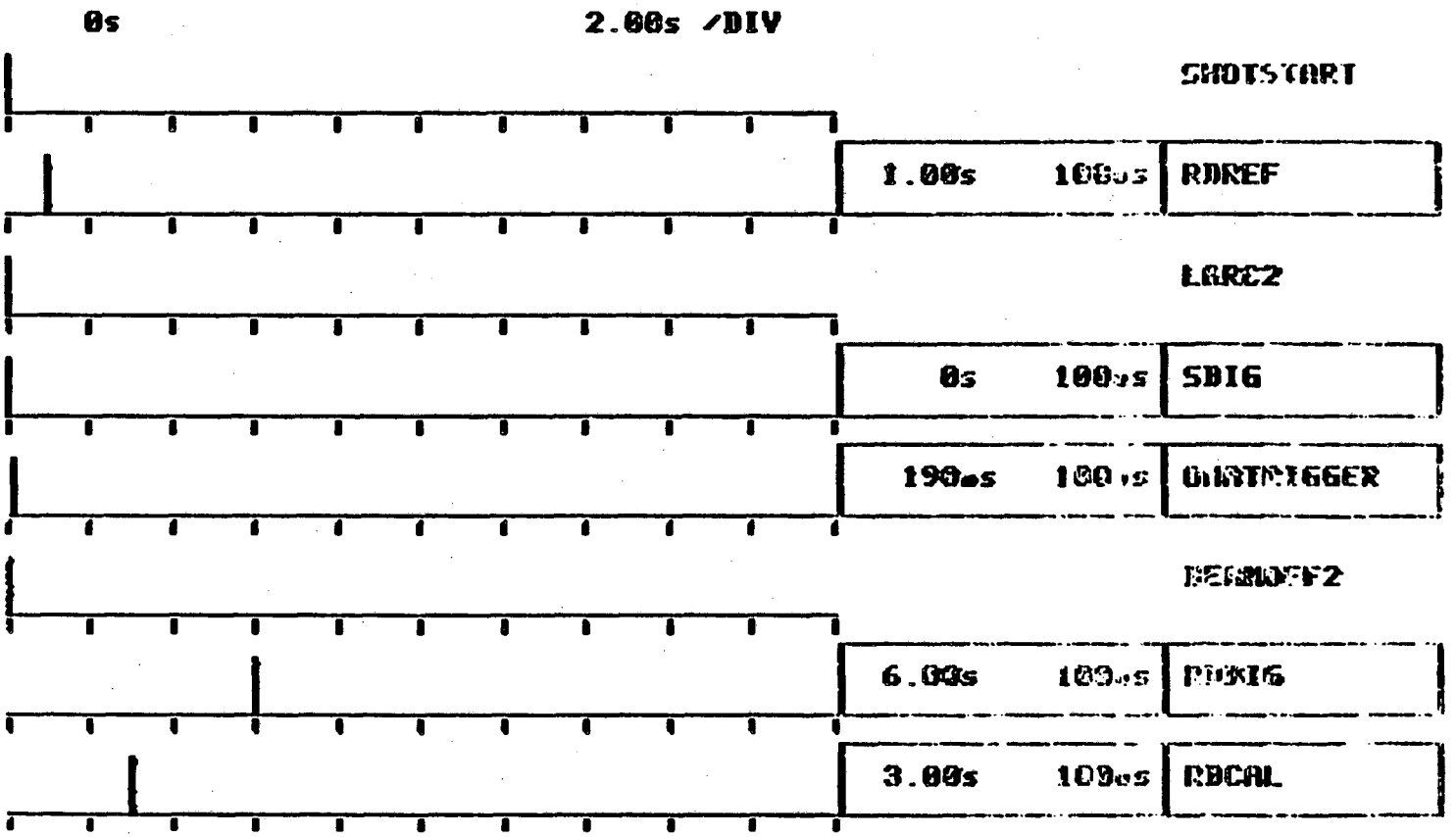
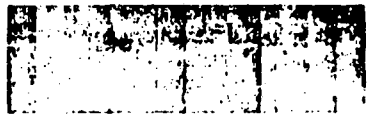
SHOTSTART
-200ms 0s
ACLPERM
-130ms -70.0ms
ACLPRI.MIN
-30.0ms 0s
ACLPRI.1
0s 30.0ms
ACLPRI.2
-120ms 0s
ACLHANG
0s 10.0ms
BEAMPOST
0s 100us
SLOWSCOPE
EXIT
DEFAULT DISPLAY
EXPAND DISPLAY
SHRINK DISPLAY
CANCEL

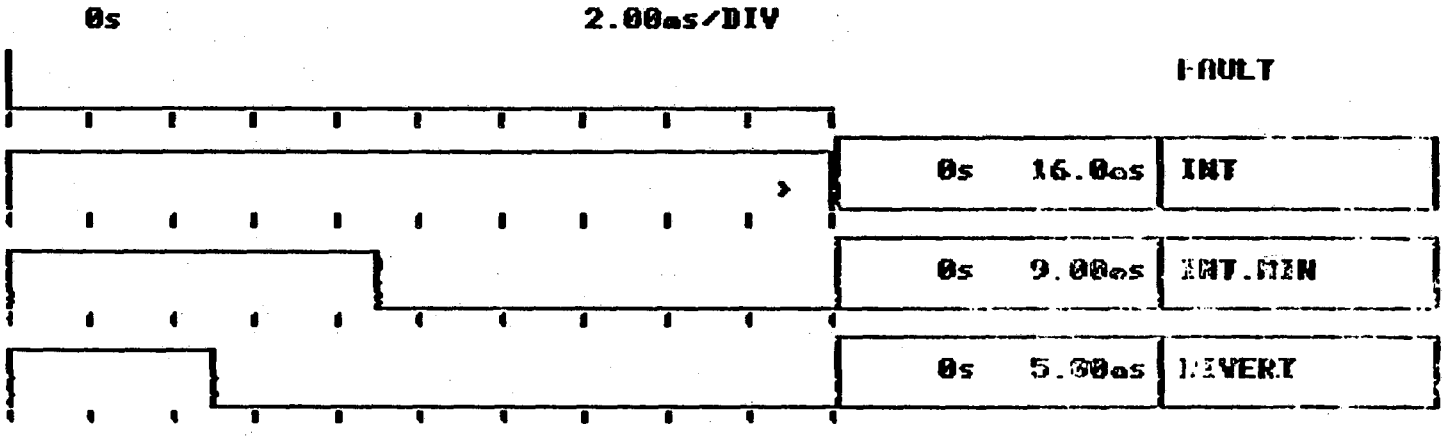
SHOT 65931 DATA ACQUISITION TIMING 09/30/81 11:32



EXIT	DEFAULT DISPLAY	EXPAND DISPLAY	SHRINK DISPLAY	CANCEL

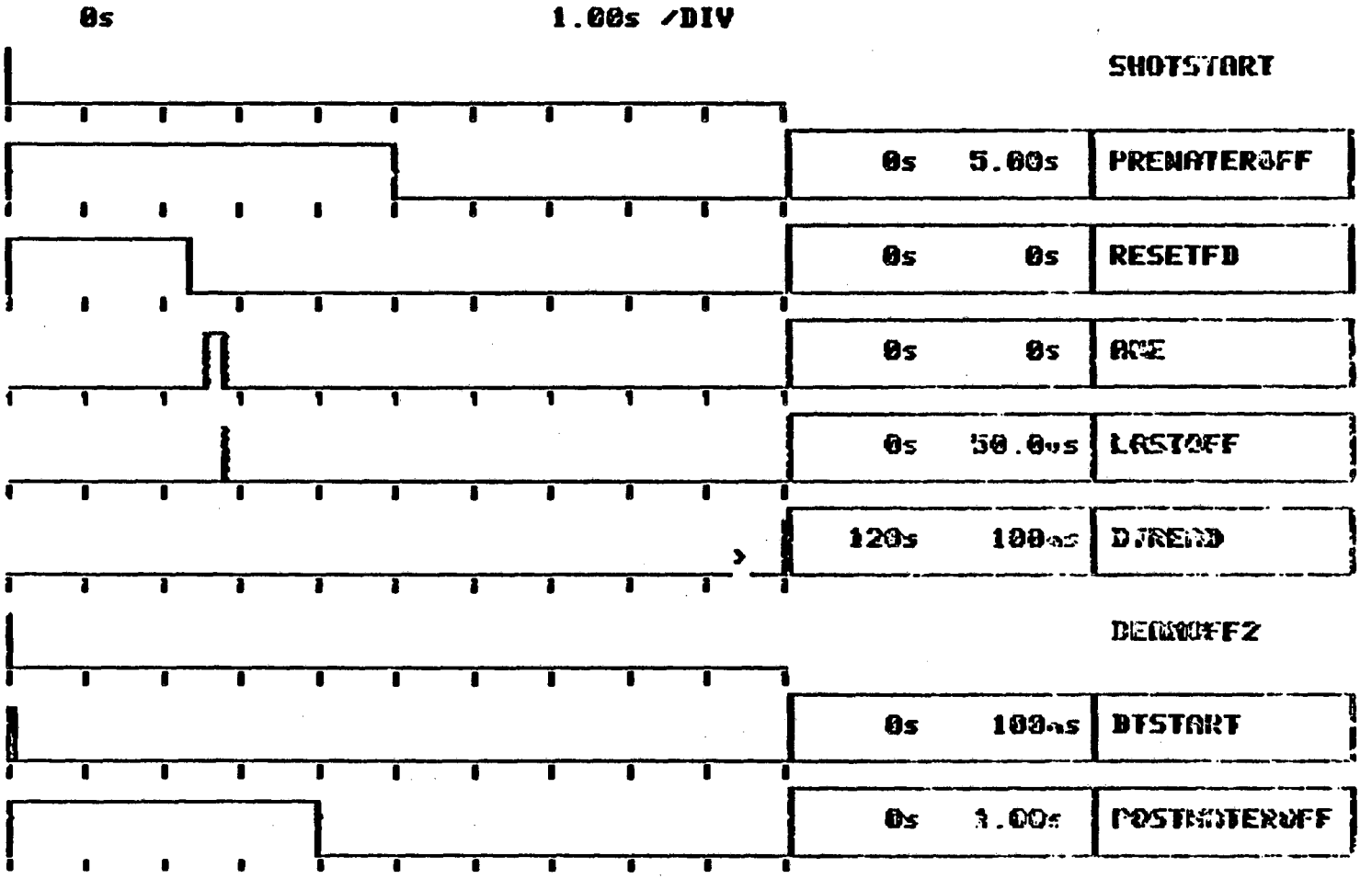
SHOT 65931 INTERRUPT TIMING 09/30/91 11:32





EXIT	DEFAULT DISPLAY	EXPAND DISPLAY	SHRINK DISPLAY	CANCEL

SHOT 65931 MISC.1 TIMING 09/30/81 11:32



EXIT	DEFAULT DISPLAY	EXPAND DISPLAY	SHRINK DISPLAY	CANCEL

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