Journal of Mechatronics and Robotics

Original Research Paper

Modeling and Simulation of the Impact of Temperature on Single Point Load Cell using Trnsys 16.0: Measured, Uncompensated and Error Data for Zaria Kaduna State

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Article history
Received: 26-03-2022
Revised: 15-05-2022
Accepted: 16-05-2022

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Abstract: A load cell is a piece of machined metal called a transducer or load sensor. As a measuring device, the entire framework is prone to the impact of environmental forces which can produce errors in the load cell output. The most significant force or input modifier is high ambient temperature. Typical meteorological year document demonstrates that in March, April, and May the temperature in Zaria can surpass 40ºC degrees on some days, including in most parts of northern Nigeria. It then implies that most weighing scales in the open environment will normally have a diminished sensitivity and along these lines yield wrong outcomes which can affect critical decisions with respect to weight control and well-being. Thus, this research aims to model and simulate the impact of high ambient temperature on a load cell using TRNSYS simulation studio. And its specific objectives are; to develop the model mathematically using the method of high gain feedback in a closed-loop to measure and compensate for errors due to ambient temperature above 40°C, to program the model using FORTRAN programming language at the back end, to simulate the model using a typical year meteorological weather data file for Zaria (11.0855°N, 7.7199°E). The procedures to model and simulate the effect of high ambient temperatures on load cell sensitivity include; the development of the model mathematically using the equation for high gain feedback in a closed-loop, programing the model using FORTRAN programming language (g 95 in Code block IDE), simulation of the model using a typical year meteorological weather data file for Zaria, (obtainable from meteorological Agencies). In the simulation, 75 kg was used as the sample weight. And the data obtained shows that in March at 1416.0 h, when no load is applied, there is a drift in the output range of the system even though the ambient temperature 20.152°C is within the scope of load cell compensation. Noticeably, the feedback system re-calibrated the scale thus eliminating the error and returning the gauge to 0.0 kg. The highest ambient temperature in March was recorded at 1981.0 h as 47.246°C with a corresponding error of 0.142. The feedback system evaluates the uncompensated value, eliminates the error and returns a correct value of 75 kg corresponding to the measured value. In April a drift in the system output range was also noticed at 2160.0 h, with a corresponding error of 0.150 before the feedback system re-calibrated the scale to 0.0 kg. The highest ambient temperature for April is 46.48°C at 2292.0 h and the corresponding error is 0.139. The feedback system again evaluates the uncompensated value, resolves the error and returns 75 kg corresponding to the measured value or known weight. While in May a drift in the system output range was also noticed at 2880.0 and the feedback system quickly returns the value to 0.0 kg. The highest ambient temperature of 46.86 is seen at 3037.0 h with a corresponding error of 0.141. The feedback system again evaluates the uncompensated value, resolves the error and returns 75 kg corresponding to the measured value.

Keywords: TRNSYS, Temperature, Load Cell, Weighing Scale, Simulation

Introduction

A load cell is a piece of machined metal called a transducer or load sensor. It is designed to bend with mechanical force and thus convert the mechanical force into an electronic signal with the aid of a strain gauge embedded in the metal. As a measuring device, the entire framework is prone to environmental forces which can produce errors in the load cell signal. The most significant force or input modifier is high ambient temperature. Because it is not possible to keep up a controlled environment, in this manner the load cell's accuracy and precision are influenced. Of all the errors that the scale is inclined to, high ambient temperature enormously diminishes the sensitivity of the weighing scale. Changes in surrounding temperature cause load cell sensitivity to drift, and this impact warrants re-alignment of the framework as temperature change is steady. This change on the load cell at zero load causes the whole cell's output range to shift. (Science Direct, 2019) Characterized sensitivity drift is the sum by which an instrument's sensitivity of measurement fluctuates as surrounding conditions change (Stern *et al*., 2004). Satake and Maeda (2017), formulated a load cell temperature compensation framework for precisely measuring a load mounted on it during naturally changing temperature regimes such that temperature varieties will be made for by a compensation framework (Briggs, 2002). Formulated a strategy for temperature compensation for a scale that included four burden cells organized as an extension circuit. The strategy contained a structure for compensating the system separately over the temperature range for which the load cell is to be rectified. In this way, the measurement of the recompensed load cell was with the end goal that the zero error in the measurement was generously decreased, and that adjustments in the load cell sensitivity because of temperature changes over a range were likewise diminished (Harold and Tomlinson, 2000). Weighing scale with dynamic zero mistake amendment. A weighing scale with an electrical yield incorporates a mechanical-to-electrical signal transducer which has a zero-weight sign worth and may fluctuate because of surrounding conditions.

Statement of the Problem

NIMET (2019) Typical meteorological year document demonstrates that in March, April, and May the temperature in Zaria can surpass 40° degrees on some days, including most parts of northern Nigeria and different parts of the world like the middle east, North America and so on (INDEPENDENT, 2019). It then implies that most weighing scales in the open environment will normally have a diminished sensitivity and along these lines yield wrong outcomes which are basic to weight control and well-being. From the properties of the load cell in view in Table 5, it is worthy of note that the load cell is compensated up to the range of (-10-40). However, the compensated temperature range is still less than the operating temperature, suggesting that beyond the compensated temperature range of (-10-40) and within the operating temperature range of (-20-60), the load cell is prone to error of 0.03% per 10°C (see appendix 1) once the compensated temperature is exceeded. Thus there is a need to develop a model which can be used in embedded system design to correct the anomaly when these load cells are selected for embedded system projects.

Aim and Objectives

This research aims to model and simulate the impact of high ambient temperature on a load cell using TRNSYS simulation studio. And its specific objectives are:

1. Develop the model mathematically using the method of high gain feedback in a closed-loop to measure and compensate for errors due to ambient temperature rising above 40º.
2. Program the model using FORTRAN programming language at the backend, and link it to the TRNSYS using the Code block.
3. To simulate the model using a typical year meteorological weather data file for Zaria (11.0855° N, 7.7199°E)

Methodology

The procedures to model and simulate the effect of high ambient temperatures on load cell sensitivity are now highlighted:

1. Develop the model mathematically using the method of high gain feedback in a closed-loop.
2. Program the model using FORTRAN programming language (g 95 in Code block IDE) (TRNSYS-*Coordinator*, 2007a)
3. To simulate the model using a typical year meteorological weather data file for Zaria, (obtainable from meteorological Agencies)
4. To discuss the results and analyze the charts

Modelling of the Component (TRNSYS-Coordinator, 2007b)

Mathematical Modelling of the Component (using Method of High Gain Feed-Back) the Method of High-Gain Feedback

This is the use of feedback to check the bias in a measured value, process it, and feed the difference back into the system with the aid of a sensor, thus eliminating the error in the measurement. This process can either be an open-loop or closed-loop system. Practically, this technique often leads to great improvements in inaccuracy. The open-loop formula is given by (Ernest, 2014) as shown in Fig. 1:

$$x_0 = \left(K_{Mo} K_{sp}\right) ei \tag{1}$$

For the closed-loop system.

Suppose the output x_o is measured by a feedback device, which produces a voltage e_o proportional to the output x_o. The voltage is subtracted from the input voltage e_i and the difference is applied to an amplifier, the microcontroller, and thus the output x_o:

$$(e_i - e_0) K_{AM} K\mu C = \left(e_i - K_{FB} x_o\right) K_{AM} K\mu C = x_o \tag{2}$$

$$e_i K_{AM} K\mu C = (1 K_{AM} K\mu C K_{FB}) x_o \tag{3}$$

$$x_o = (K_{AM} K\mu CK / K_{AM} K\mu C K_{FB}) e_i \tag{4}$$

Suppose K_{AM} to be very large i.e., a high gain system, so that:

$$K_{AM} K\mu C K_{FB} \gg 1.$$

Then:

$$x_o = K\_\_FB\ e_i \tag{5}$$

The implication of Eq. (5) is that the effect of variations in the system (as a result of modifying inputs i_m on the relation between input and output x_o has been made negligible. Only K_{FB} is constant and unaffected by any modifying input to maintain constant input-output calibration as shown in Eq. (5).

Simulation

After fully developing the model, the model was then used in the TRNSYS simulation studio as shown in Fig. 2. The models developed include a 200 kg load cell, HX711 amplifier, Atmega328P microcontroller, and thermistor. They were created using the FORTRAN programming language. The reason for using FORTRAN is because it is the only language that TRNSYS understands and was designed to work with. Within the simulation window, the load cell is linked to the amplifier, then linked to the microcontroller which in turn is linked to a thermistor, and lastly to the display.

Description of the System

The system is made up of a load cell, amplifier, microcontroller, thermistor, plotter, and weather file. The load cell measures the force and sends an electrical signal to the amplifier, which magnifies the signal and sends it to the microcontroller. The microcontroller reads the signal, then reads the thermistor to get the ambient temperature. It checks and compares the temperature whether it is within the scope of the design. If the temperature exceeds the compensated temperature, the system uses the high-gain feedback method to measure the error and compensate it, then send the correct measurement to the display module.

The flowchart in Fig. 3 demonstrates the flow of logic. The use of a microcontroller is to enable the fusion of the high-gain feedback method in the logic or firmware development.

The simulation start time, stop time, and time step are shown according to Table 1. The months of March, April, and May were selected for the simulation as they are the months with the highest solar insolation.

Table 1: Table showing global information of the simulation

	Days of the month and its equivalence in TRNSYS studio		
Month	No. of days in the month	Simulation start time and stop time (days)	Simulation time step (hour)
January	0–310	0–310	0–7440
February	31–590	31–590	744–1416
March	59–900	59–900	1416–2160
April	90–120	90–120	2160–2880
May	120–151	120–151	2880–3624
June	151–181	151–181	3624–4344
July	181–212	181–212	4344–5088
August	212–243	212–243	5088–5832
September	243–273	243–273	5832–6552
October	273–304	273–304	6552–7296
November	304–334	304–334	7296–8016
December	334–365	334–365	8016–8760

DOI: 10.3844/jmrsp.2022.47.56

Table 2: Showing results for March on the days when ambient temperature exceeded 40ºC

C Hours	Measured value kg	Uncompensated value kg	Error kg	With Feedback kg	Ambient temperature °C	Total solar insolation kJ/hr-m^2
1416.0	0.0	0.150	0.149	0.0	20.152	0.0000
1693.0	75.0	75.122	0.122	75.0	40.773	3754.8000
1694.0	75.0	75.123	0.123	75.0	40.853	3672.0000
1695.0	75.0	75.120	0.120	75.0	40.017	3297.6000
1717.0	75.0	75.120	0.120	75.0	40.007	3805.2000
1718.0	75.0	75.121	0.121	75.0	40.457	3718.8000
1739.0	75.0	75.121	0.121	75.0	40.171	3110.4000
1740.0	75.0	75.128	0.128	75.0	42.590	3614.4000
1741.0	75.0	75.125	0.125	75.0	41.805	3830.4000
1742.0	75.0	75.120	0.120	75.0	40.082	3747.6000
1765.0	75.0	75.125	0.125	75.0	41.699	3855.6000
1766.0	75.0	75.128	0.128	75.0	42.795	3769.2000
1767.0	75.0	75.126	0.126	75.0	41.921	3376.8000
1789.0	75.0	75.120	0.120	75.0	40.096	3711.6000
1790.0	75.0	75.122	0.122	75.0	40.503	3621.6000
1791.0	75.0	75.120	0.120	75.0	40.099	3240.0000
1812.0	75.0	75.130	0.130	75.0	43.242	3441.6000
1813.0	75.0	75.122	0.122	75.0	40.681	3646.8000
1859.0	75.0	75.122	0.122	75.0	40.641	2991.6000
1860.0	75.0	75.121	0.121	75.0	40.500	3474.0000
1884.0	75.0	75.133	0.133	75.0	44.253	3448.8000
1885.0	75.0	75.132	0.132	75.0	43.856	3654.0000
1886.0	75.0	75.125	0.125	75.0	41.786	3564.0000
1887.0	75.0	75.123	0.122	75.0	40.849	3186.0000
1908.0	75.0	75.121	0.121	75.0	40.426	3452.4000
1932.0	75.0	75.127	0.127	75.0	42.206	3412.8000
1933.0	75.0	75.140	0.140	75.0	46.655	3628.8000
1934.0	75.0	75.132	0.132	75.0	44.092	3546.0000
1935.0	75.0	75.126	0.126	75.0	42.002	2649.6000
1936.0	75.0	75.121	0.121	75.0	40.407	2358.0000
1956.0	75.0	75.121	0.121	75.0	40.356	3517.2000
1957.0	75.0	75.123	0.123	75.0	41.100	3729.6000
1958.0	75.0	75.122	0.123	75.0	40.961	3654.0000
1959.0	75.0	75.123	0.124	75.0	41.093	3222.0000
1960.0	75.0	75.122	0.122	75.0	40.690	2638.8000
1980.0	75.0	75.132	0.132	75.0	44.077	3502.8000
1981.0	75.0	75.142	0.142	75.0	47.246	3700.8000
1982.0	75.0	75.135	0.135	75.0	44.976	3614.4000
1983.0	75.0	75.126	0.126	75.0	42.124	3240.0000
1984.0	75.0	75.121	0.121	75.0	40.207	2512.8000
2028.0	75.0	75.131	0.131	75.0	43.785	3510.0000
2029.0	75.0	75.137	0.137	75.0	45.648	3704.4000
2030.0	75.0	75.131	0.131	75.0	43.628	3610.8000
2031.0	75.0	75.124	0.124	75.0	41.494	3229.2000

Results and Discussion

From the simulation, the results obtained are presented for March, April, and May, the months with the highest solar insolation. 75 kg was used as the sample weight. Below are extracts of the results showing values for scenarios where the ambient temperature exceeded 40°C. In March (Table 2) at 1416.0 h, when no load is applied, there is a drift in the output range of the system even though the ambient temperature 20.152°C is within the scope of load cell compensation. Noticeably, the feedback system re-calibrated the scale thus eliminating the error and returning the gauge to 0.0 kg. The highest ambient temperature in March was recorded at 1981.0 h as 47.246°C with a corresponding error of 0.142. The feedback system evaluates the uncompensated value, eliminates the error and returns a correct value of 75 kg corresponding to the measured value. In April (Table 3) a drift in the system output range was also noticed at 2160.0 h, with a corresponding error of 0.150 before the feedback

DOI: 10.3844/jmrsp.2022.47.56

system re-calibrated the scale to 0.0 kg. The highest ambient temperature for April is 46.48°C at 2292.0 h and the corresponding error is 0.139. The feedback system again evaluates the uncompensated value, resolves the error and returns 75 kg corresponding to the measured value or known weight. While in May (Table 4) a drift in the system output range was also noticed at 2880.0 and the feedback system quickly returns the value to 0.0 kg. The highest ambient temperature of 46.86 is seen at 3037.0 h with a corresponding error of 0.141. The feedback system again evaluates the uncompensated value, resolves the error and returns 75 kg corresponding to the measured value.

Table 3: Showing results for April on the days when ambient temperature exceeded 40 ºC

Time Hours	Measured value kg	Uncompensated value kg	Error kg	With Feedback kg	Ambient temperature øC	Total solar insolation kJ/hr-m^2
2160.0	00.0	00.150	0.150	0.0	17.30	0000.00
2222.0	75.0	75.121	0.121	75.0	40.27	3740.40
2244.0	75.0	75.121	0.121	75.0	40.32	3621.60
2245.0	75.0	75.123	0.123	75.0	40.85	3798.00
2246.0	75.0	75.121	0.121	75.0	40.35	3686.40
2268.0	75.0	75.133	0.132	75.0	44.32	3474.00
2269.0	75.0	75.129	0.129	75.0	42.95	3679.20
2270.0	75.0	75.124	0.124	75.0	41.22	3596.40
2271.0	75.0	75.123	0.123	75.0	41.01	3214.80
2291.0	75.0	75.121	0.121	75.0	40.50	2930.40
2292.0	75.0	75.139	0.139	75.0	46.48	3517.20
2293.0	75.0	75.130	0.130	75.0	43.47	3715.20
2294.0	75.0	75.123	0.123	75.0	40.90	3592.80
2316.0	75.0	75.124	0.124	75.0	41.34	3250.80
2340.0	75.0	75.122	0.122	75.0	40.56	3538.80
2341.0	75.0	75.129	0.129	75.0	42.92	3718.80
2342.0	75.0	75.130	0.130	75.0	43.26	3578.40
2343.0	75.0	75.125	0.125	75.0	41.50	1969.20
2344.0	75.0	75.121	0.121	75.0	40.45	2246.40
2365.0	75.0	75.123	0.123	75.0	41.12	3697.20
2366.0	75.0	75.124	0.124	75.0	41.43	3582.00
2388.0	75.0	75.132	0.133	75.0	44.10	3297.60
2389.0	75.0	75.135	0.135	75.0	45.01	3488.40
2390.0	75.0	75.125	0.125	75.0	41.69	3420.00
2411.0	75.0	75.122	0.122	75.0	40.69	2718.00
2412.0	75.0	75.135	0.135	75.0	44.92	3218.40
2413.0	75.0	75.129	0.129	75.0	43.04	3254.40
2414.0	75.0	75.121	0.121	75.0	40.42	2750.40
2435.0	75.0	75.120	0.120	75.0	40.06	3200.40
2436.0	75.0	75.128	0.128	75.0	42.81	3639.60
2437.0	75.0	75.126	0.126	75.0	41.96	3808.80
2438.0	75.0	75.121	0.121	75.0	40.31	3690.00
2531.0	75.0	75.124	0.124	75.0	41.31	3186.00
2532.0	75.0	75.135	0.135	75.0	44.98	3618.00
2533.0	75.0	75.130	0.130	75.0	43.18	3787.20
2534.0	75.0	75.123	0.123	75.0	40.93	3664.80
2535.0	75.0	75.120	0.120	75.0	40.05	3272.40
2556.0	75.0	75.135	0.135	75.0	45.06	3603.60
2557.0	75.0	75.137	0.137	75.0	45.65	3765.60
2558.0	75.0	75.135	0.135	75.0	44.98	3646.80
2559.0	75.0	75.129	0.129	75.0	43.15	3247.20
2560.0	75.0	75.122	0.122	75.0	40.75	2599.20
2581.0	75.0	75.120	0.120	75.0	40.15	3722.40
2604.0	75.0	75.126	0.126	75.0	42.15	3603.60
2605.0	75.0	75.138	0.138	75.0	46.00	3754.80
2606.0	75.0	75.135	0.135	75.0	44.97	3625.20
2607.0	75.0	75.128	0.128	75.0	42.77	3218.40
2608.0	75.0	75.121	0.121	75.0	40.27	2570.40
2629.0	75.0	75.125	0.125	75.0	41.54	3708.00

Table 3: Continue

2630.0	75.0	75.133	0.133	75.0	44.18	3574.80
2631.0	75.0	75.123	0.123	75.0	41.02	3074.40
2652.0	75.0	75.131	0.131	75.0	43.52	3520.80
2653.0	75.0	75.138	0.138	75.0	46.14	3664.80
2654.0	75.0	75.122	0.123	75.0	40.85	3380.40
2676.0	75.0	75.129	0.129	75.0	43.10	3384.00
2677.0	75.0	75.143	0.143	75.0	47.73	3538.80
2678.0	75.0	75.128	0.128	75.0	42.59	3376.80
2700.0	75.0	75.128	0.128	75.0	42.60	3524.40
2701.0	75.0	75.134	0.134	75.0	44.80	3672.00
2702.0	75.0	75.124	0.124	75.0	41.47	3553.20
2749.0	75.0	75.129	0.129	75.0	42.90	3358.80
2750.0	75.0	75.124	0.124	75.0	41.48	3243.60
2772.0	75.0	75.122	0.122	75.0	40.81	3513.60
2773.0	75.0	75.125	0.125	75.0	41.55	3668.40
2774.0	75.0	75.126	0.126	75.0	42.03	3542.40
2775.0	75.0	75.124	0.124	75.0	41.47	3132.00
2776.0	75.0	75.122	0.122	75.0	40.64	2332.80
2797.0	75.0	75.132	0.132	75.0	44.06	3650.40
2798.0	75.0	75.131	0.131	75.0	43.75	3510.00
2799.0	75.0	75.126	0.126	75.0	41.97	3114.00
2800.0	75.0	75.123	0.123	75.0	40.86	2415.60
2846.0	75.0	75.127	0.127	75.0	42.21	3423.60
2847.0	75.0	75.123	0.123	75.0	40.94	3002.40

Table 4: Showing results for May on the days when ambient temperature exceeded 40 ºC

Time	Measurd value	Uncompensated value	Error	With feedback	Ambient temperature	Total solar insolation
hours	kg	kg	kg	kg	øC	kJ/hr-m^2
2880.0	0.0	0.150	0.150	0.0	26.03	0.00
2918.0	75.0	75.121	0.121	75.0	40.44	3603.60
2919.0	75.0	75.120	0.120	75.0	40.10	3211.20
2963.0	75.0	75.122	0.122	75.0	40.74	3106.80
2964.0	75.0	75.123	0.123	75.0	40.94	3520.80
2965.0	75.0	75.121	0.121	75.0	40.22	3672.00
2966.0	75.0	75.120	0.120	75.0	40.01	3542.40
2989.0	75.0	75.124	0.124	75.0	41.28	3654.00
2990.0	75.0	75.124	0.124	75.0	41.21	3520.80
2991.0	75.0	75.123	0.123	75.0	40.87	3124.80
3012.0	75.0	75.121	0.121	75.0	40.34	3510.00
3013.0	75.0	75.128	0.128	75.0	42.64	3639.60
3036.0	75.0	75.134	0.134	75.0	44.52	3510.00
3037.0	75.0	75.141	0.141	75.0	46.86	3650.40
3038.0	75.0	75.130	0.130	75.0	43.19	3513.60
3061.0	75.0	75.123	0.123	75.0	41.16	3603.60
3062.0	75.0	75.123	0.123	75.0	41.03	3452.40
3276.0	75.0	75.121	0.121	75.0	40.50	3452.40
3277.0	75.0	75.126	0.126	75.0	42.05	3603.60
3278.0	75.0	75.127	0.127	75.0	42.26	3477.60
3279.0	75.0	75.124	0.124	75.0	41.20	3085.20
3398.0	75.0	75.125	0.125	75.0	41.74	3366.00
3419.0	75.0	75.121	0.121	75.0	40.25	3006.00
3420.0	75.0	75.124	0.124	75.0	41.36	3391.20
3445.0	75.0	75.123	0.123	75.0	41.11	3488.40
3517.0	75.0	75.129	0.130	75.0	43.03	3276.00
3539.0	75.0	75.121	0.121	75.0	40.50	2977.20
3540.0	75.0	75.120	0.120	75.0	40.01	3373.20
3590.0	75.0	75.121	0.121	75.0	40.23	3348.00

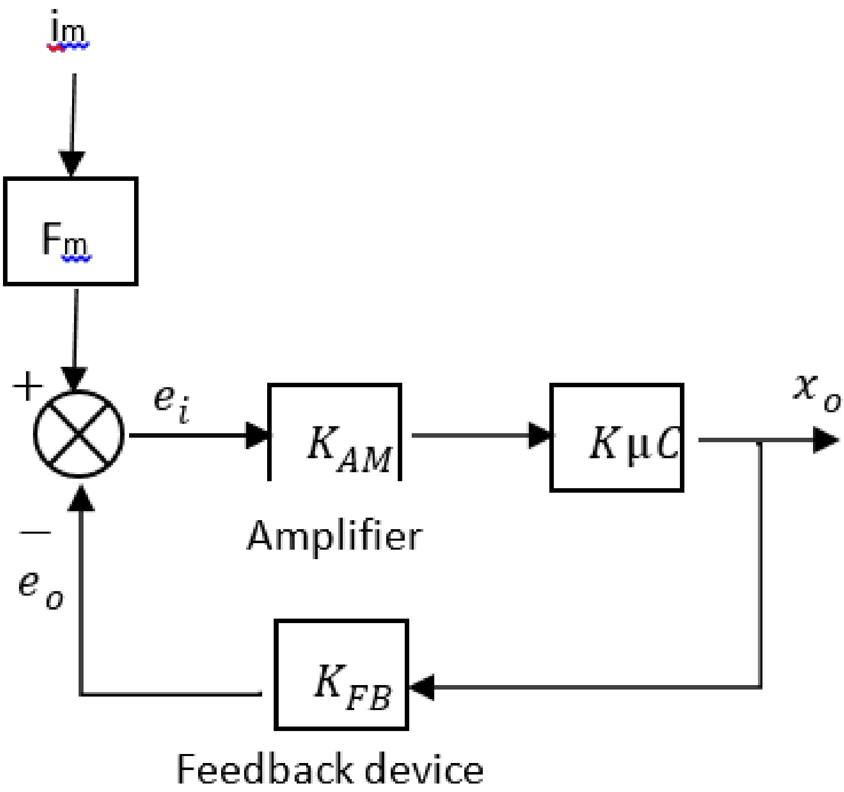

Fig. 1: closed-loop feedback system

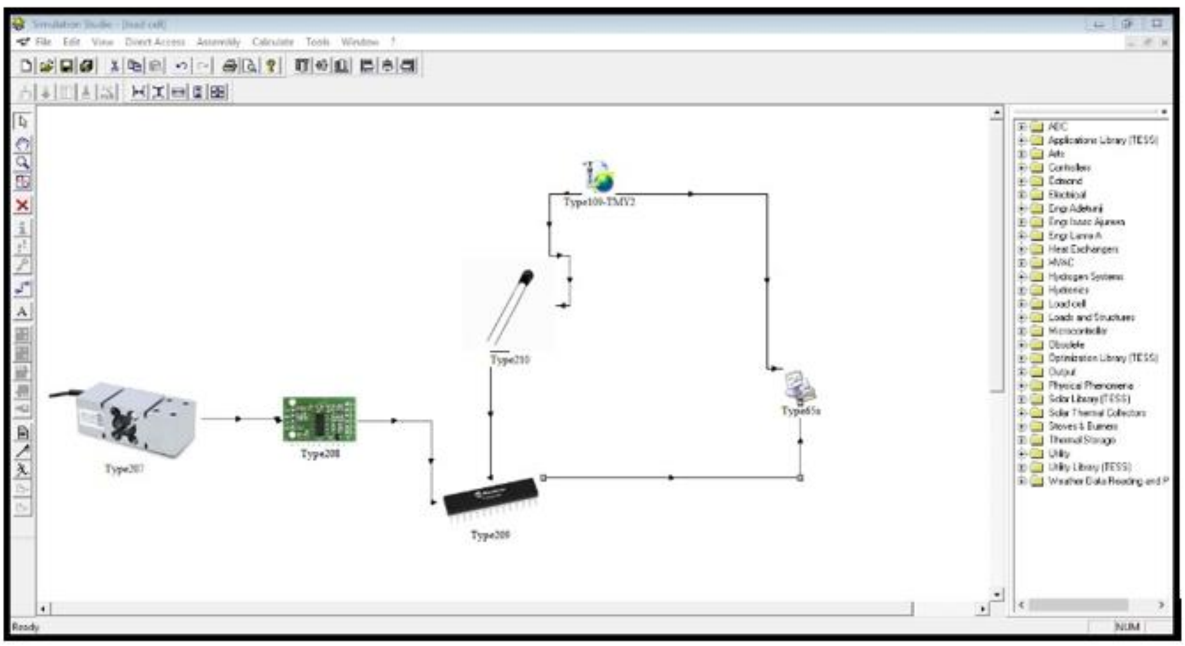

Fig. 2: TRNSYS simulation window showing the models

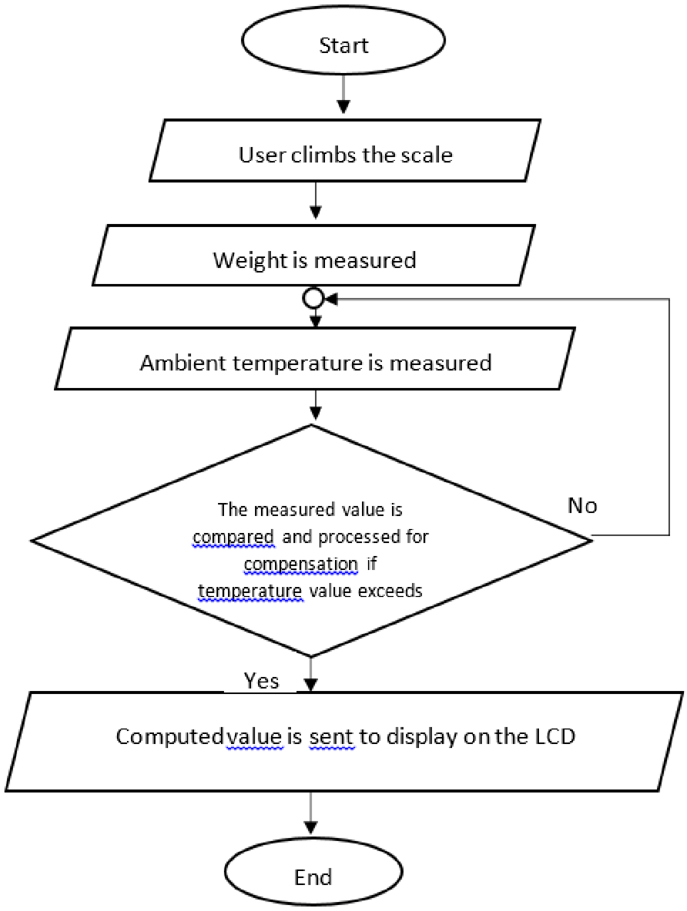

Fig. 3: Flow chart of the system

Conclusion

Conclusively, a model was developed using the method of high gain feedback in a closed-loop to measure and compensate for errors due to ambient temperature above 40º. The feedback method checked and eliminated the error in the measured value, and improved the accuracy of the system. All the models were created with FORTRAN programming language at the backend, while the frontend features the TRNSYS interface. Code block IDE was used to debug and link the backend to the frontend. The created models were tested in the

TRNSYS simulation window using a typical year meteorological weather data file for Zaria (11.0855°N, 7.7199°E). With these steps the objectives of the research have been clearly met and it has proven that high ambient temperature does have a negative impact on load cell output and the high gain feedback method does work effectively to free the measured from error.

Contribution to Knowledge

Because most load cells are manufactured with no ability to compensate for errors in their output concerning changing environmental conditions of operation. The method of high gain feedback can be used in the firmware design to correct this anomaly if the load cell is chosen as a sensor in any electronic or embedded system.

Author’s Contributions

Albright A. Edet: Designed and developed the models using trnsys. Programmed the models using Fortran programming language.

Afolayan M. O: Designed the research plan and organized the study. Contributed to the development of the manuscript. Reviewed the manuscript.

Umar A. Umar: Supervised and participated in the simulation. Drew the research gap and contributed to the development of the manuscript.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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Appendix 1

Table 5: Features of the simulated load cell (Source: (New Resistance, 2019))

Load cell features	Single point load cell
Load cell image	
Material	Aluminium alloy
Application	Electronic balance, price computing scales, bathroom scales and kitchen scales etc.
Capacity	20–200 kg
Accuracy (OIML standard)	C3
Output sensitivity	2.0±10% mv/v
Zero balance	±5% F.S.
Combined error	±0.028% F.S.
Creep in 30 min	±0.03% F.S
Linearity error	±0.02% F.S.
Repeatability error	±0.015% F.S.
Hysteresis error	±0.015% F.S.
Input resistance	405±10 Ω
Output resistance	350±3 Ω
Temp. effect on sensitivity	±0.03% F.S./10℃
Temp. effect on zero	±0.03% F.S./10℃
Compensated temp. range	-10-＋40℃
Operating TEMP. Range	-20-＋60℃
Recommended excitation	5-12 VDC
Max. excitation voltage	18 VDC
Safe overload	150% F.S.
Ultimate overload	200% F.S.
Insulation resistance	≥5000 M Ω (50 VDC)
Cable length	∮4*400 mm
Protection class	IP 65

DOI: 10.3844/jmrsp.2022.47.56

Nomenclature:

Symbol	Value	Unit
x_o	Output	Kg
$K\mu C$	Maximum weight constant	V
K_{AM}	Maximum excitation voltage constant	V
e_i	Input voltage	mV
e_o	Output voltage	mV
K_{FB}	Feedback constant	mV
F_M	Measured force	Kg
i_m	Modifying input	mV