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A
ODE23t solver

The choice of the solver is important to ensure the results. This choice depends of the type of ordinary equation (ODE) problems. For numerical solvers, an ODE problem is *stiff* if the equation holds some terms that can face rapid and great variations in the solution.

In this dissertation, the friction torque and the bit speed present sudden changes due to the assumed resistive torque friction model on the bit. Therefore, the method adopted were *ODE23t* which is recommended for moderately stiff equations. This method is an implementation of the trapezoidal rule (considered as a special case of the second-order Runge-Kutta method) for approximating the integral. The trapezoidal rule is an implicit method of integration.

For a rough understanding, considering an ODE of the form

$$y' = f(t, y) \tag{A-1}$$

with initial condition $y(0) = y_0$. In the integration form, this equation can be written as

$$y(t) = y_0 + \int_0^t f\left(s, y(s)\right) ds \tag{A-2}$$

For a trapezoidal rule, the Eq. A-2 becomes

$$y_{n+1} = y_n + \frac{h}{2}\left[f(t_n, y_n) + f(t_{n+1}, y_{n+1})\right] \tag{A-3}$$

where h is the step size, and $n = 0, 1, \cdots, ((t_0 - t_f) - 1)/h$. t_0 and t_f are the initial and final time, respectively. The integration is approximated by an average of y'_n and y'_{n+1}. As can be noted, a nonlinear equation must be solved.

B
Block diagrams and algorithm

B.1
Block diagrams

In *LabView*, Figures B.1 and B.2 illustrate the block diagram of the test rig acquisition and the front panel, respectively. The torsional dynamic system is illustrated in Figure B.3 (developed by L. Pereira).

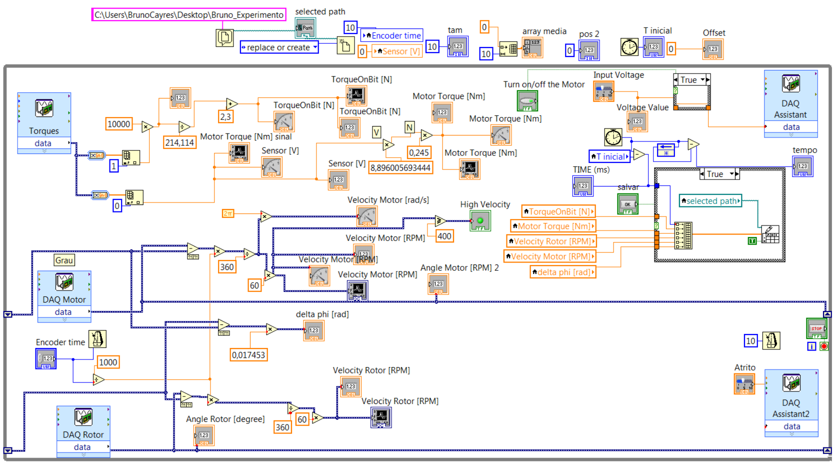

Figure B.1: *LabView* block diagram.

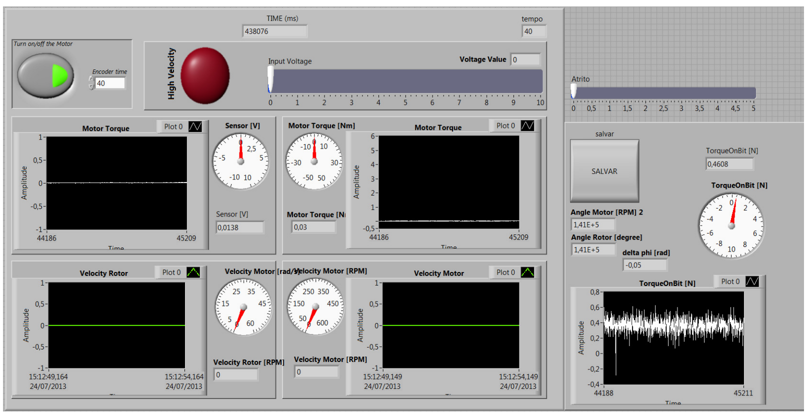

Figure B.2: *LabView* front panel.

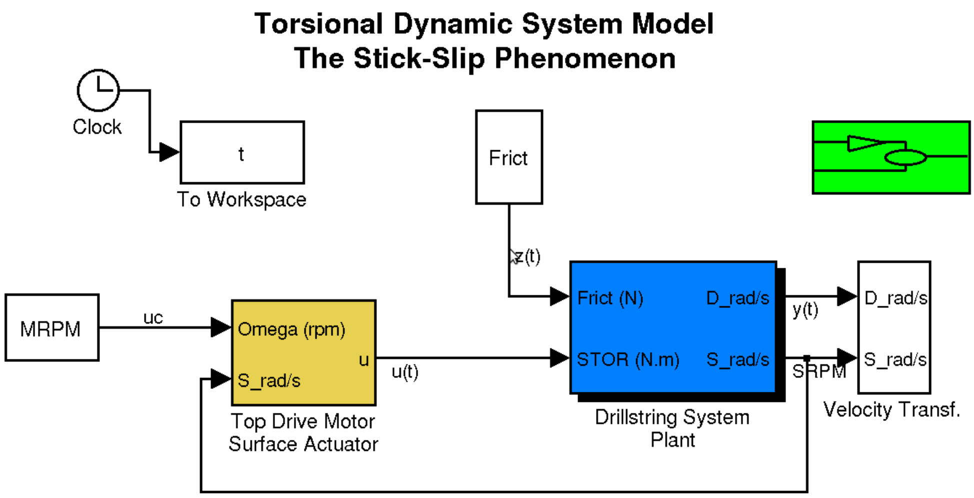

Figure B.3: *Simulink* block diagram.

B.2
Arduino algorithm

The pulse width modulation algorithm was developed by Ph.D. student Marcelo Pereira. This algorithm is responsible to control (opening and close) the analogue servo controller by means a input voltage.

```
// Read analogue pin A0
// Write digital pin D3 in PWM

void setup(){
 pinMode(3, OUTPUT);
 pinMode(A0, INPUT);
 //Serial.begin(9600);
}

void loop()
{
  int a = analogRead(A0); // a = 0 to 1023
  int duty = 1000 + a;
  //Serial.println(duty);
  digitalWrite(3,HIGH);
  delayMicroseconds(duty);
  digitalWrite(3,LOW);
  delayMicroseconds(1000 - duty);
  delay(18);
}
```

Figure B.4: Arduino algorithm.