
# MUĞLA SITKI KOÇMAN UNIVERSITY
# ELECTRICAL & ELECTRONICS ENGINEERING

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## Programmable Logic Controllers Report

## Rocket Test Stand Sequence Logic

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Platform: PLCnext Engineer

Language: Structured Text (IEC 61131-3)

## Contents

## System Overview

This report will explain the details of the automated control sequence designed in PLCnext for the Rocket Test Sequence. The system utilizes a deterministic state machine architecture implemented in Structured Text (ST). The logic is divided into four well defined phases to ensure the safe handling of every part of the rocket, for example the fuel, cryogenic propellants and high-pressure gases. Which are the reasons to build a safety system because one small mistake can cause a catastrophe.

This analysis focuses specifically on how On-Delay Timers (TON) manage critical durations and how Comparison Operators (GT, LT, GE, LE) function as safety gates in each specific phase thus combining it into a big flow of safety that makes sure at each step if the system is safe at each step so the flow can continue to the end to launch the rocket.

## Logic Phase Breakdown

### Phase 1: Pre-Launch Safety & Arming

Before the sequence starts, we need to arm the system which is a latch system that starts with a safety start button and can end with the safety stop or emergency stop buttons. For the continuing part of the system the logic relies heavily on comparison operators to define "Safe Operating Windows." If any value falls outside these mathematical comparisons, the Safety_OK bit remains FALSE, mechanically preventing the system from arming.

Comparator Logic (GT, LT, GE, LE)

- Wind Speed Window (GT & LT):
    1. Logic: (Wind_speed > 25.0) AND (Wind_Speed < 30.0)
    2. Function: The GT (Greater Than) and LT (Less Than) operators create a specific permissive window. The system prevents launch if the wind is too calm (risk of gas pooling) or too high (structural risk). Both conditions must be true simultaneously.
- Propellant Tank Pressures (GE & LE):
    1. Logic: Fuel: (Fuel_P >= 400.0) AND (Fuel_P <= 500.0)
    2. Oxidizer: (Ox_P >= 400.0) AND (Ox_P <= 500.0)
    3. Function: We use GE (Greater or Equal) to ensure the turbopumps have sufficient inlet head pressure (avoiding cavitation). We use LE (Less or Equal) to verify the tanks are not over-pressurized, preventing potential structural bursts before ignition. Both the Fuel and Liquid Oxygen (Ox) tanks must be within this nominal 400-500 PSI range.

- Cockpit Pressure Safety (LE):
    1. Logic: Cockpit_Pr <= 14.7
    2. Function: The LE (Less or Equal) operator monitors the avionics/cockpit environment. It ensures the internal pressure does not exceed 1 standard atmosphere (14.7 PSI), verifying that venting systems are active and the module is safe for operation.
- Nitrogen Supply (GT):
    1. Logic: Nitrogen_Supply > 2000.0
    2. Function: Uses GT to verify sufficient purge gas exists. If the supply is 1999 PSI or lower, the logic assumes there is not enough gas to safely purge the lines later, and the start is inhibited.

**Phase 2: System Purge & Stabilization**

Once armed, the system uses timers to manage the flow of inert gas.

Timer Logic (TON)

- TON1 (Nitrogen Purge Duration):
    1. Action: Keeps the N2 Purge Valve open for exactly 7.5 seconds.
    2. Specific Role: This duration is calculated to displace the internal volume of the fuel plumbing three times. It ensures that 100% of atmospheric oxygen and moisture is ejected before any fuel enters.
- TON2 (Mechanical Settle):
    1. Action: Enforces a 3.0-second "All-Valves-Closed" state immediately after the purge.
    2. Specific Role: This allows the turbulence and pressure shockwaves (water hammer) from the high-pressure nitrogen purge to dissipate, ensuring the sensors read "Static Pressure" rather than "Dynamic Pressure" before the next phase begins.

### Phase 3: Valve Sequencing & Cryogenic Warmup

This phase manages the thermal shock of introducing Liquid Oxygen (LOX).

Timer Logic (TON)

- TON3 (Chill-down / Warmup Timer):
    1. Action: Delays the Fuel Valve opening 10.0 seconds *after* the Oxidizer valve opens.
    2. Specific Role: Liquid oxygen boils immediately upon hitting warm pipes. This timer forces the system to flow LOX solely for cooling purposes. It ensures the stainless-steel manifolds reach cryogenic temperatures (-183°C) so the oxidizer remains liquid during the actual engine run.

Comparator Logic (LT)

- Thermal Interlock (LT):
    1. Logic: Manifold_Temp < -180.0
    2. Function: The LT (Less Than) operator monitors the thermocouple feedback. Even if the timer finishes, if this comparison is false (meaning the pipe is still too warm), the logic will prevent the Fuel Valve from opening to avoid cavitation.

### Phase 4: Ignition & Run State

The final phase manages the combustion event, relying on precise timing and rapid sensor comparison.

Timer Logic (TON)

- TON7 (Igniter Duty Cycle):
    1. Action: Energizes the ignition relay for exactly 1.0 second.
    2. Specific Role: Provides a precise window of spark energy. It prevents the igniter coil from overheating by cutting power automatically once the combustion window has opened.
- TON4 (Safety Watchdog):
    1. Action: Starts counting the moment the fuel valve opens.
    2. Specific Role: This defines the "Time to Auto-Abort." If the flame is not detected before this timer finishes (1.0s), the PLC assumes ignition failed and triggers a SCRAM.
    3. PSI to confirm that the fire is not just a spark but is generating thrust. If this condition is not met, the system aborts.

# ST Code of the System

Components / Main / Code

```
//phase1
System_Armed:= (Start_Button OR System_Armed) AND NOT Stop_Button AND NOT Abort_Active ;                    //Start latch



Fuel_Pres_OK := GE(Fuel_Pres_sensor, fuel_Min_Limit );                                          //Fuel pressure check

Oxidizer_Pres_OK := GE(Oxidizer_Pres_Sensor, Oxidizer_Min_Limit );                              //Oxidizer pressure check

Cockpit_pres_G := GE(Cockpit_Pres_Sensor, Cockpit_Min );
Cockpit_pres_L := LE(Cockpit_Pres_Sensor, Cockpit_Max );
Cockpit_pres_OK := Cockpit_pres_G AND Cockpit_pres_L ;                                  //Cockpit pressure check

N2_Supply_OK := GE(N2_Supply_Sensor, N2_Required_Pressure );                             //Nitrogen supply check

Wind_unsafe := GT(Wind_Speed_Sensor, (30.0) );                                          //Wind speed check
Wind_safe   := LT(Wind_Speed_Sensor, (25.0) );
 Wind_OK     := Wind_safe AND NOT Wind_unsafe ;

Safety_OK := Fuel_pres_OK AND Cockpit_pres_OK AND N2_Supply_OK AND Oxidizer_Pres_OK AND Wind_OK ;



//phase2

TON1(IN := (Safety_OK AND Start_Phase2), PT := TO_TIME(7500), Q => Purge_timer, ET => ET1);
Open_Valve := Start_Phase2 AND NOT Purge_timer;  // Valve opens for 7.5s

TON2(IN := Purge_timer, PT := TO_TIME(3000), Q => Settle_timer, ET => ET2);// Waits to settle for 3s

Phase2_comp := Settle_timer ;

//phase3

Oxidizer_Valve:= Phase2_comp AND NOT Abort_Active ;

TON5(IN := Oxidizer_Valve, PT := TO_TIME(1000) , Q => Valve_timer, ET => ET6);

Ox_valve_check := (Ox_valve AND NOT Valve_timer) OR Ox_valve_check ; // valve is the sensor output and will be a parameter that is always 1 or 0 depending on user

Temp_safe  := GE(Ox_Temp, Ox_Min_Temp );

WarmupVar := Oxidizer_Valve AND NOT Temp_safe;

TON3(IN := WarmupVar, PT := TO_TIME(10000), Q => Ox_Warmup, ET => ET4); // can do cehck again for temp after warup

Fuel_Valve := Oxidizer_Valve AND (Temp_safe OR Ox_Warmup) AND Ox_valve_check AND NOT Abort_Active;



Phase3_comp := Fuel_Valve ;

//phase4


TON7(IN := Phase3_comp, PT := TO_TIME(1000), Q => Igniter, ET => ET4);

TON4(IN := Igniter, PT := TO_TIME(1000), Q => Flame_timer, ET => ET5);
Flame_check := (Flame AND Flame_timer) OR Flame_check ; // Flame is the sensor output and will be a parameter that is always 1 or 0 depending on user

Run_State := Phase3_comp AND Flame_check AND Start_rocket ;

```