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Bachelor of Engineering Technology: Electrical Engineering

CONTROL SYSTEMS 3 (CSS370S)

FINAL PROJECT PART 1: GA1 EVALUATION

PROJECT V04: TC7107 / LM35 ANALOG DISPLAY CRUISE SPEED CONTROL SYSTEM

System Design and Development, Simulation, Truth Tables and Practical Implementation Discussion

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Declaration

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Summary/Abstract

This report presents Project V04 of the CSS370S GA1 cruise speed control simulation. The project requires an electronic solution without a microcontroller or PLC. The required outputs are a green indicator for speeds 0 to 5, a yellow/amber indicator for speeds 6 to 9, a flashing red warning when the selected cruise speed is reached, a maximum displayed speed of 10, and an automatic cruise reset/warning reset action that is not only a manual reset button.

Project V04 uses LM35 analog detector/reference inputs and TC7107 analog-to-display circuits to represent the current and reference speed values. The TC7107 display/ADC stage drives seven-segment displays and provides segment signals used by the logic section. The system also uses gate logic, cascaded 74LS85 comparators, a 2N3904 transistor/relay driver and an NE555 astable timer for the flashing red warning.

The solution was analysed stage by stage. The analog/display calibration, normalized seven-segment signals, green/yellow logic, comparator truth table, NE555 warning circuit and final operating summary are documented through formal truth tables. The analysis confirms that Project V04 satisfies the main control requirements using electronic components only.

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Table of Acronyms

Table A: Acronyms used in the report

Acronym	Meaning
ADC	Analog-to-Digital Converter
BCD	Binary Coded Decimal
LED	Light Emitting Diode
IC	Integrated Circuit
VCC	Positive supply voltage
GND	Ground reference
GA1	Graduate Attribute 1: Problem Solving

1. Introduction

The CSS370S GA1 project is performed to develop a practical electronic cruise speed control simulation. The work demonstrates problem solving by dividing the system into detector, display, comparator, indicator and warning stages. A microcontroller or PLC is not used, so the required behaviour must be achieved using electronic circuits and logic.

The aim of Project V04 is to implement the cruise-speed display and warning behaviour using an analog-input and display-driver approach. The LM35 devices represent analog detector/reference inputs, while the TC7107 circuits convert the analog values into display and logic signals.

The problem addressed by this design is how to produce the required 0 to 10 cruise-speed indication from analog/digital display hardware. The system must separate the green 0 to 5 range from the yellow 6 to 9 range, show 10 as the maximum speed and flash red when the selected cruise condition is reached.

The simulated design achieves these requirements by using the TC7107 display stage for speed representation, logic gates for range detection, 74LS85 comparators for the set-speed comparison and an NE555 timer for flashing warning output.

2. System description

Project V04 is an analog-display based cruise speed control solution. The TC7107 is used as a direct display-drive analog-to-digital converter, which makes it suitable for a circuit where an analog input is translated into seven-segment display information [1]. The LM35 devices provide analog voltage inputs that are interpreted as the detector/reference speed signals [2].

Figure 1 presents the complete Project V04 circuit used for this report. The figure shows the TC7107 display/ADC stages, LM35 input sections, green/yellow range logic, cascaded 74LS85 comparator section, transistor/relay driver and NE555 red flashing stage.

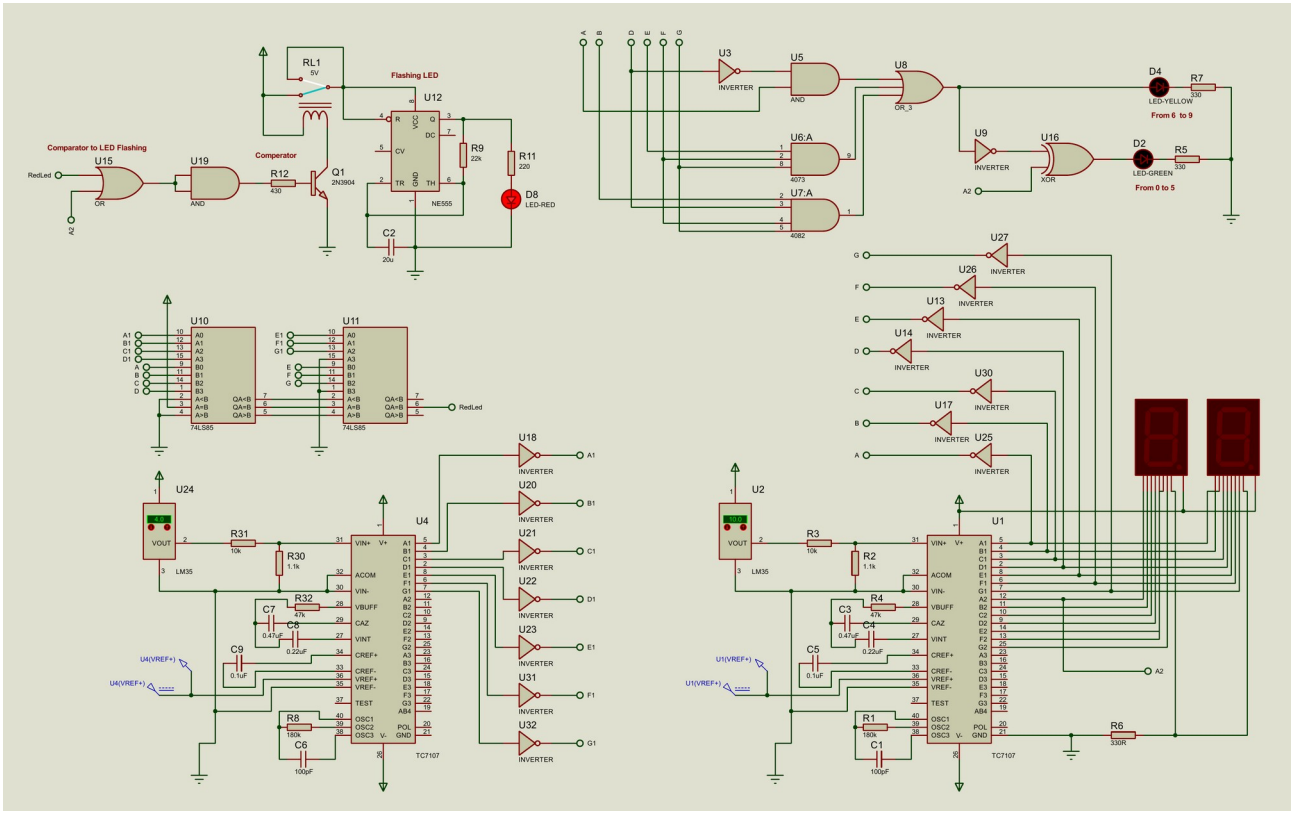

Figure 1: Project V04 TC7107 / LM35 cruise speed control circuit

Table 1 defines the required operating conditions used to evaluate Project V04. These conditions are the standard requirements that the circuit must satisfy during simulation and reporting.

Table 1: Required operating conditions for the cruise speed control system

Condition	Required output
Current speed = 0 to 5	Green LED ON, yellow LED OFF. Red LED depends on selected set speed.
Current speed = 6 to 9	Yellow/amber LED ON, green LED OFF. Red LED depends on selected set speed.
Current speed reaches selected cruise speed	Comparator output enables the NE555 stage and the red LED flashes.
Current speed = 10	Maximum speed is displayed as 10; green and yellow are OFF.
Current speed falls below selected speed	Comparator output resets the warning path automatically and red LED turns OFF.

Table 2 identifies the main component groups in Project V04. This helps separate the display, range indication, comparator and warning sections before the detailed stage discussion.

Table 2: Main component function table for Project V04

Component / label	Circuit part	Purpose in the Project V04 solution
U1	TC7107	Main analog-to-display section for current speed display and segment logic outputs.
U4	TC7107	Second analog/display section used for the reference or set-speed side.
U2 and U24	LM35	Analog detector/reference voltage sources.
Two 7-segment displays	LED displays	Show the current speed as a two-digit value including 10.
U5, U6:A, U7:A	AND gates	Generate yellow-range detection terms from segment outputs.
U8	3-input OR gate	Combines yellow detection terms.
U9 and U16	Inverter and XOR gate	Generate final green output and inhibit green at 10.
U10 and U11	74LS85	Compare current speed signals with set/reference speed signals.
U15 and U19	OR and AND gates	Combine comparator outputs to enable the red flashing path.
Q1, RL1 and U12	2N3904, relay and NE555	Drive and flash the red warning LED when enabled.
D2, D4 and D8	LEDs	Green, yellow and red speed indicators.

Table 3 summarises the signal flow through the circuit. It shows how the analog detector/reference values are converted into display signals and then used for range and warning decisions.

Table 3: Overall signal-flow table

Stage	Signal path	Meaning
Analog detection	LM35 output -> TC7107 input	Analog voltage represents the simulated speed/reference value.
Display	TC7107 segment outputs -> seven-segment displays	Displays the current speed value from 00 up to 10.
Range logic	Segment signals A, B, D, E, F, G -> logic gates	Separates green 0-5 from yellow 6-9.
Maximum-speed inhibit	Tens-active signal A2 -> XOR/inhibit section	Prevents 10 from being treated as digit 0.
Comparator	Current signals -> 74LS85 A-side; set signals -> B-side	Detects lower, equal or greater speed condition.
Flashing warning	Comparator RedLed signal -> Q1/RL1 -> NE555 -> red LED	Flashes red when cruise speed is reached or exceeded.

2.1 Stage 1: Development and overall approach to solution of automated system

The Project V04 solution was developed as a staged analog/display-based electronic control system. The first stage is the LM35 and TC7107 display arrangement because the displayed speed must be available before the range LEDs and comparator can be verified.

The TC7107 stage provides a direct display-drive approach. This reduces the need for a separate ADC and decoder stage, because the analog value is converted and shown on the seven-segment displays within the same display subsystem.

2.2 Stage 2: Development and solution of the analog detection/sensors stage

The analog detector stage is represented by LM35 devices and their associated scaling circuitry. In the Project V04 simulation, the analog input values are interpreted as speed values between 0 V and 1 V, corresponding to displayed speeds from 00 to 10.

This stage is closer to an analog detector approach than the counter-only designs. The displayed speed is linked to an analog voltage level, which supports the project requirement for an analog detection or sensor stage.

2.3 Stage 3: Development and solution of determination of increasing/decreasing speed

The increasing and decreasing speed condition is represented by changing the analog input voltage applied to the TC7107 section. As the voltage increases, the displayed speed increases; as the voltage decreases, the displayed speed decreases.

The design also uses the tens-active signal A2 to identify the maximum display condition. This prevents the logic from treating the unit digit 0 at speed 10 as part of the green 0 to 5 range.

2.4 Stage 4: Development and solution of relevant alarms/indicators/displays of the system

The display and alarm stage includes the two seven-segment displays, green LED, yellow/amber LED and flashing red LED. The green/yellow logic uses normalized segment signals from the display stage to detect the required ranges.

The red warning LED is controlled by the comparator section. When the current speed equals or exceeds the selected set speed, the comparator output enables the transistor/relay path and the NE555 astable circuit flashes the red LED.

2.5 Stage 5: Overall approach to system design and solution development

The complete design combines analog detection, TC7107 display conversion, range logic, comparator decision logic and NE555 warning output. This provides a full electronic solution to the cruise-speed control problem without a microcontroller or PLC.

The truth tables in Section 3 verify the circuit stage by stage. This is important because each part of the design must be understood before the full circuit can be evaluated.

3. Observations and results

Table 4 links the analog input voltage to the intended displayed speed. The exact scaling depends on the selected reference and resistor values, but the table gives the project-level interpretation used for the simulation.

Table 4: Display and analog input truth table

Speed value	Example analog input	Tens display	Unit display	Meaning
0	0.00 V	0	0	Green range
1	0.10 V	0	1	Green range
2	0.20 V	0	2	Green range
3	0.30 V	0	3	Green range
4	0.40 V	0	4	Green range
5	0.50 V	0	5	Green range
6	0.60 V	0	6	Yellow/amber range
7	0.70 V	0	7	Yellow/amber range
8	0.80 V	0	8	Yellow/amber range
9	0.90 V	0	9	Yellow/amber range
10	1.00 V	1	0	Maximum speed

Table 5 gives the normalized seven-segment truth table used by the range logic. In this table, 1 means the segment is ON and 0 means the segment is OFF.

Table 5: Normalized seven-segment truth table

Digit	A	B	C	D	E	F	G	Pattern	Display
0	1	1	1	1	1	1	0	1111110	0
1	0	1	1	0	0	0	0	0110000	1
2	1	1	0	1	1	0	1	1101101	2
3	1	1	1	1	0	0	1	1111001	3
4	0	1	1	0	0	1	1	0110011	4
5	1	0	1	1	0	1	1	1011011	5
6	1	0	1	1	1	1	1	1011111	6
7	1	1	1	0	0	0	0	1110000	7
8	1	1	1	1	1	1	1	1111111	8
9	1	1	1	1	0	1	1	1111011	9

Table 6 identifies the TC7107 signal groups used in the design. These signals are used for display, range detection and comparator/reference functions.

Table 6: TC7107 display and logic signal table

Signal group	Example labels in circuit	Use
Current-speed display outputs	A, B, C, D, E, F, G and A2	Drive the display and feed green/yellow range logic. A2 is the tens-active signal.
Reference/set display outputs	A1, B1, C1, D1, E1, F1, G1	Feed the comparator/reference side after normalisation.
TC7107 analog inputs	VIN+, VIN-, ACOM, VREF+, VREF-	Set measured and reference voltage levels.
Oscillator/reference pins	OSC1, OSC2, OSC3, CREF+, CREF-	Support conversion timing and reference stability.

Table 7 verifies the full green/yellow range logic. The result confirms that green is active from 00 to 05, yellow is active from 06 to 09, and both are OFF at 10.

Table 7: Green/yellow LED range logic truth table

Speed	Tens A2	Unit digit	Y1 = A.NOT D	Y2 = E.F.G	Y3 = A.B.F.G	Yellow	Green	Result
0	0	0	0	0	0	0	1	Green ON
1	0	1	0	0	0	0	1	Green ON
2	0	2	0	0	0	0	1	Green ON
3	0	3	0	0	0	0	1	Green ON
4	0	4	0	0	0	0	1	Green ON
5	0	5	0	0	0	0	1	Green ON
6	0	6	0	1	0	1	0	Yellow ON
7	0	7	1	0	0	1	0	Yellow ON
8	0	8	0	1	1	1	0	Yellow ON
9	0	9	0	0	1	1	0	Yellow ON
10	1	0	0	0	0	0	0	Max 10 / red warning

Table 8 summarises how the two 74LS85 comparators are used in the comparison section. The 74LS85 provides A>B, A=B and A<B comparison outputs and can be cascaded for larger comparisons [3].

Table 8: Comparator block function table

Comparator block	A-side input meaning	B-side input meaning	Output used
U10 74LS85	Current/reference segment group A1, B1, C1, D1	Selected set-speed segment/reference group	Cascaded/combined comparison result
U11 74LS85	Current/reference group E1, F1, G1 with cascade input	Selected set-speed segment/reference group	RedLed comparator output path
U15 OR + U19 AND	Comparator status outputs and A2/tens logic	Enable condition	Final warning-enable signal to Q1 and NE555 path

Table 9 gives the comparator operating result used for the flashing red warning decision.

Table 9: 74LS85 comparator operation truth table

Current speed condition	QA>B	QA=B	QA<B	RedLed/F	Red flashing LED
Current speed < set speed	0	0	1	0	OFF
Current speed = set speed	0	1	0	1	Flashing
Current speed > set speed	1	0	0	1	Flashing

Table 10 gives the set-speed/reference segment patterns used to explain the comparator input states for the main cruise settings.

Table 10: Set-speed/reference segment table

Set speed	Pattern ABCDEFG	Warning meaning
6	1011111	Red flashes when current speed >= 6
7	1110000	Red flashes when current speed >= 7
8	1111111	Red flashes when current speed >= 8
9	1111011	Red flashes when current speed >= 9
10	A2 = 1, Unit = 0	Maximum speed condition

Table 11 lists the NE555 pins used in the warning stage. The NE555 is used as an astable timer so that the red LED flashes when enabled [4].

Table 11: NE555 connection table

NE555 pin	Name	Connection/use in circuit
1	GND	Ground.
8	VCC	+5 V supply rail.
4	RESET	Enabled by comparator/transistor/relay path. HIGH allows flashing.
2	TRIG	Connected into astable timing network.
6	THRESH	Connected into astable timing network.
7	DISCH	Connected to timing resistor/capacitor network.
5	CV	Control-voltage capacitor connection.
3	OUT	Flashing output to the red LED through a resistor.

Table 12 shows the red flashing warning truth table. When the comparator output is LOW, the red LED is OFF. When the comparator output is HIGH, the NE555 flashes the red LED.

Table 12: Red flashing warning truth table

Comparator RedLed/F	Q1 transistor	Relay/enable path	NE555 state	Red LED state
0	OFF	OFF / not energised	Disabled	OFF
1	ON	ON / energised	Enabled astable mode	Flashing

Table 13 explains the cruise warning reset and maximum-speed operation. The red warning resets automatically when the speed falls below the selected set speed, which is different from a normal push-button reset.

Table 13: Cruise warning reset and maximum-speed table

Condition	Comparator output	Action	Why this is a cruise reset and not a normal reset button
Current speed below selected speed	0	NE555 warning path disabled; red LED OFF	Warning resets automatically because comparator condition is no longer true.
Current speed equal to selected speed	1	NE555 warning path enabled; red LED flashes	Cruise speed has been reached.
Current speed above selected speed but below 10	1	Red LED continues flashing	Speed has passed the selected cruise value.
Current speed = 10	1 if set speed <= 10	Maximum speed displayed and red warning remains available	System shows max speed and does not rely on a push-button reset.

Table 14 summarises the final operating behaviour of Project V04. The results confirm that the required range and warning conditions are satisfied.

Table 14: Final operating summary

Displayed speed	Green LED	Yellow/amber LED	Red flashing LED	System meaning
00 to 05	ON	OFF	Depends on comparator set speed	Normal/low speed range.
06 to 09	OFF	ON	Depends on comparator set speed	Higher speed range before maximum.
10	OFF	OFF	Flashing when comparator warning condition is active	Maximum speed display condition.
Current speed < set speed	Range LED works normally	Range LED works normally	OFF	Cruise warning not reached.
Current speed = set speed	Range LED works normally	Range LED works normally	Flashing	Selected cruise speed reached.
Current speed > set speed	Range LED works normally	Range LED works normally	Flashing	Selected cruise speed passed.

4. Conclusion

Project V04 demonstrates an electronic cruise speed control simulation using LM35 analog detector/reference inputs, TC7107 display/ADC stages, logic gates, cascaded 74LS85 comparators, a 2N3904 transistor/relay driver and an NE555 flashing red LED stage. The design avoids microcontrollers and PLCs, which matches the project instruction.

The truth-table results show that the display can represent speeds from 00 to 10. The green LED is active from 0 to 5, the yellow/amber LED is active from 6 to 9, and both range LEDs are OFF at 10. The A2 tens-active signal prevents the maximum value 10 from being treated as a unit digit 0 in the green range.

The comparator and NE555 stages provide the required flashing red warning when the current speed reaches or exceeds the selected cruise speed. When the speed falls below the selected speed, the comparator output becomes inactive and the warning resets automatically. This gives the project a cruise-warning reset function rather than relying only on a manual reset button.

Bibliography

[1] Microchip Technology, “TC7106A/TC7107A 3-1/2 Digit Direct Display Drive Analog-to-Digital Converters Data Sheet.”

[2] Texas Instruments, “LM35 Precision Centigrade Temperature Sensors Data Sheet.”

[3] Texas Instruments, “SN74LS85 4-Bit Magnitude Comparators Data Sheet.”

[4] Texas Instruments, “NE555 Precision Timer Data Sheet.”

[5] onsemi, “2N3904 NPN General Purpose Transistor Data Sheet.”

Appendices

APPENDIX A: Truth-table pack used for Project V04

The detailed Project V04 truth-table pack is attached separately as project_v06_truth_tables.pdf. The main report includes the key truth tables required to explain the operation of the circuit.

APPENDIX B: Practical evaluation scheme

This appendix follows the GA1 practical evaluation focus: identify the problem, formulate a strategy, implement the solution and evaluate the result.

APPENDIX C: Report evaluation scheme

This appendix follows the report evaluation focus: stage-wise development, implementation discussion, observations, limitations, conclusion and professional presentation.