FLOW CHART BLOCK C (FIGURE 1A) - DETERMINATION OF AVERAGE PRM INPUT

The PRM input is a normalized variable that is always between zero and unity (see Figures 1 and 2). The process of obtaining an average value of this variable over any interval - say t_1 to t_2 - is summarized below.

Assume the filter output varies linearly from t_1 to t_2. Therefore, when a signal starts from $|y(t_1)|$, the curve varies linearly from $|y(t_1)|$ to $|y(t_2)|$ when $y(t_1)$ and $y(t_2)$ have the same sign, and varies linearly from $|y(t_1)|$ to $-|y(t_2)|$ when they are of opposite sign. Define

$$x_1 = \frac{|y(t_1)| - DZ}{SAT - DZ}$$ and

$$x_2 = \frac{|y(t_2)| - DZ}{SAT - DZ}$$ when $y(t_1)$ and $y(t_2)$ have the same sign, or

$$x_2 = \frac{-|y(t_2)| - DZ}{SAT - DZ}$$ when $y(t_1)$ and $y(t_2)$ have the opposite sign

and define

x_3 = the larger of the two (x_1 or x_2) and

x_4 = the smaller of the two.

Six possible cases now arise:

1. $x_3 > 1.$ and $x_4 > 1.$
2. $x_3 < 0.$ and $x_4 < 0.$
3. $0. < x_3 < 1.$ and $0. < x_4 < 1.$
4. $x_4 < 0.$ and $0. < x_3 < 1.$
5. $x_3 > 1.$ and $0. < x_4 < 1.$
6. $x_3 > 1.$ and $x_4 < 0.$

In the first case the average PRM input (x_{PRM}) is equal to 1. In the second $x_{PRM} = 0.$ and in the third the average is simply $(x_3 + x_4)/2.$ In the fourth

$$x_{PRM} = \frac{x_3^2}{2. * (x_3 - x_4)}$$

In the fifth

$$x_{PRM} = \frac{2. * x_3 - x_4^2 - 1.}{2. * (x_3 - x_4)}$$

and in the sixth

$$x_{PRM} = \frac{2. * x_3 - 1.}{2. * (x_3 - x_4)}$$

As can be seen, x_{PRM} is independent of t_1 and t_2 and depends only on $y(t_1)$ and $y(t_2)$. In the flow chart (Figure 1A) three sets of filter outputs are used: $y(T_o)$ and $y(T)$, $y(T_{off})$ and $y(T_{off} + T_1)$, and $y(T_{on})$ and $y(T_{on} + T_2)$.

FLOW CHART BLOCK D (FIGURE 1A) - INTEGRAL FULFILLMENT TIMES

The fact that the PRM integrals (Figure 2) are rarely fulfilled at exact multiples of ΔT necessitates interpolation for a more exact determination of the fulfillment times. Methods of determinating off- and on-time integral completion times are outlined in Figures 3A and 4A, respectively. Straight-line interpolation between filter output values is assumed for every interval under consideration.

FLOW CHART BLOCK E (FIGURE 1A) - EQUATIONS OF MOTION

$$\theta(T) = \theta(T_o) + \{\dot{\theta}(T_o)\} * \Delta\tau + (\ddot{\theta}/2) * (\Delta\tau)^2$$

$$\dot{\theta}(T) = \dot{\theta}(T_o) + \ddot{\theta} * (\Delta\tau)$$

Refer to Section B for an explanation of using $\Delta\tau$ as the integration interval from T_o to T. ($\ddot{\theta}$ remains constant during $\Delta\tau$.)

FLOW CHART BLOCK F (FIGURE 1A) - GIMBAL TRIM SYSTEM

To simplify calculations, the angular acceleration caused by the GTS (Figure 1) is assumed to be constant during each iteration interval and is determined by the value of the GTS output at the beginning of each interval. No interpolation is used to find the exact times at which the RCS filter output reaches GDZ. The equations used in the GTS simulation are given in Figure 5A.

FLOW CHART BLOCK G (FIGURE 1A) - PROPELLANT CONSUMPTION

The equations used in computing propellant consumption are listed below:

PRM electrical on time = time taken to complete on-time integral = $T_{on} - T_k = T_T$

Specific Impulse during thrusting period = I_{sp}

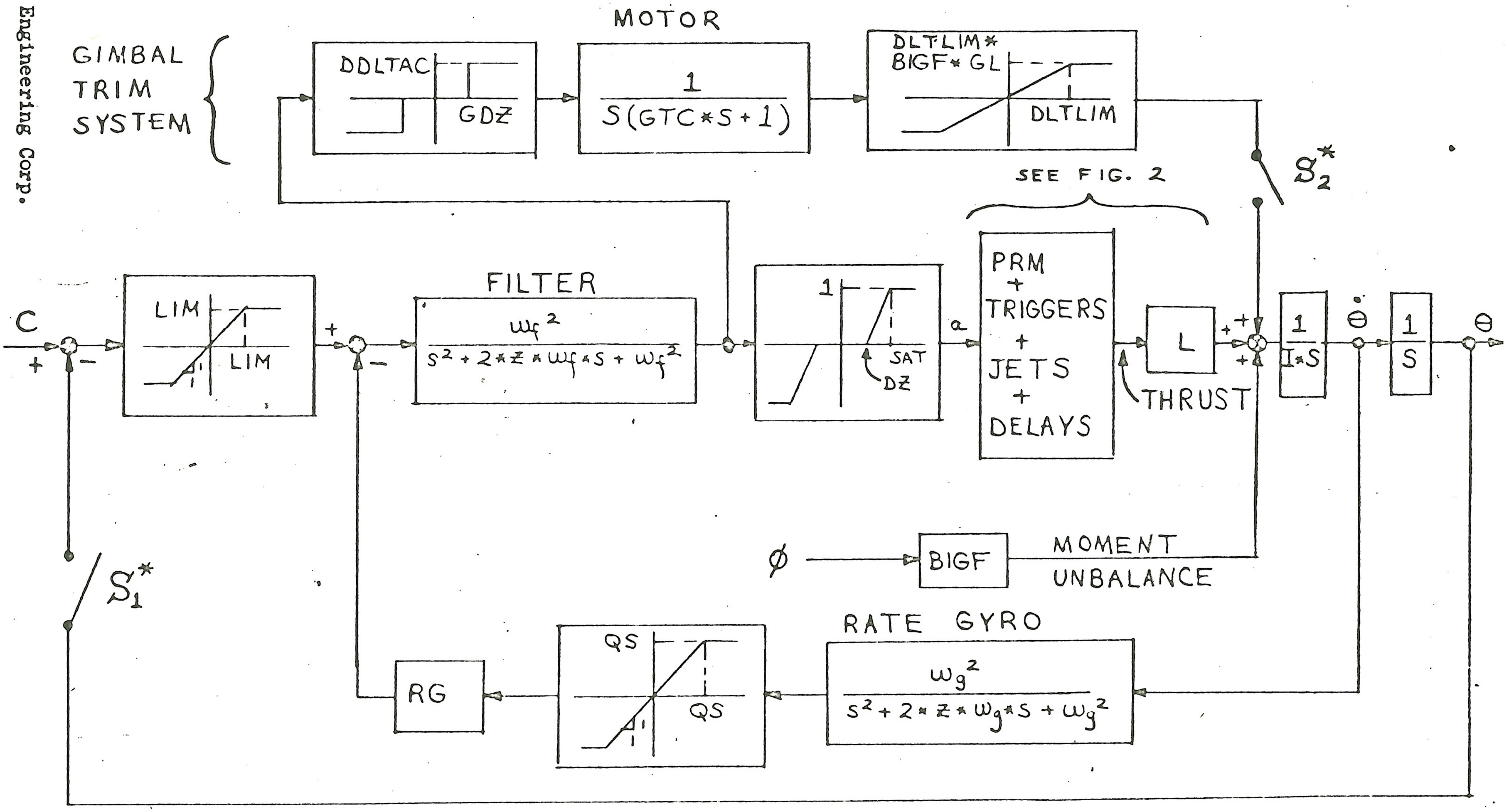
$$= 270. * (1. - e^{-T_T/0.024})$$

$$\Delta F = F * (T_T + T_2 - T_1)/I_{sp}$$

SD/jle

FIGURE O

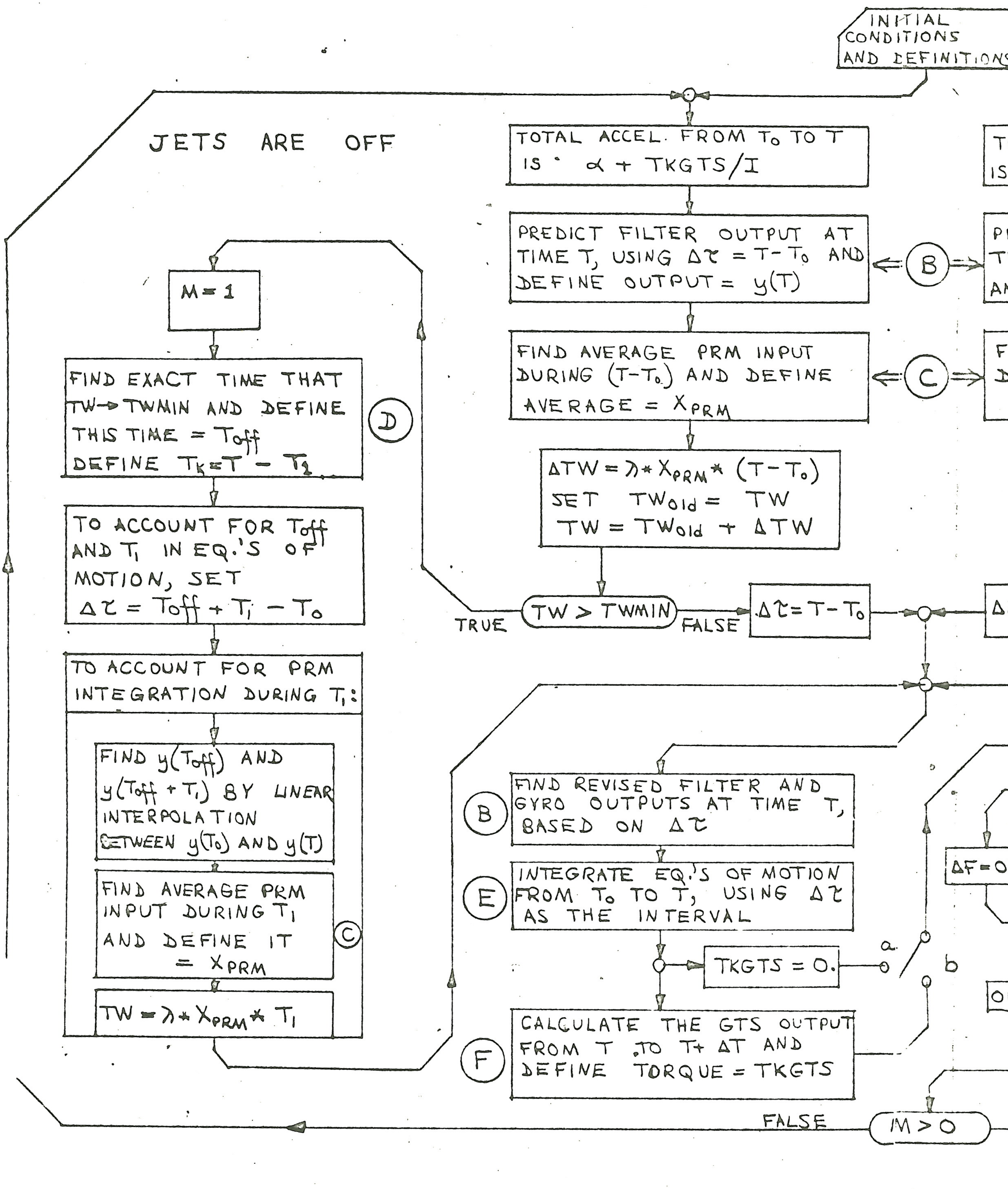
SINGLE AXIS ATTITUDE CONTROL SYSTEM



* S_1 IS CLOSED FOR ATTITUDE HOLD MODE AND IS OPEN FOR RATE COMMAND MODE
S_2 IS CLOSED FOR POWERED DESCENT AND IS OPEN AT ALL OTHER TIMES

FIGURE 1A

FLOW CHART FOR CONTROL S



IGURE 1A

NTROL SYSTEM SIMULATION

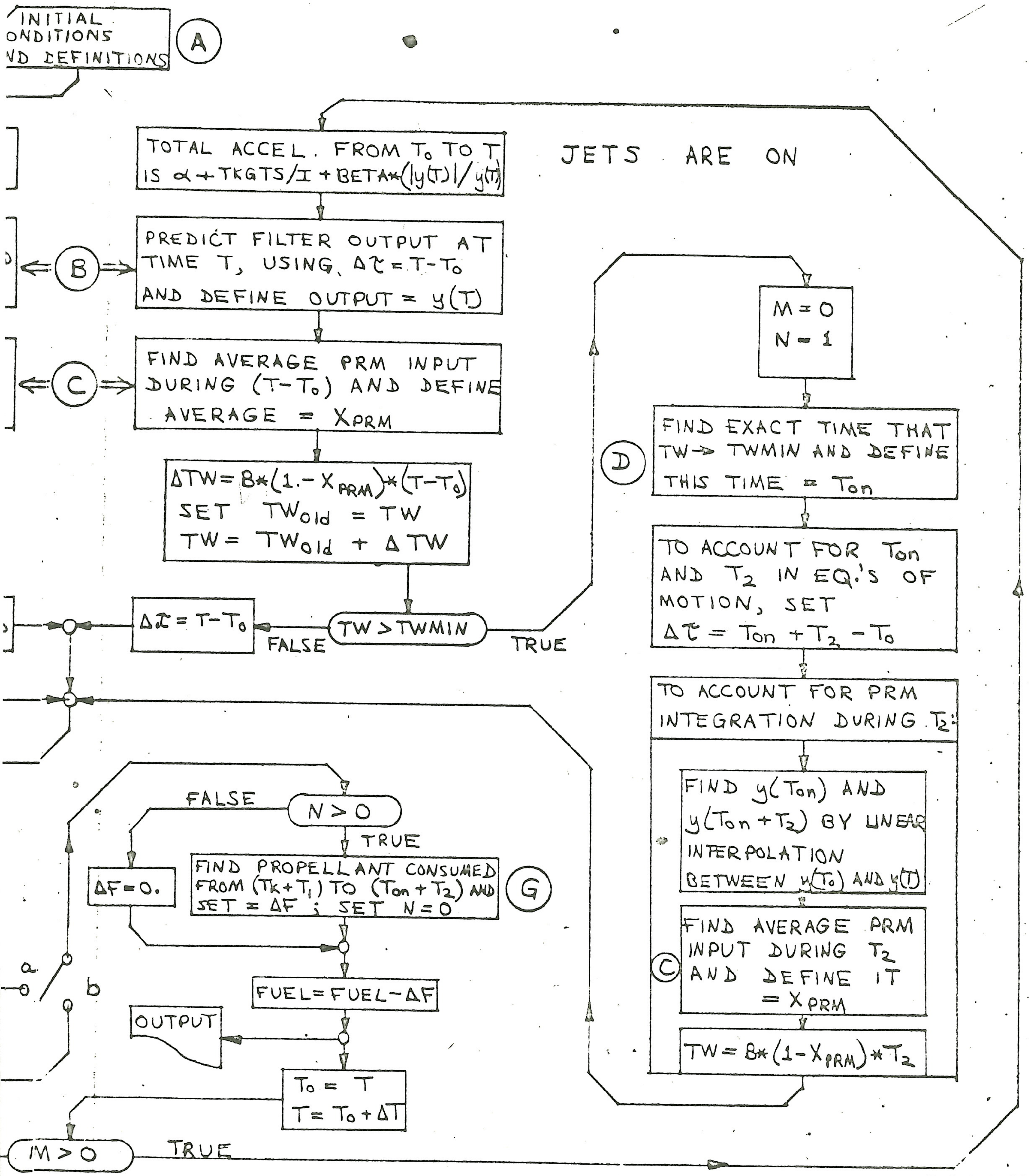
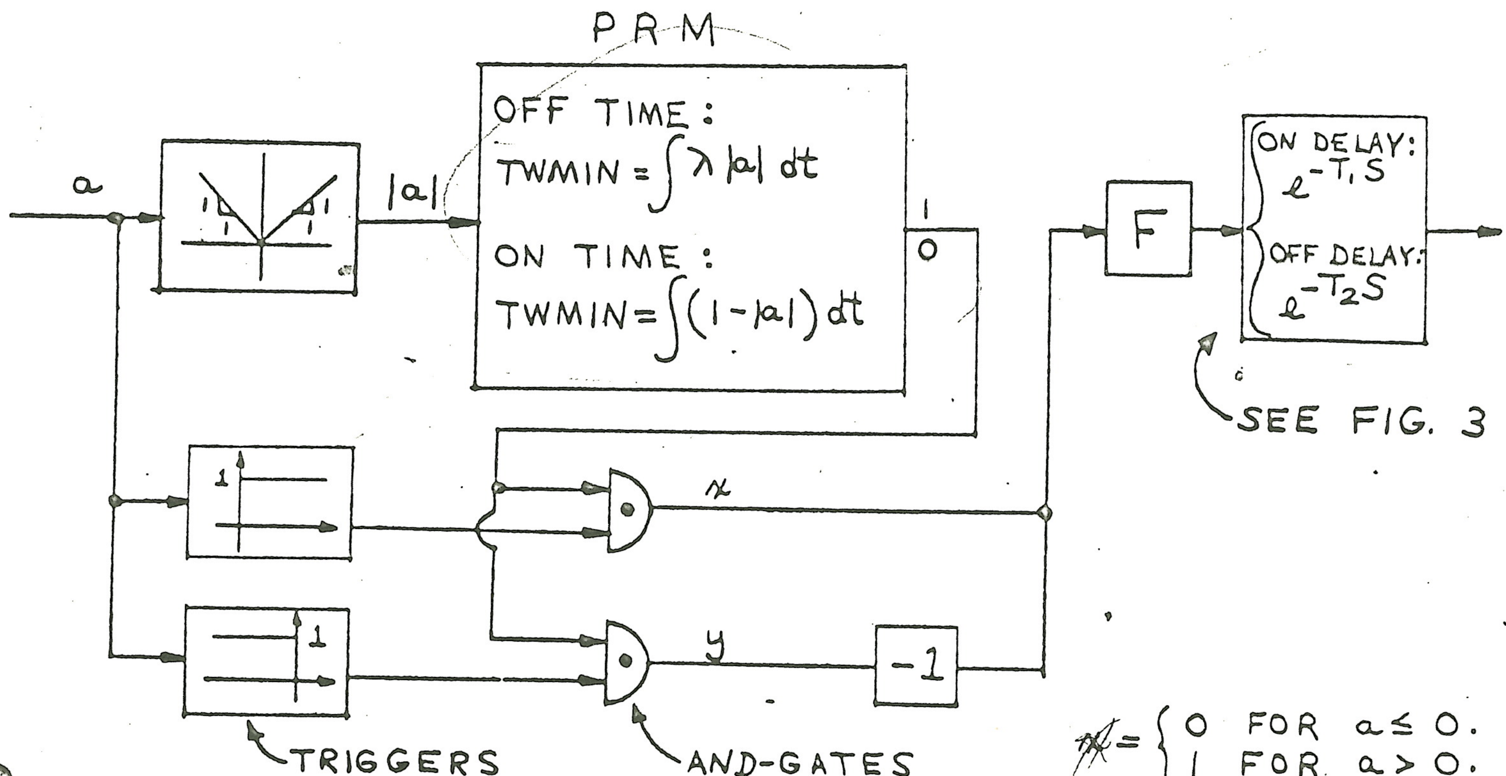


FIGURE 2

DETAIL FROM FIG. 1



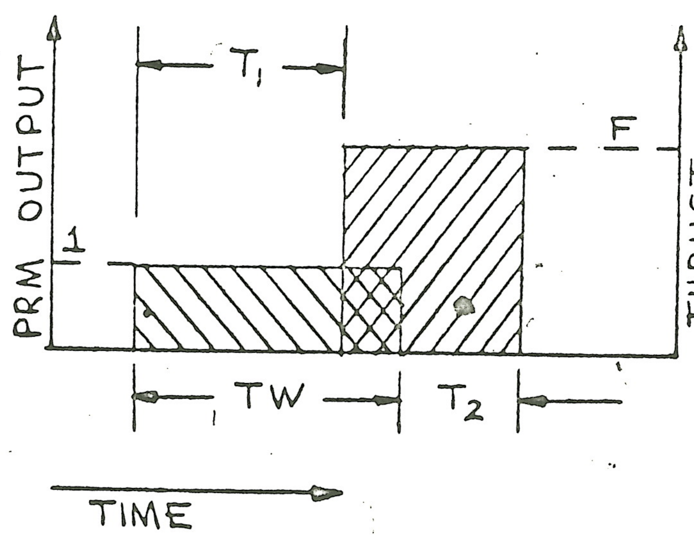
$$x = \begin{cases} 0 & \text{FOR } a \leq 0. \\ 1 & \text{FOR } a > 0. \end{cases}$$

$$y = \begin{cases} 1 & \text{FOR } a < 0. \\ 0 & \text{FOR } a \geq 0. \end{cases}$$

FIGURE 3

PRM OUTPUT - THRUST RELATIONSHIP

$(a > 0.)$



$$T_2 = T_1 - 0.004$$

FIGURE 2A

PRM ON-TIME INTEGRATION FACTOR AS A FUNCTION OF MOMENT-UNBALANCE CAUSED ACCELERATION

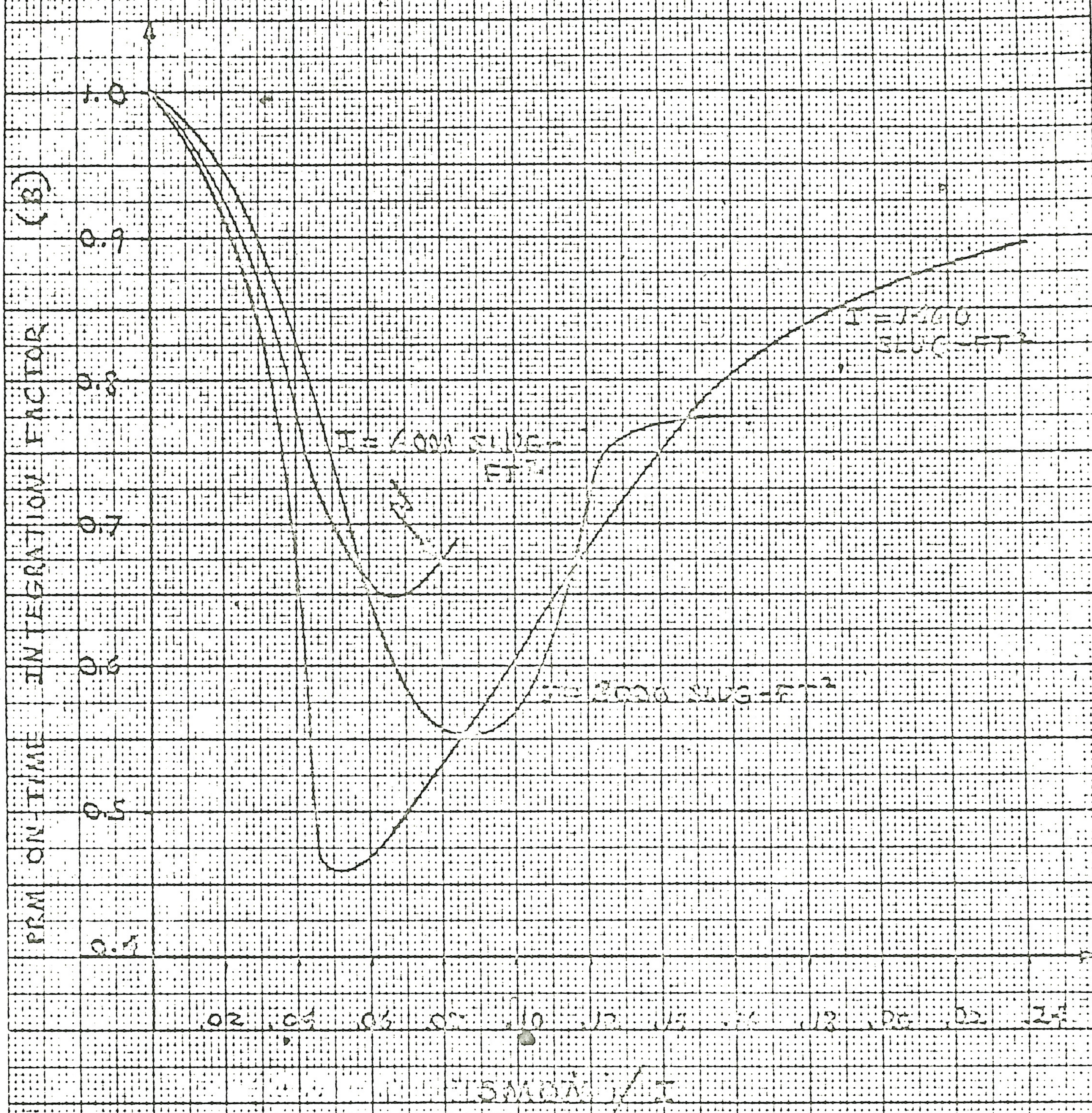


FIGURE 3A

DETERMINATION OF OFF-TIME INTEGRAL COMPLETION TIME

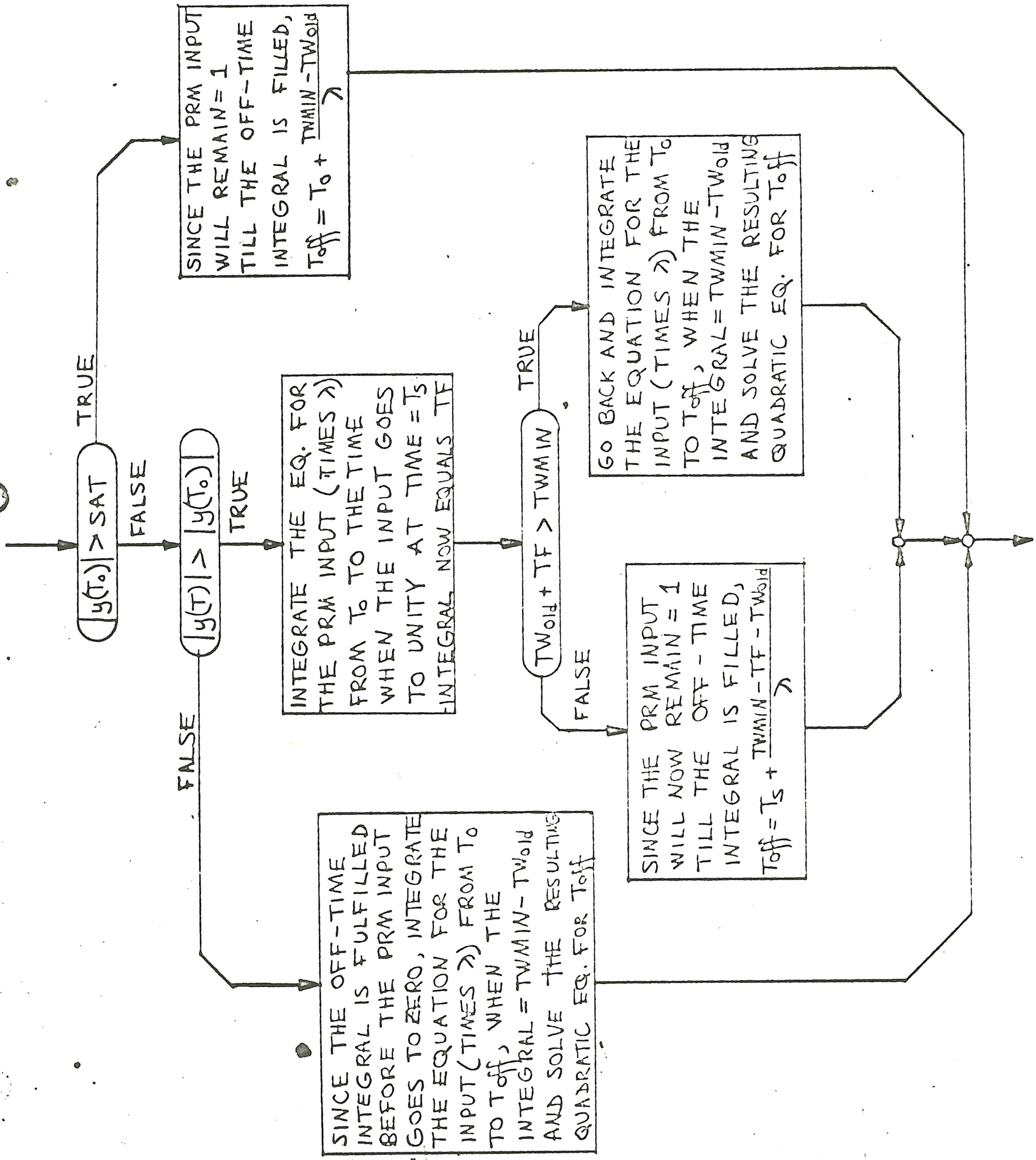


FIGURE 4A

DETERMINATION OF ON-TIME INTEGRAL COMPLETION TIME

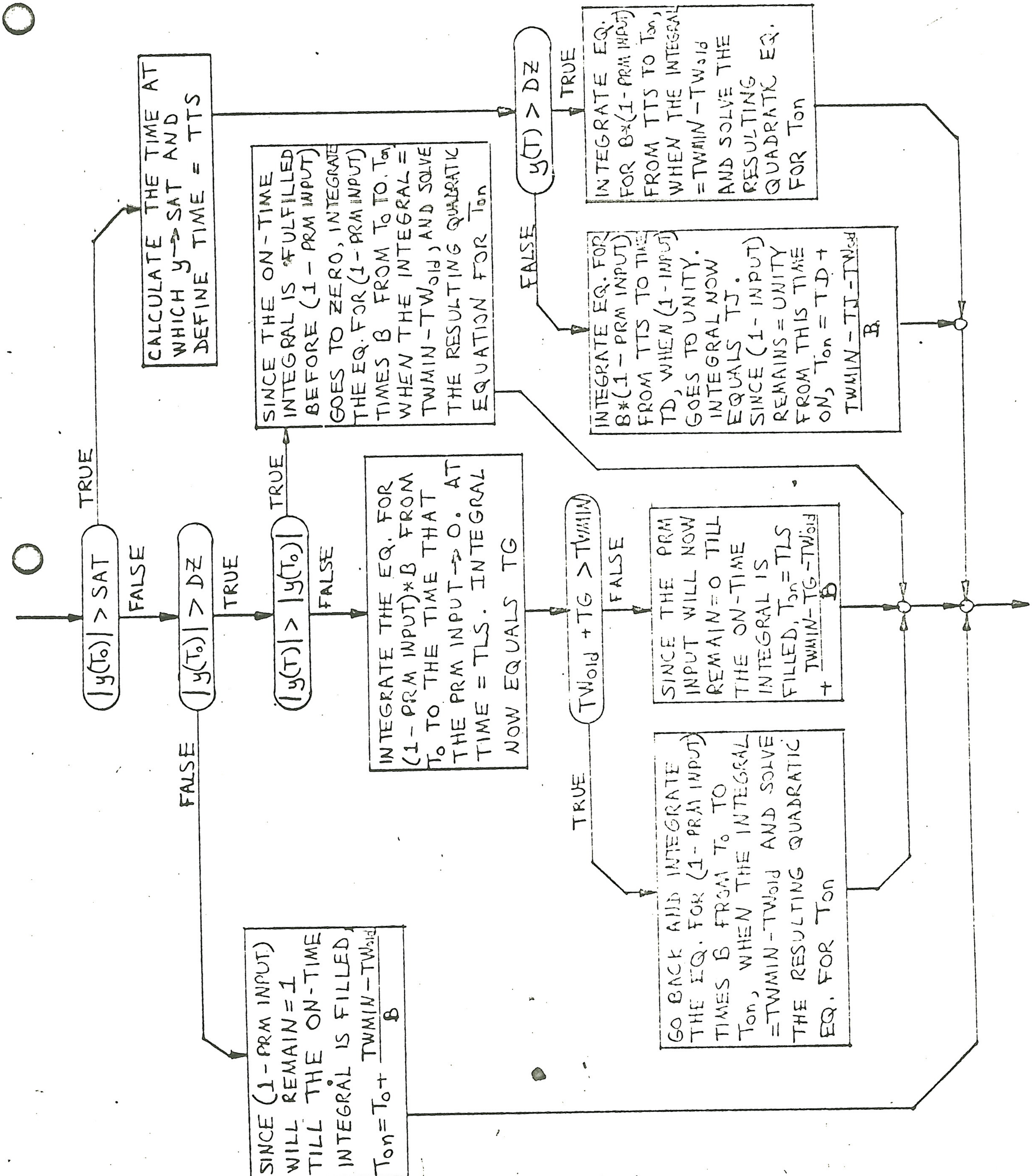
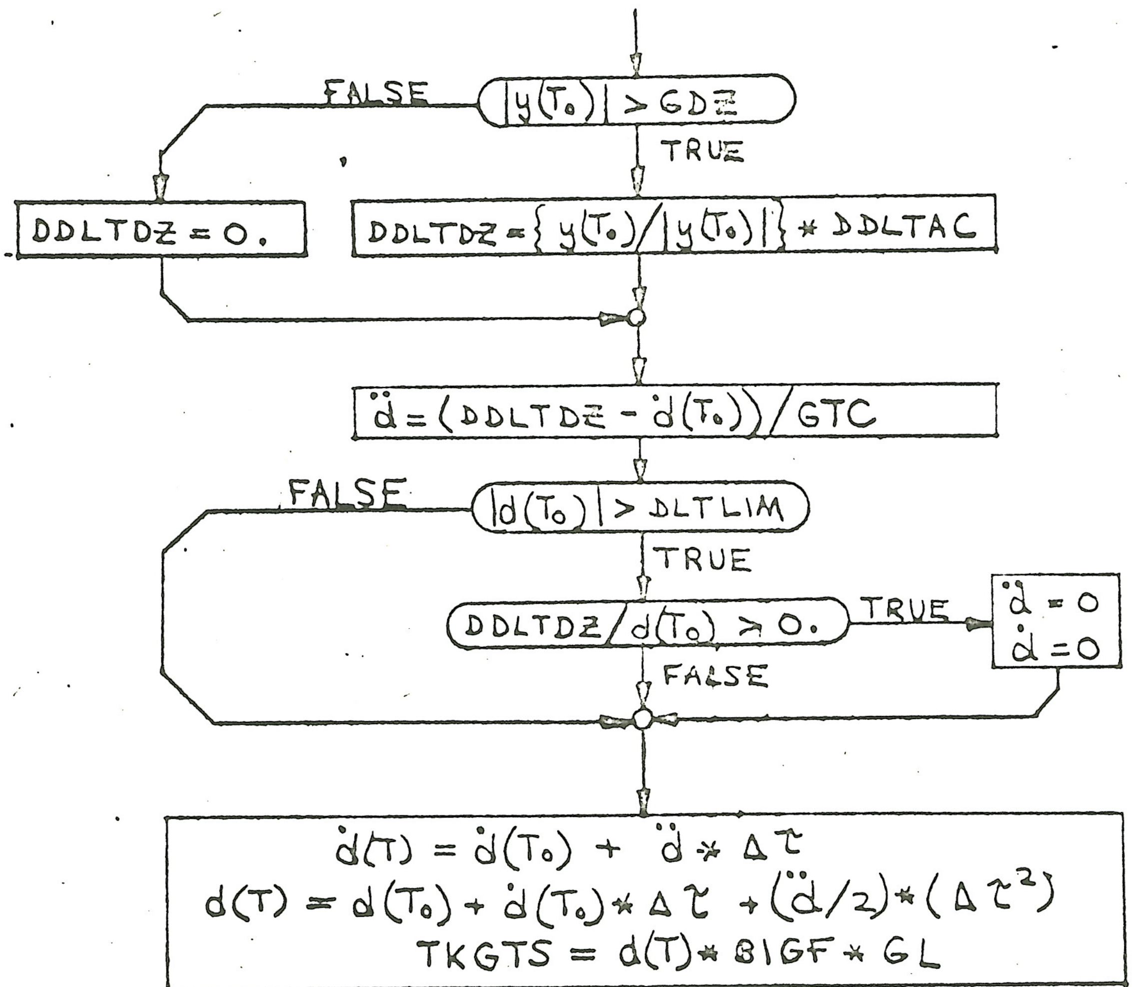


FIGURE 5A

GIMBAL TRIM SYSTEM SIMULATION

DEFINE:

DDLTDZ = GTS MOTOR INPUT AT TIME = T_0.
$d(t)$ = GTS MOTOR OUTPUT AT TIME = t
$\dot{d}(t)$ = DERIVATIVE OF MOTOR OUTPUT AT TIME = t
$\ddot{d}$ = SECOND DERIVATIVE OF MOTOR OUTPUT FROM T_0 TO T
TKGTS = GTS OUTPUT TORQUE FROM T TO $T+\Delta T$



SEE SECTION 8 FOR EXPLANATION OF USE OF $\Delta\tau$