



```
void loop()
{
  while(1)
  {
    a=analogRead(A1);
    float mv = (a/1024.0) * 5000;
    float cel = mv / 10;
    Serial.println(cel);
    delay(30000);
  }
}
```

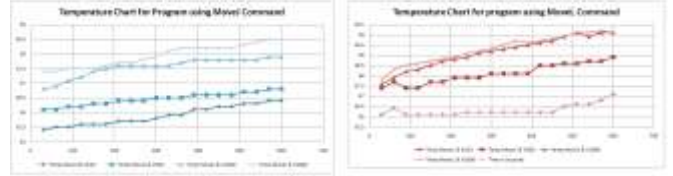
### 3. Data Acquired and Graphical Plot

The data are acquired in MatLab. The temperature sensor readings are recorded once per every 30 seconds and it is continued up to 600 seconds. Initially the temperature of the servo drive rose up and by 10 minutes time the temperature raise is stabilised by the ambient cooling process & the graph showed a horizontal curve. So the study was limited to 10 minutes or 600 seconds. The Temperature values recorded by the Temperature Sensor for programs using MoveL and MoveJ for velocities from 100 to 2000 are given in the table below.

**Table 1:** Data acquired using LM35 Temperature Sensor for 10 minutes at 30 seconds intervals.

Time in Seconds	Temp MoveL & V100	Temp MoveL & V500	Temp MoveL & V1000	Temp MoveL & V2000	Time in Seconds	Temp MoveJ & V100	Temp MoveJ & V500	Temp MoveJ & V1000	Temp MoveJ & V2000
30	36.1	37.4	37.6	37.8	30	35.4	36.1	36.8	37.4
60	36.4	37.7	37.9	38.3	60	35.5	36.1	36.9	37.4
90	36.1	37.4	38.2	38.5	90	35.5	36.2	37.1	37.5
120	36.1	37.4	38.3	38.6	120	35.6	36.2	37.2	37.5
150	36.1	37.7	38.5	38.7	150	35.6	36.3	37.4	37.5
180	36.1	37.7	38.7	38.8	180	35.6	36.3	37.5	37.6
210	36.1	37.9	38.8	38.9	210	35.7	36.4	37.6	37.7
240	36.2	37.9	38.9	39.1	240	35.7	36.4	37.6	37.7
270	36.2	37.9	39.1	39.2	270	35.7	36.4	37.6	37.8
300	36.2	38.1	39.2	39.3	300	35.8	36.5	37.6	37.9
330	36.2	38.1	39.3	39.5	330	35.9	36.5	37.6	38.1
360	36.2	38.1	39.4	39.7	360	35.9	36.5	37.7	38.2
390	36.2	38.1	39.5	39.6	390	36.1	36.6	37.8	38.2
420	36.2	38.5	39.6	39.7	420	36.1	36.6	37.8	38.2
450	36.2	38.5	39.7	39.8	450	36.2	36.6	37.8	38.2
480	36.5	38.6	39.9	39.9	480	36.2	36.6	37.8	38.2
510	36.6	38.6	40.1	40.1	510	36.3	36.7	37.8	38.3
540	36.6	38.7	39.9	40.1	540	36.3	36.7	37.8	38.4
570	36.8	38.7	40.1	40.2	570	36.4	36.8	37.9	38.5
600	37.1	38.9	40.1	40.1	600	36.4	36.8	37.9	38.5

The graph of all the above readings are plotted with Time on x axis & the temperature recorded on y axis. It is observed that the Temperature raise in the servo drives with MoveL commands is marginally greater than the respective Temperature raise using MoveJ commands.



**Figure 3:** Temperature Chart for Program using MoveL & MoveJ commands

### 4. Results and Discussions

**Table 2:** Paired Sample Means

	Mean		Std. Deviation		Std. Error Mean		95% Confidence Interval		t	df	Sig. (2-tailed)
	Temp MoveL & V100	Temp MoveJ & V100	Temp MoveL & V500	Temp MoveJ & V500	Temp MoveL & V1000	Temp MoveJ & V1000	Temp MoveL & V2000	Temp MoveJ & V2000			
Pair 1	36.310000	35.895000	.2751076	.2751076	.0515159	.0515159	2.093	19	.050		
Pair 2	38.095000	36.465000	.4729248	.4729248	.1057492	.1057492	11.906	19	.000		
Pair 3	39.140000	37.560000	.7590853	.7590853	.1597355	.1597355	49.472	19	.000		
Pair 4	39.295000	37.940000	.5878456	.5878456	.1538070	.1538070	24.245	19	.000		

**Table 3:** Paired Sample Difference between means & t value.

	Mean	N	95% Confidence Interval	
			Lower	Upper
Pair 1	36.310000	20	35.895000	36.725000
Pair 2	38.095000	20	36.465000	39.725000
Pair 3	39.140000	20	37.560000	40.720000
Pair 4	39.295000	20	37.940000	40.650000

The statistical tool “t test for difference between sample means” was employed for the analysis as the sample size is small. The Mean value of temperature recorded using MoveL program was compared with MoveJ program.

The t value calculated using SPSS package shown in Table1 was compared with the t value at 95% confidence and 19 DOF. The t value is 2.093 whereas the calculated values in table 3 are 11.906 for V100, 49.472 for V500, 24.245 for V1000 and 14.318 for V2000. All the calculated values by SPSS package (Table 3 values) are greater than the t value of 2.093.

This clearly indicates that their exist a remarkable difference in temperature between the two methods of programming. The paired mean values calculated for all methods in Table 2 indicates that Temperature raise for program using MoveL is greater than the corresponding Temperature raise for program using MoveJ.

### Conclusion

It is evident that, the temperature of the servo drives increases with the following parameters.

- 1) Increase in number of MoveL commands in the program code.

- 2) Increase in the velocity of motion. High V Value.
- 3) Decrease in the Error Zone. Low Z Value.
- 4) Increase in Pay Load & Reach of the Robot.
- 5) Higher Ambient Temperature of the work environment.

Lowering of Pay Load / Reach is not possible in an Organization, which is the basic function for Robots are employed. Changing the Environment Temperature is normally costly. Reducing the error zone is not possible all the time, as few operations require precision. More velocity reduction leads to drop of productivity. Change of program code using MoveJ commands are economical and also provide better performance with less heat generation.

Referring Table 2, it is evident that the difference in temperature between MoveL command & the respective MoveJ command is 1 or 2 degrees higher. This difference can go higher, if the payload capacity & reach of the Robot is increased. This leads to maintenance problems. Hence MoveJ commands can be replaced by MoveL commands where ever motion geometry permits, as it can enhance the Servo Drive performance.

## References

- [1] Geoffrey Biggs & Bruce MacDonald, "A Survey of Robot Programming Systems", *University of Auckland*, pp. 1 - 10.
- [2] Gavin Simmons and Yiannis Demiris, "Optimal Robot Arm Control using the minimum Variance Model" *Journal of Robotics System*, vol. 22, pp. 677 - 690, 2005.
- [3] Richard H. Welch Jr, George W. Younkin, "How Temperature Raise affects a Servo Motor's Electrical and Mechanical Time Constants", *IEEE Transaction*.

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