LAB 3 REPORT: EVALUATING MIXED-SIGNAL CLOSED-LOOP EMBEDDED SYSTEMS

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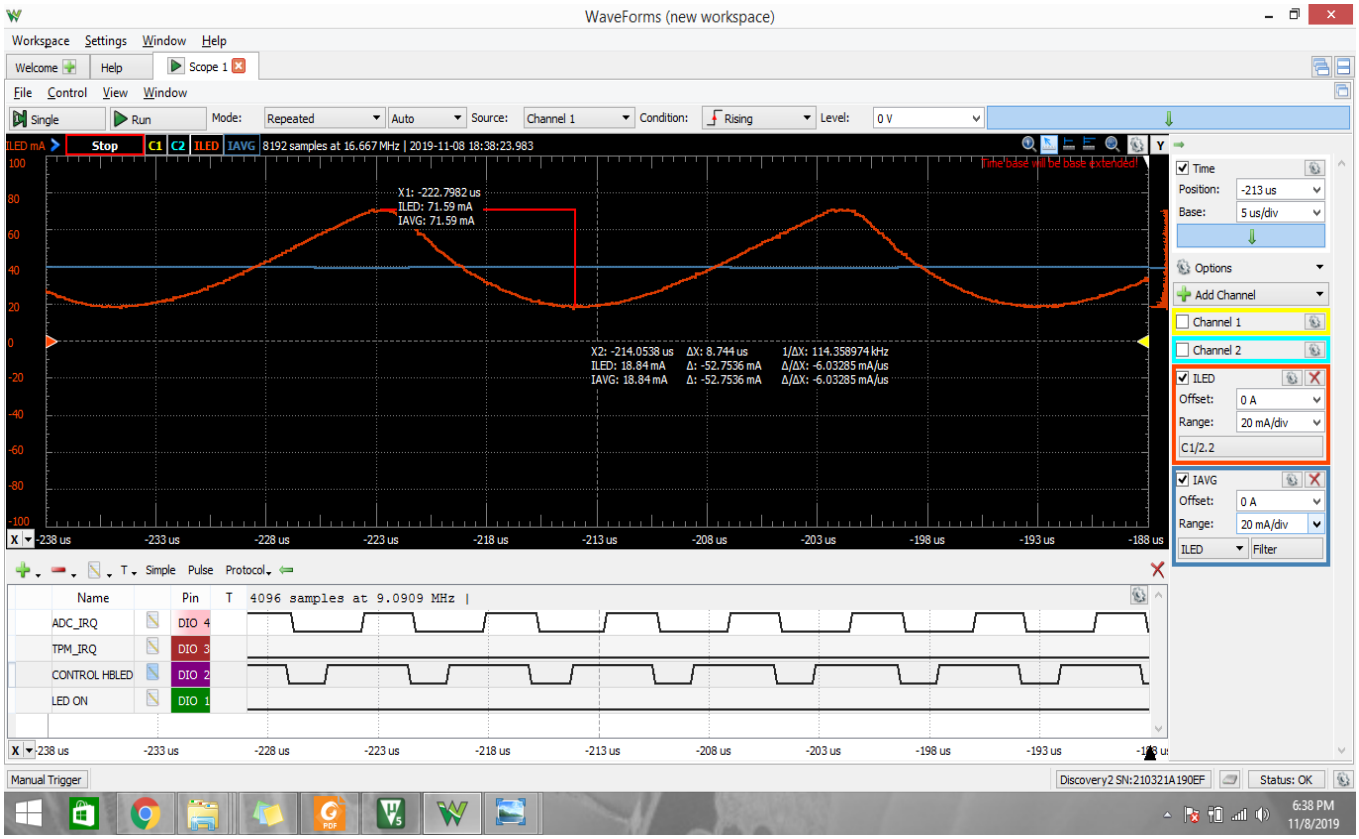
EVALUATING OPEN-LOOP CONTROL

STARTER CODE

1. What is the switching frequency for converter? Monitor the digital signal BUCK_DRV (also called Q Drive), available on J2 at pin 13. Or examine the frequency of the ripple in I_{LED}. **47.8993 kHz**
2. What is the control loop frequency? Monitor the digital signal Control_HBLED. **178.89 kHz**
3. Complete the table below. Run the code, modify **g_duty_cycle** using a debugger variable watch window, and measure average and peak-to-peak voltages across R10, available as V_{S--} on J13. For the last row, you'll need to adjust **g_duty_cycle** until the average LED current matches the specified value.

g_duty_cycle	Average I_{LED} (mA)	I_{LED_Ripple}: Peak-to-Peak I_{LED} Ripple Current (mA)
100	**5.73**	**9.13**
150	**11.67**	**20.43**
325	**40**	**52.75**

4. Take a mixed-signal screenshot of I_{LED} (with average value of 40 mA) showing two cycles of its ripple and include it in your report.



EVALUATING CLOSED-LOOP CONTROL WITHOUT TRANSIENTS

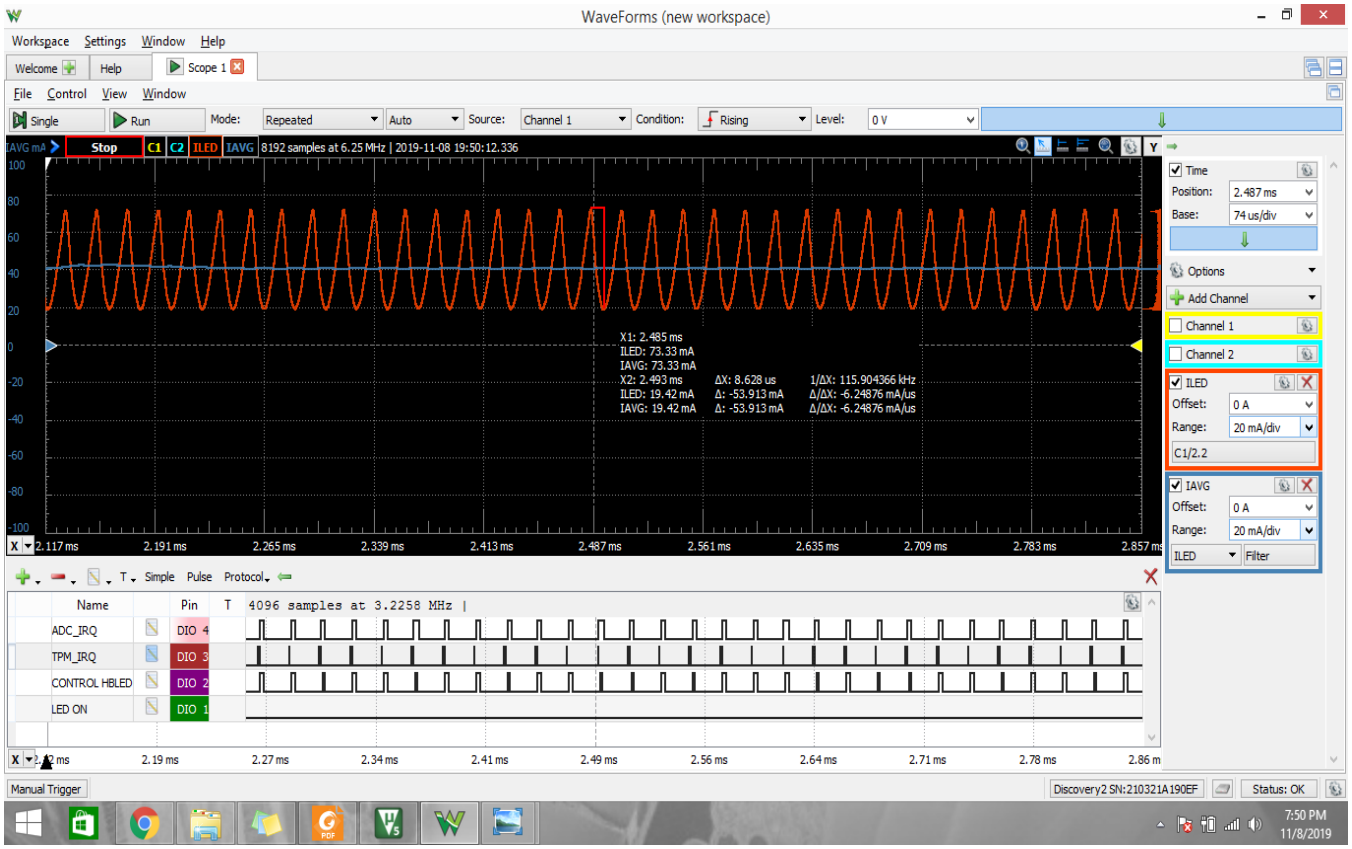
ASYNCHRONOUS SAMPLING

5. Complete the following table. Change **g_control_mode** to select the different controllers. In the last column compute the maximum error due to the controller: (maximum I_{LED} minus minimum I_{LED}) minus I_{LED_Ripple} for the open-loop 40 mA case (from the table above).

Controller	Control Loop Frequency (kHz)	Minimum I_{LED} (mA)	Maximum I_{LED} (mA)	$I_{Steady\ State\ Controller\ Error}$
Bang-Bang (1)	**163.67**	**5.072**	**134.1**	**76.278**
Incremental (2)	**156.99**	**21.16**	**76.23**	**2.32**
Proportional (3)	**153.85**	**19.42**	**73.33**	**1.16**
Fixed Point PID (5)	**59.524**	**97.68**	**6.667**	**38.263**

6. Take a mixed-signal screenshot of about 20 cycles of I_{LED} for any one control mode (your choice of which) and include it in your report.

   This is mixed signal screenshot for Proportional (3) mode only.



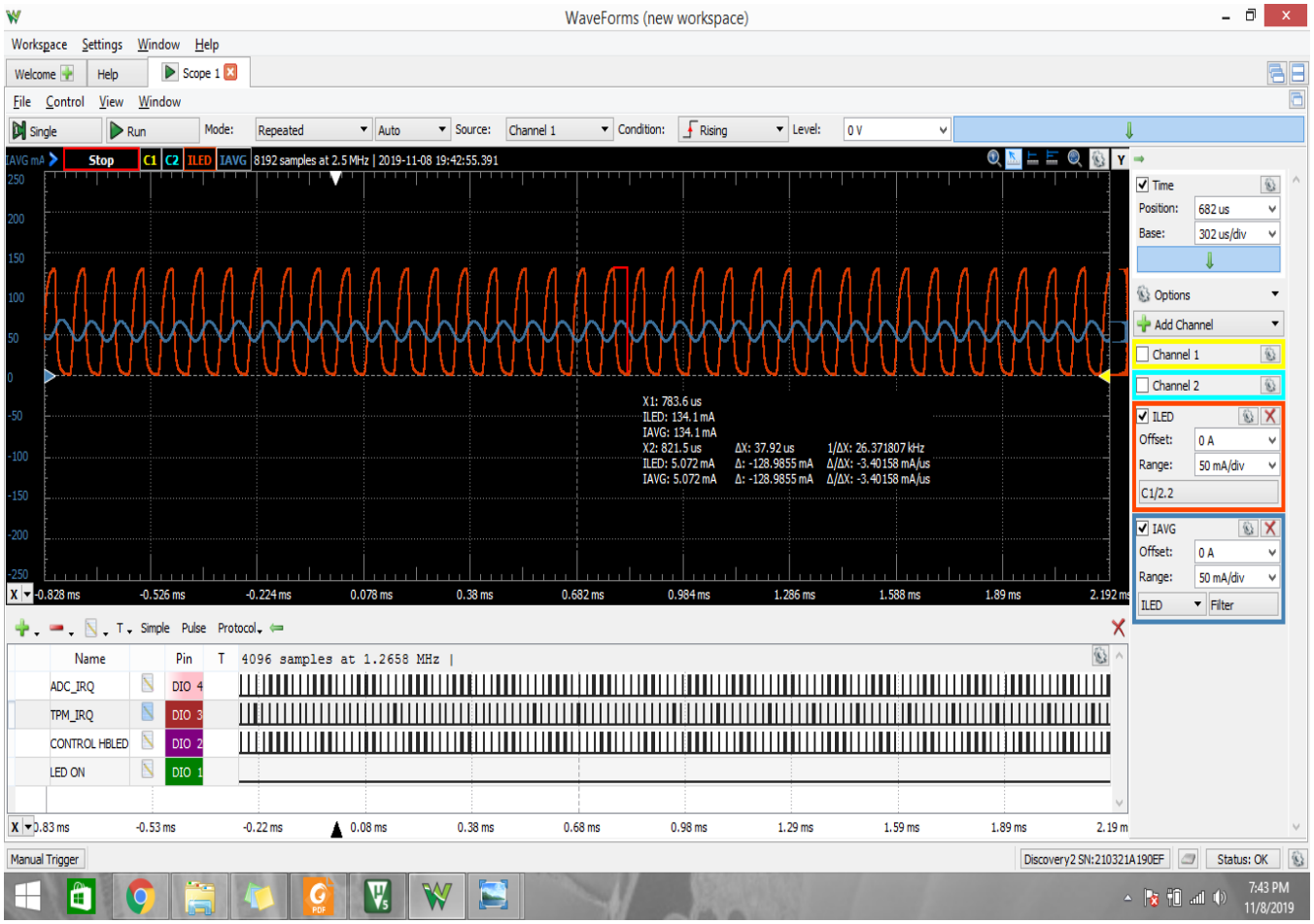
SYNCHRONOUS SAMPLING

7. Complete the following table. Change **g_control_mode** to select the different controllers. Compute the maximum error due to the controller: (maximum I_{LED} minus minimum I_{LED}) minus I_{LED_Ripple}. Use the logic analyzer window to determine the duration of Control_HBLED.

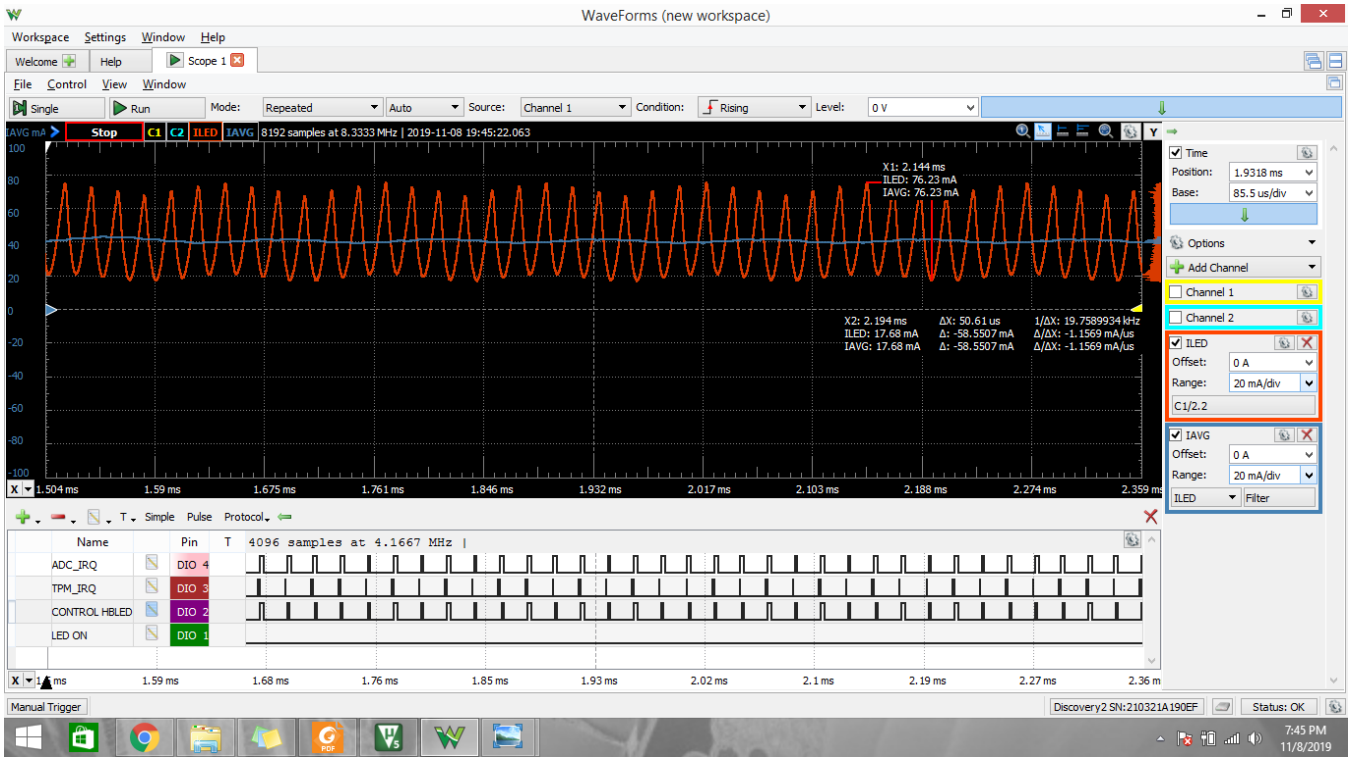
	Minimum I_{LED} (mA)	**Maximum I_{LED} (mA)**	**$I_{Steady\ State\ Controller\ Error}$ (mA)**	**Control_HBLED Duration**
Bang-Bang	5.072	134.1	76.278	2.37 µs (Period = 20.54 µs)
Incremental	17.68	76.23	5.8	1.92 µs (Period = 20.88 µs)
Proportional	19.42	73.33	1.16	2.17 µs (Period = 20.86 µs)
Fixed Point PID	19.42	72.75	0.58	7.22 µs (Period = 20.71 µs)

8. Take mixed-signal screenshots of about 20 cycles of I_{LED} for each of the control methods and include them in your report.

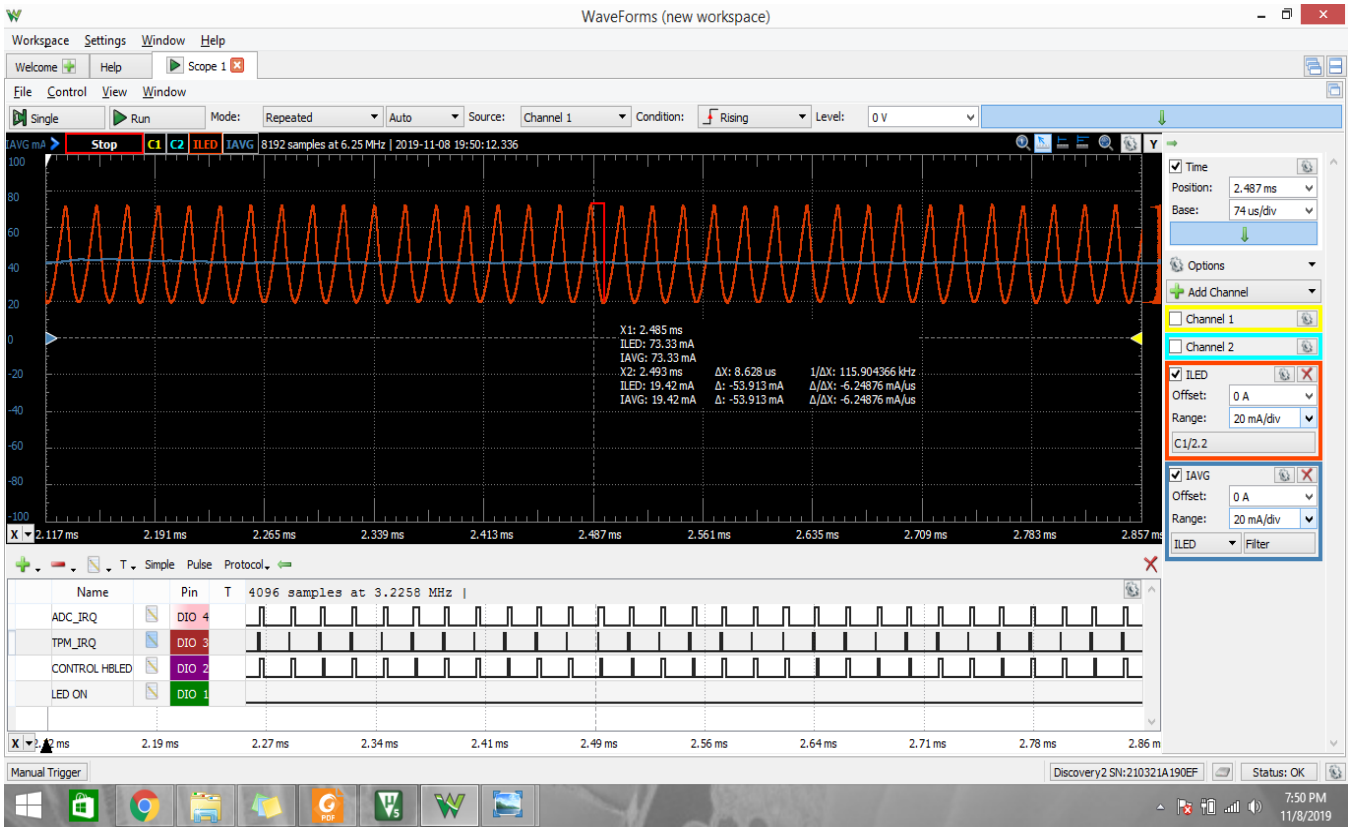
   Bang-Bang:



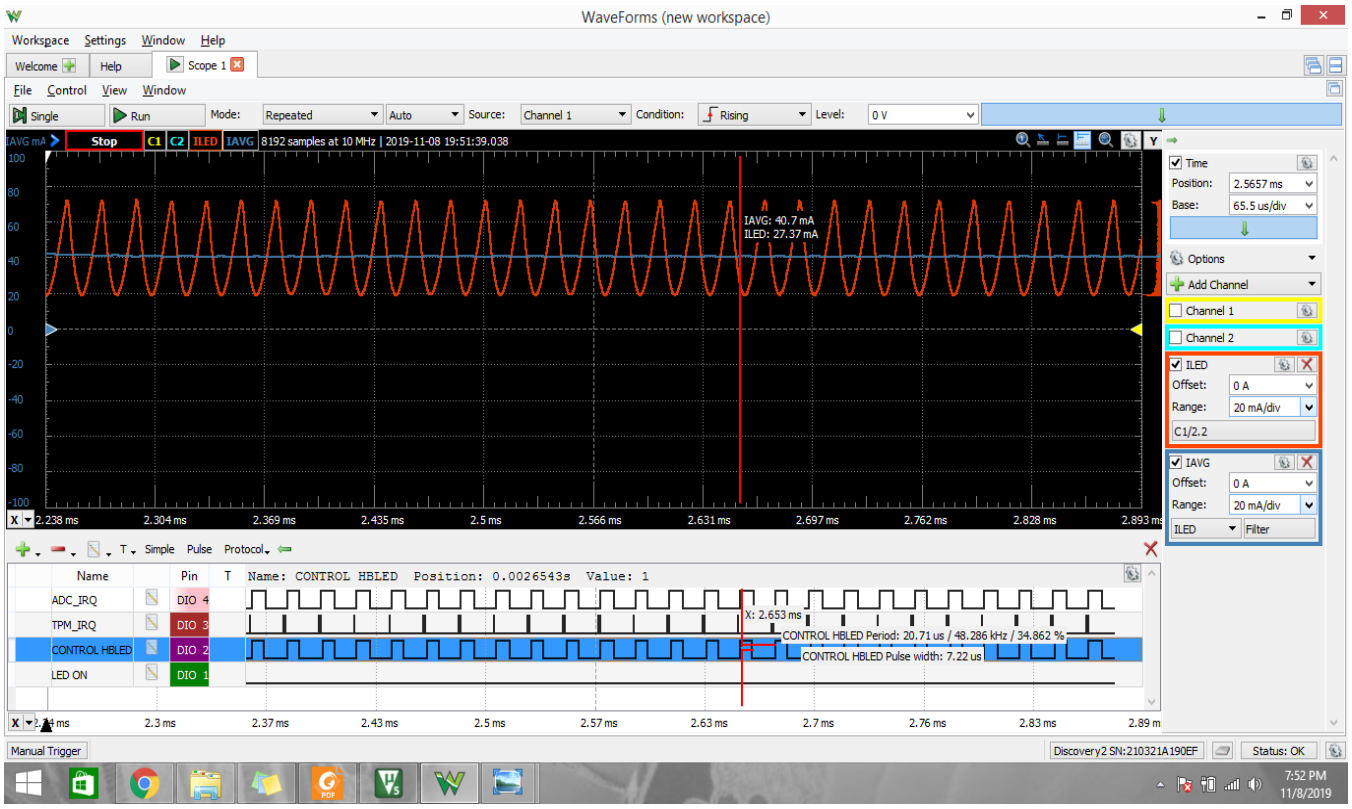
Incremental:



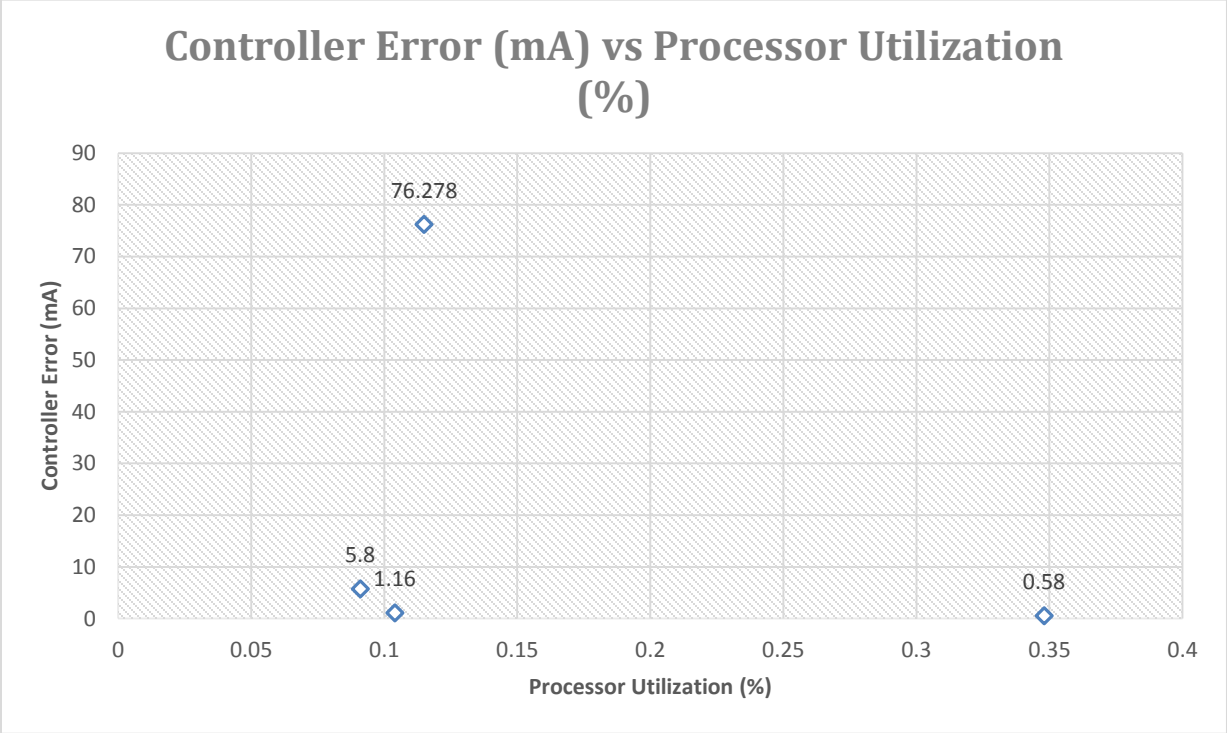
Proportional:



Fixed PID:



9. Create one scatter plot showing the controller error (mA, vertical) vs. processor utilization (%, horizontal) for the control approaches. Calculate processor utilization as Control_HBLED duration * control loop frequency.



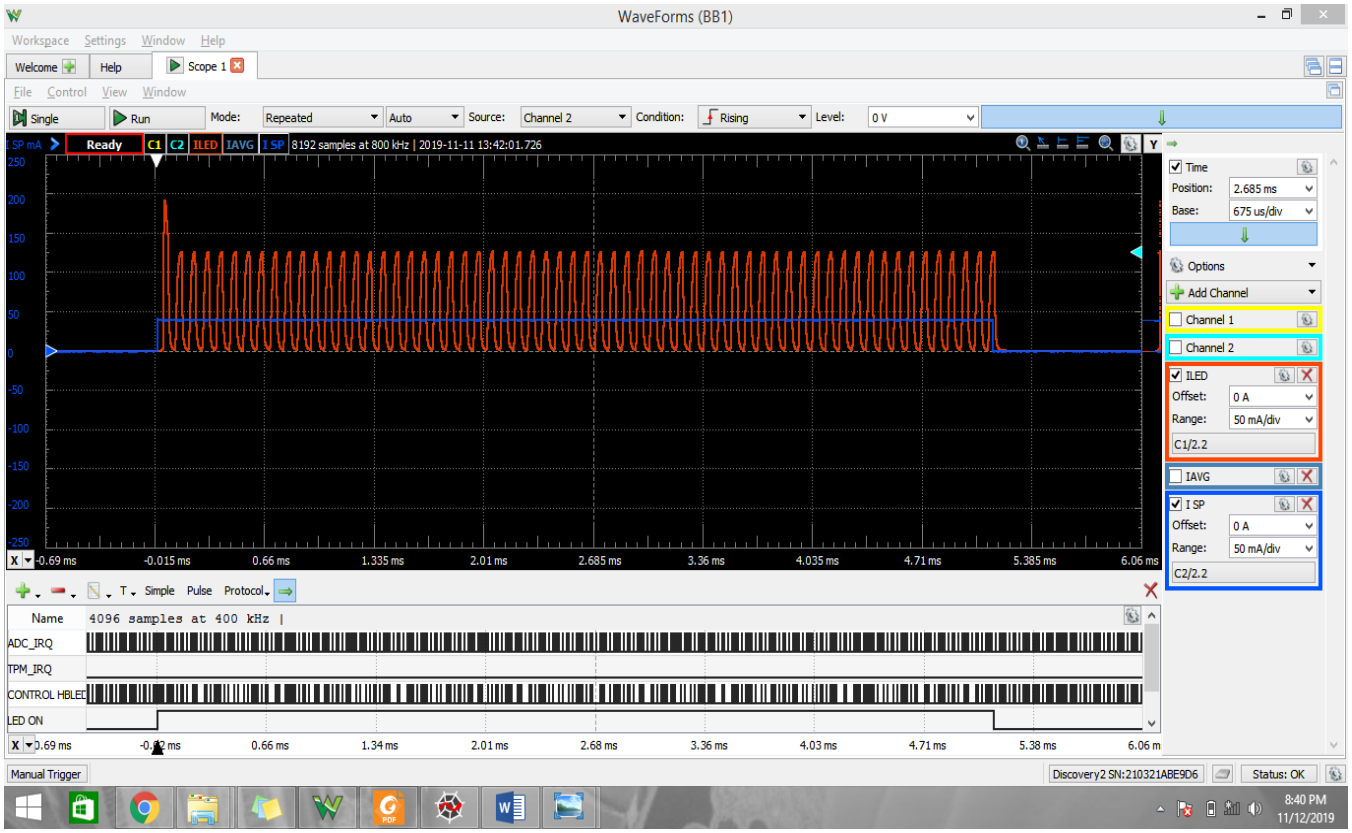
EVALUATING CLOSED-LOOP CONTROL WITH TRANSIENTS

10. Complete the following table. Change **g_control_mode** to select the different controllers. In the last column compute the maximum error due to the controller: (maximum I_{LED} minus minimum I_{LED}) minus the peak-to-peak I_{LED} ripple for the corresponding open-loop case (as you determined previously).

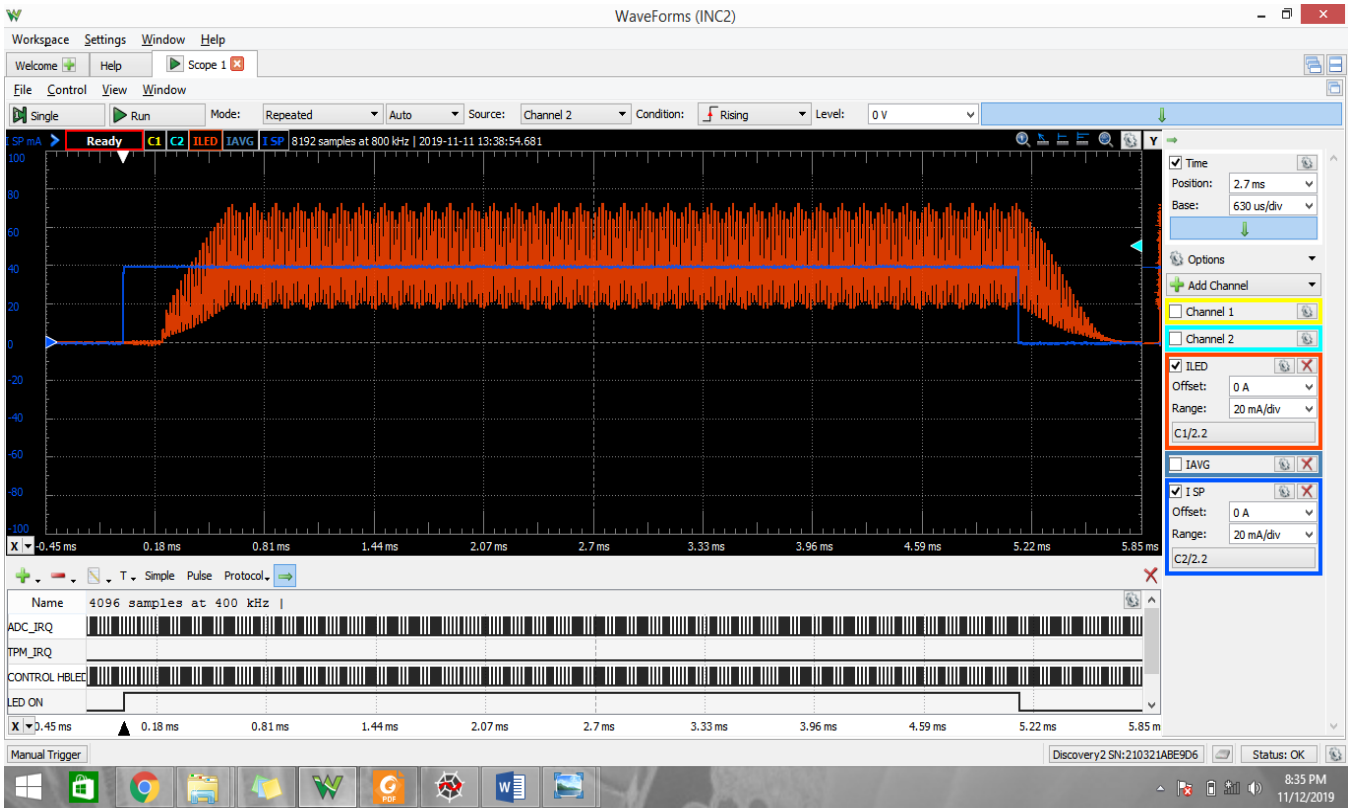
	Delay From $I_{setpoint}$ Change Until I_{LED} First Reaches $I_{Setpoint}$		**I_{LED_Max} (includes overshoot)**	**I_{LED_Ripple}**		**$I_{Steady\ State\ Controller\ Error}$**	
	0 to 40 mA	**40 to 0 mA**	**40 mA**	**40 mA**	**0 mA**	**40 mA**	**0 mA**
Bang-Bang	37.66 µs	64.58 µs	194.3	129.07	0	141.55	0
Incremental	374.8 µs	546.3 µs	72.83	51.087	0	1.019	0
Proportional	443.7 µs	2.035 ms	47.83	50.54	11.41	-2.75	11.41
Fixed Point PID	80.5 µs	289.6 µs	71.74	53.26	0	0.51	0

11. Take mixed-signal screenshots of I_{LED} showing one flash for each of the control methods and include them in your report.

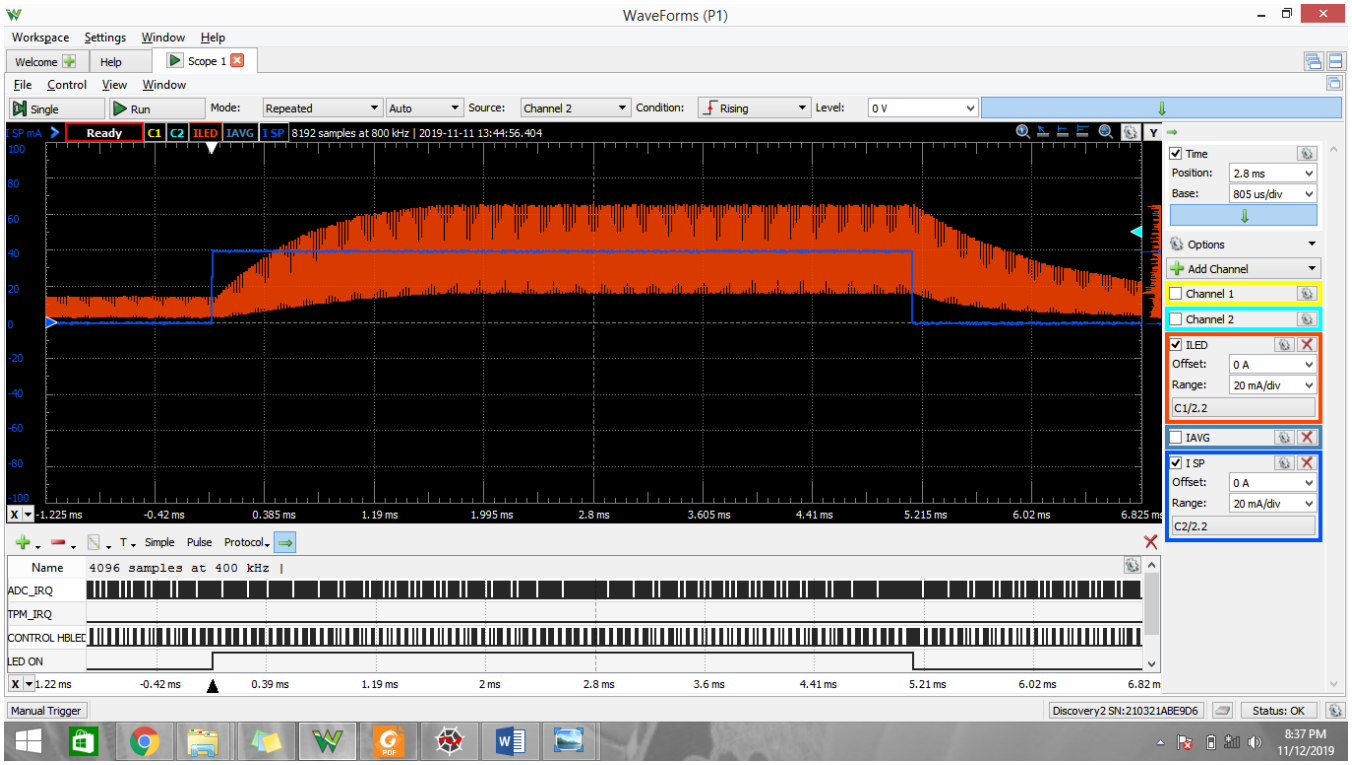
Bang-Bang:



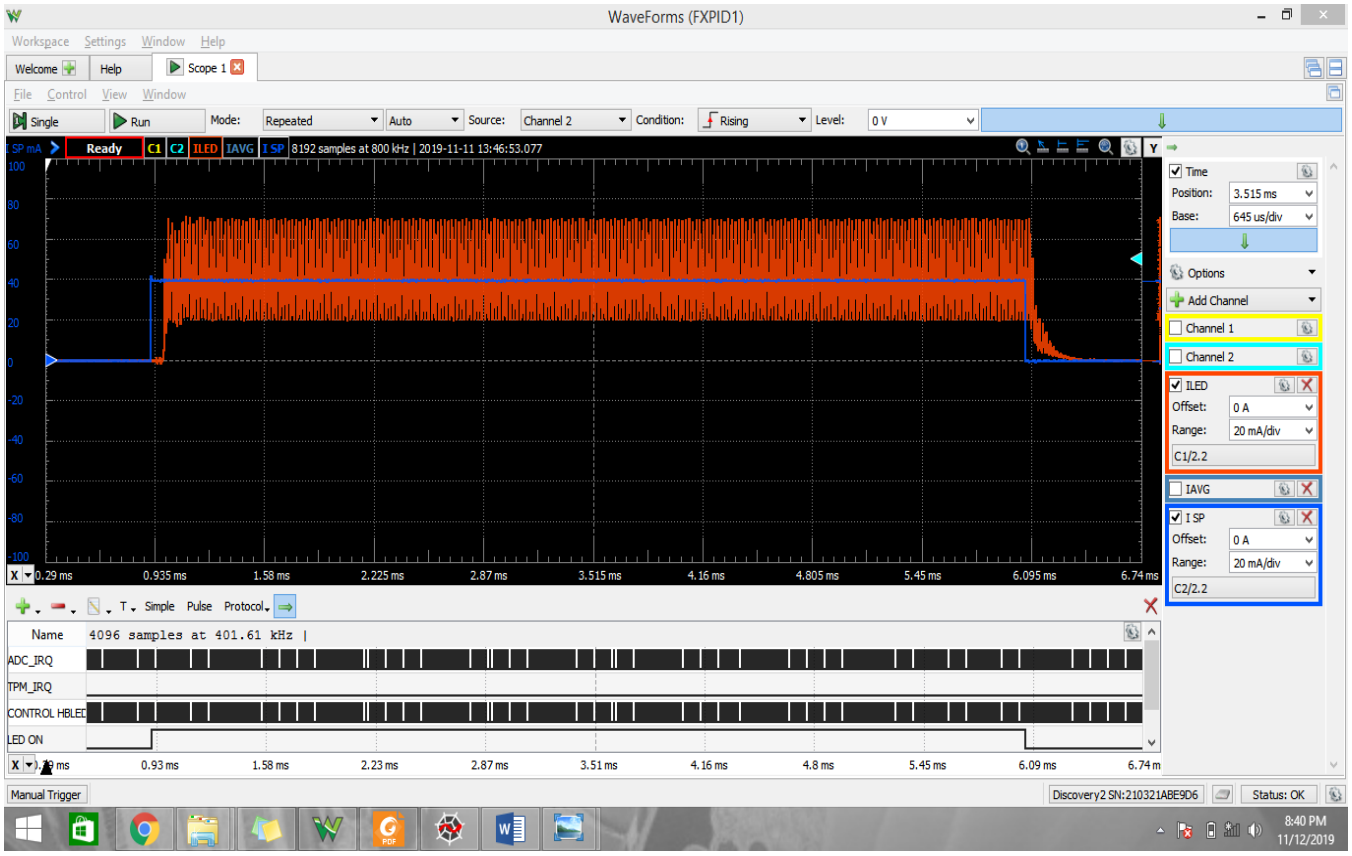
Incremental:



Proportional:



Fixed Point PID:



ECE 560 ONLY: IMPROVING CONTROL SYSTEM PERFORMANCE

RAISING SWITCHING AND CONTROL LOOP FREQUENCY

OPEN-LOOP AND CLOSED-LOOP WITHOUT TRANSIENTS

12. What is the new switching and control frequency? What is the open-loop ripple current for I_{LED} = 40 mA at this frequency? How does well does each controller work at its new frequency without transients (no HBLED flashing)? Complete the following table. Change **g_control_mode** to select the different controllers. Compute the maximum error due to the controller: (maximum I_{LED} minus minimum I_{LED}) minus the peak-to-peak I_{LED} ripple for the open-loop 40 mA case.

	Maximum $f_{control}$ and $f_{switching}$	**Minimum PWM_PERIOD**	**Open-Loop Ripple Current**	**Controller Error for I_{LED}**
Bang-Bang	Fs = 202.02 kHz Fc = 41.52 kHz	114	3.8043	57.5593
Incremental	Fs = 214.89 kHz Fc = 13.538 kHz	111	5.0272	42.7989
Proportional	Fs = 200 kHz Fc = 203.54 kHz	120	4.891	1.0873
Fixed Point PID	Fs = 65.789 kHz Fc = 64.778 kHz	365	32.0652	2.7174

CLOSED-LOOP WITH TRANSIENTS

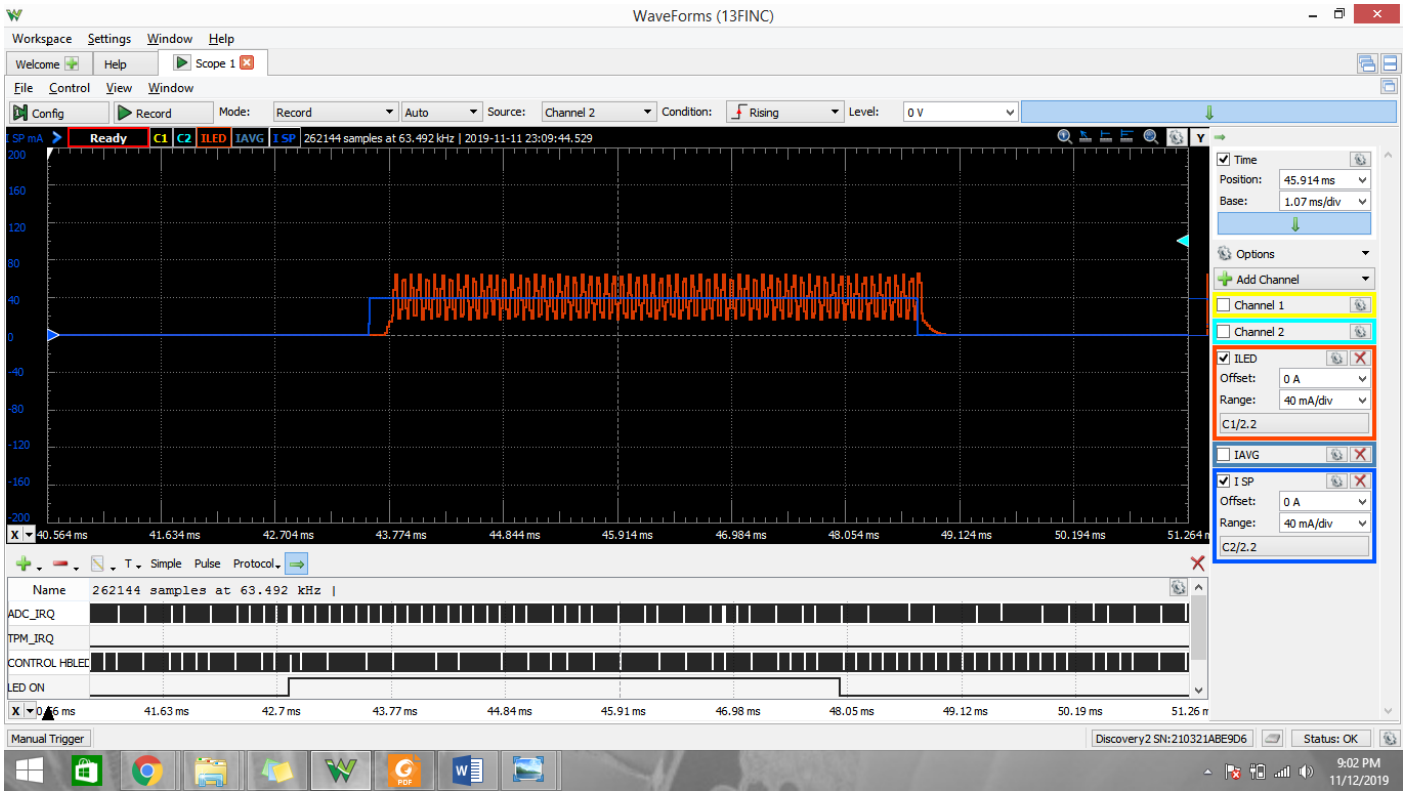
13. Complete the following table. Change **g_control_mode** to select the different controllers. In the last column compute the maximum error due to the controller: (maximum I_{LED} minus minimum I_{LED}) minus the peak-to-peak I_{LED} ripple for the corresponding open-loop case (as you determined previously).

	Delay From $I_{setpoint}$ Change Until I_{LED} First Reaches $I_{Setpoint}$		**I_{LED_Max} (includes overshoot)**	**I_{LED_Ripple}**		**$I_{Steady\ State\ Controller\ Error}$**	
	0 to 40 mA	**40 to 0 mA**	**40 mA**	**40 mA**	**0 mA**	**40 mA**	**0 mA**
Bang-Bang	20.1076	42.32	132.6	20.6522	0	17.93	0
Incremental	250.67	192.1	66.3	40.2174	0	35.19	0
Proportional	88.79	176	64.67	30.43	0	25.54	5.978
Fixed Point PID	75.1928	199.5	42.93	4.6196	0	27.46	0

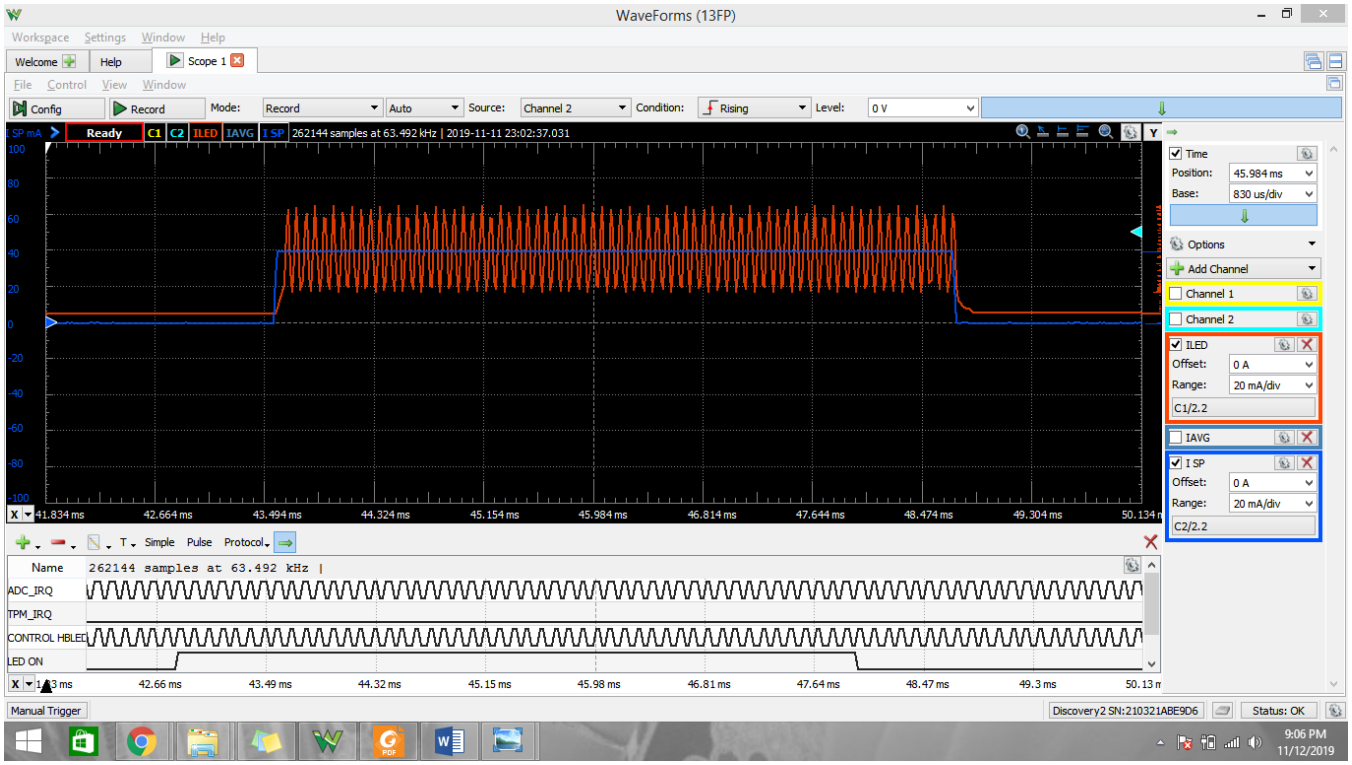
14. Take screenshots of I_{LED} showing one flash for each of the control methods and include them in your report.

Bang-Bang:

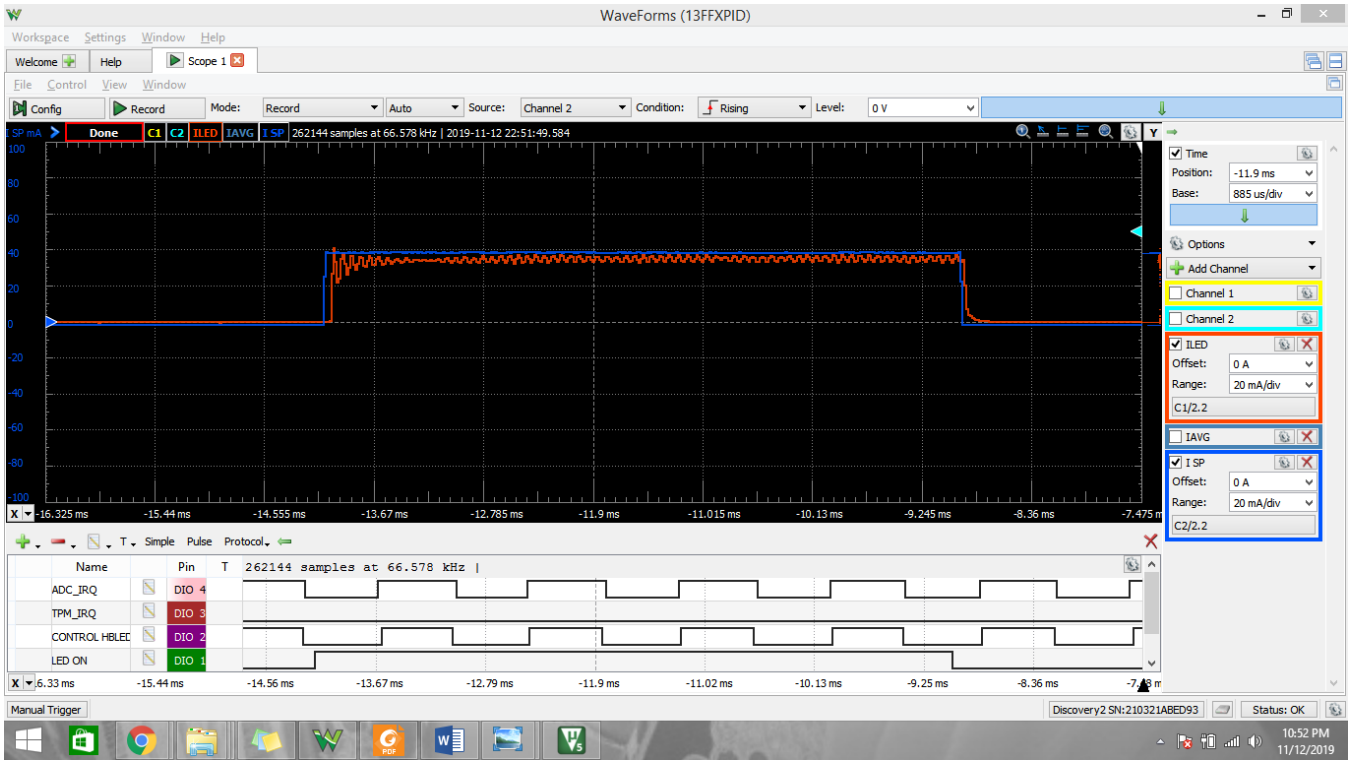
Incremental:



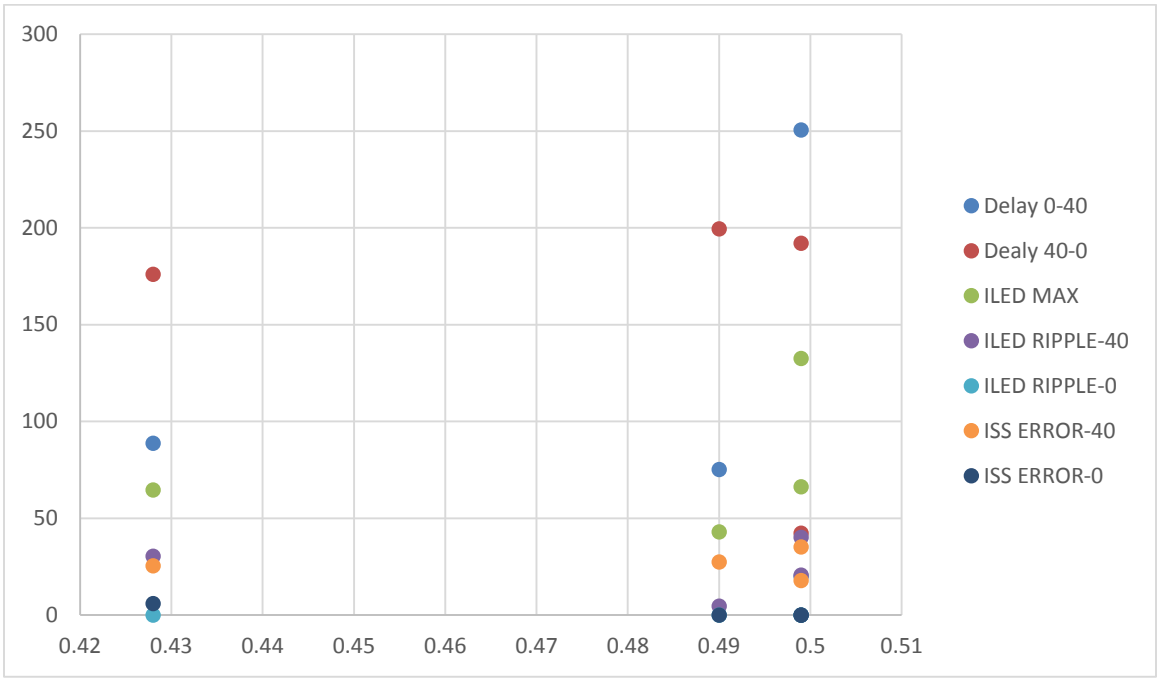
Proportional:



Fixed-Point PID:



15. Extra Credit: Create a scatter plots showing the parameters above (Delays, I_{LED_Max}, I_{LED_Ripple}, $I_{Steady\ State\ Controller\ Error}$) on the Y axis vs. CPU utilization on the X axis.


300
250
200
150
100
50
0
0.42
0.43
0.44
0.45
0.46
0.47
0.48
0.49
0.5
0.51
Delay 0-40
Dealy 40-0
ILED MAX
ILED RIPPLE-40
ILED RIPPLE-0
ISS ERROR-40
ISS ERROR-0