



32KHz CRYSTAL OSCILLATOR CHARACTERIZATION REPORT
PREPARED FOR: ATMEL
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Purpose:

- Recommend crystals for various Atmel micro controller designs
- Calculate effective load capacitance
- If external capacitive load is required, specify recommended load
- Measurements of safety factor, oscillator allowance, and negative resistance
- Crystal oscillator start up

Equipment used:

- LECROY LC684DXL
- HP E3631A
- HP 53131A
- TEKTRONIX P6245
- SAUNDERS 250B

Test procedure:

- Crystals are measured in Saunders 250B
- Crystals are mounted on characterization boards per 32 KHz crystal characterization board user guide
- For negative resistance/oscillator allowance, a variable resistor is added in series to the crystal unit. While power is applied, resistance is steadily increased until the oscillator fails. The resistance is then decreased until the oscillator resumes oscillation. The unit is power cycled to verify proper start up operation. The value of the series resistor and the ESR of the crystal are added to give the negative resistance/oscillator allowance.
- Safety factor is calculated by dividing the oscillator allowance by the specified maximum ESR of the crystal unit.
- Start up is recorded using a DSO
- Effective load capacitance is calculated using
$$C_L = \frac{F_R C_1}{2(F_L - F_R)} - C_0$$

Results and Conclusions:**BOARD/MCU: ATmega16/32 TQFP, ATmega16L**

- Effective IC and board load capacitance is approx. 20pF for all four crystals. The total load capacitance should be reduced by 7.5pF to 12.5pF.
- Only FSRLF crystal has an allowable Safety Factor (>5) for both VDD voltage levels.
- For start up see pages 5 and 6
- Because effective load capacitance and oscillator allowance/negative resistance are inversely related, decreasing the load capacitance will increase negative resistance/oscillator allowance, safety factor, and decrease start up time.

BOARD/MCU: ATmega64/128/169 TQFP, ATmega169

- Effective IC and board load capacitance is approx 6.5pF this capacitance should be increased by 6pF to 12.5pF
- All crystals have an allowable Safety factor (>5). with the FSRLF crystals having the highest and FX122 having the lowest
- For start up see pages 8 and 9
- Because effective load capacitance and oscillator allowance/negative resistance are inversely related, increasing the load capacitance will decrease negative resistance/oscillator allowance, safety factor, and increase start up time.

BOARD/MCU: ATmega164P/324P TQFP, ATmega164PA

- Effective IC and board load capacitance is approx 4.9pF this capacitance should be increased by 7.6pF to 12.5pF
- All crystals have an allowable Safety factor (>5). With the FSRLF crystals having the highest and FX122 having the lowest.
- For start up see pages 11 and 12
- Because effective load capacitance and oscillator allowance/negative resistance are inversely related, increasing the load capacitance will decrease negative resistance/oscillator allowance, safety factor, and increase start up time.

BOARD/MCU : ATmega16/32 TQFP, ATMEGA16L BOARD #1

Fundamental

Crystal Parameters					
Crystal	Freq (MHz)	C0 (pF)	C1(pF)	ESR (OHMS)	Max ESR spec
FSXLF XTAL #1	0.032765	0.88	0.001951679	46,040.44	65000.00
FX135 XTAL#2	0.032764	1.06	0.003089926	59,583.79	70000.00
FX122 XTAL #1	0.032761	1.35	0.006114381	71,046.47	90000.00
FSRLF XTAL #1	0.032765	1.13	0.002381928	20,605.32	50000.00

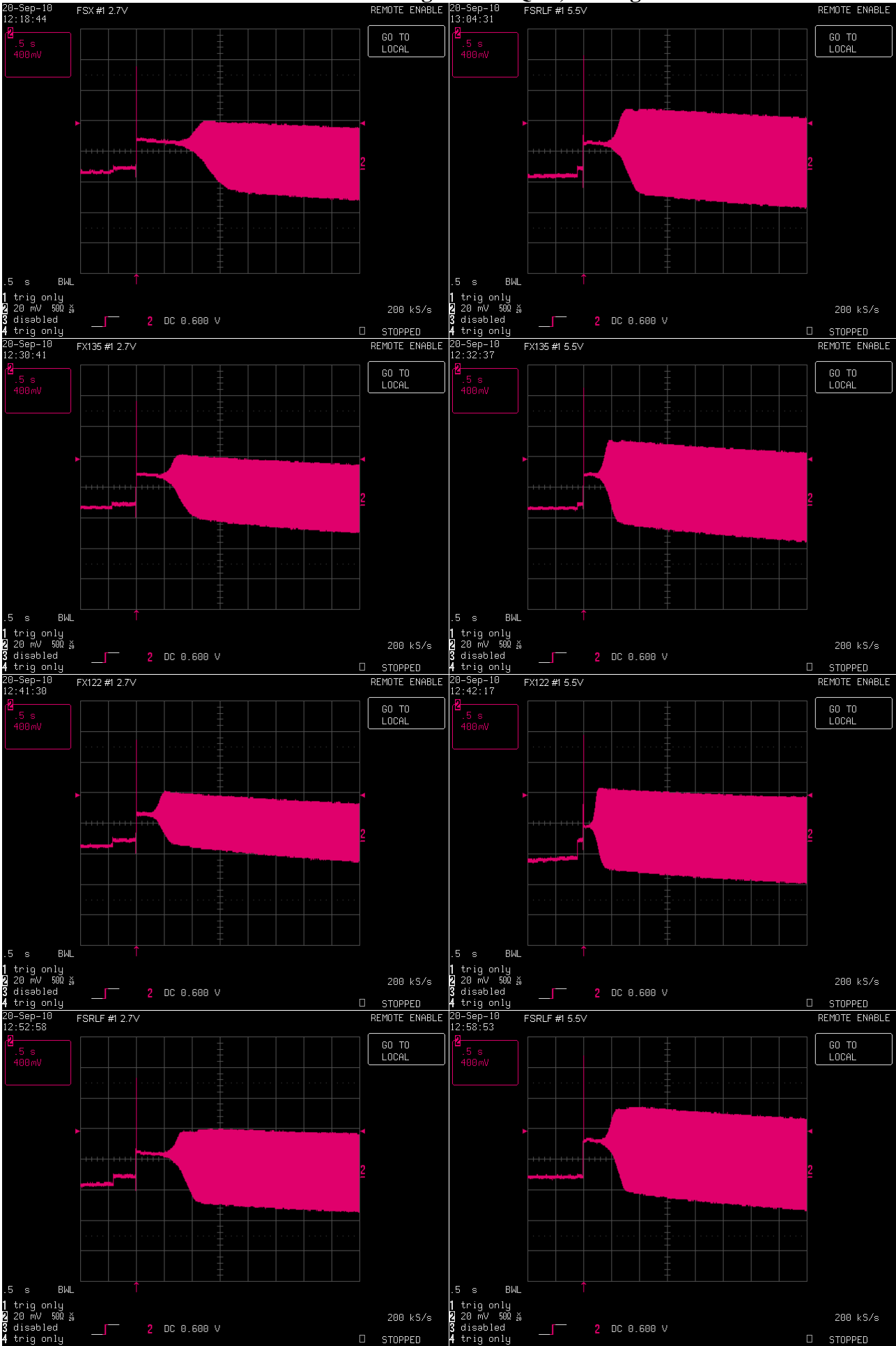
Measurements						
Crystal		Freq (MHz)	Calculated Board CL	Oscillator Allowance (Ω) or Neg Res (ohms) ¹	Series Resistor (Ω)	Safety Factor
	FSXLF XTAL #1	0.032767	21.2	188,940.44	142,900.00	2.91
	FSXLF XTAL #1	0.032767	19.1	380,040.44	334,000.00	5.85
	FX135 XTAL#2	0.032766	22.0	255,283.79	195,700.00	3.65
	FX135 XTAL#2	0.032767	18.8	447,383.79	387,800.00	6.39
	FX122 XTAL #1	0.032766	19.4	231,046.47	160,000.00	2.57
	FX122 XTAL #1	0.032766	18.2	453,446.47	382,400.00	5.04
	FSRLF XTAL #1	0.032766	21.8	285,265.32	264,660.00	5.71
	FSRLF XTAL #1	0.032767	20.0	460,005.32	439,400.00	9.20

BOARD/MCU : ATmega16/32 TQFP, ATMEGA16L BOARD #2

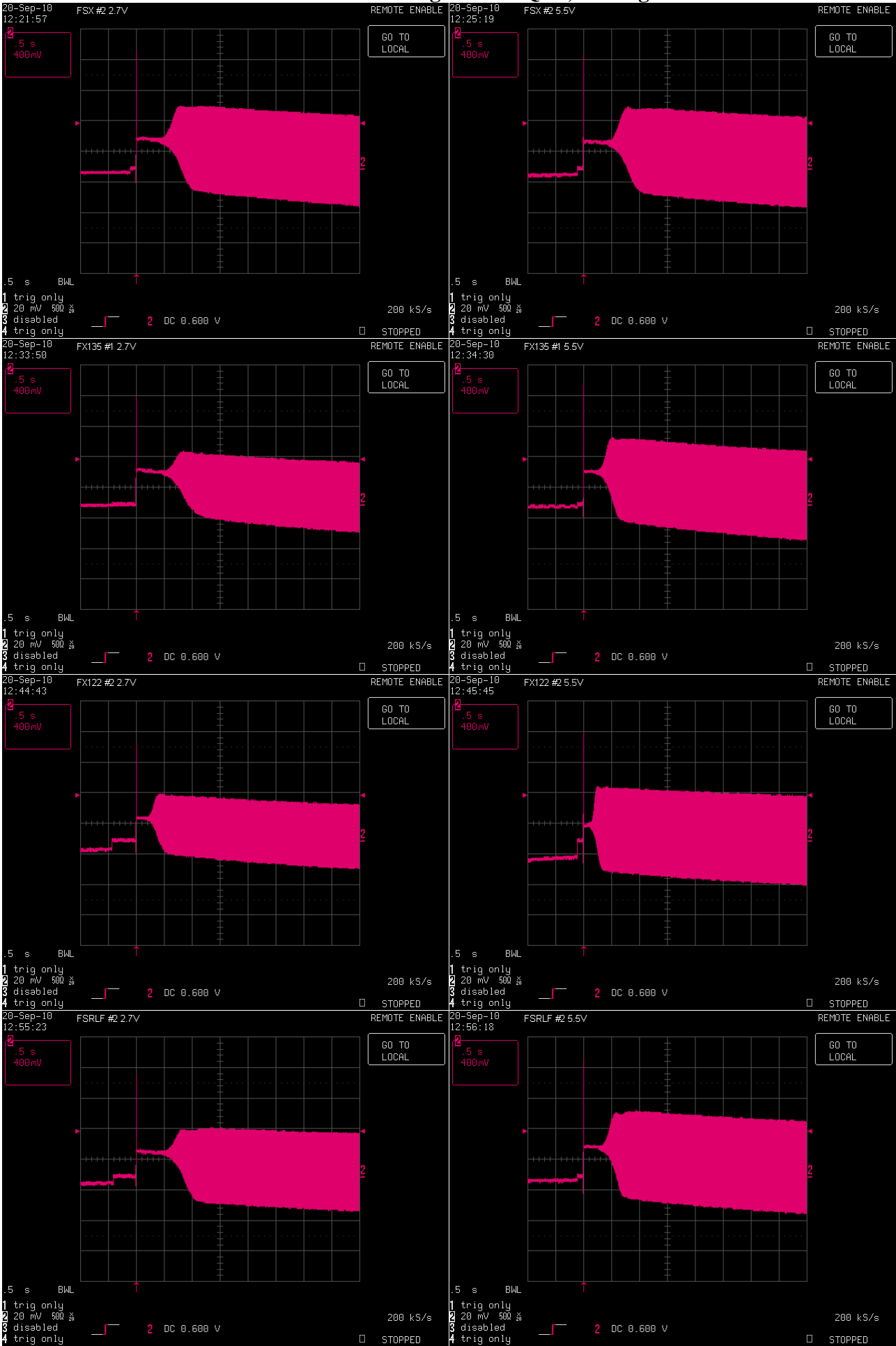
BOARD#003 : ATmega1632 TQFP, ATMECAT01E BOARD #2						
Crystal Parameters						
	Crystal	Freq (MHz)	C0 (pF)	C1(pF)	ESR (OHMS)	Max ESR spec
1	FSXLF XTAL #2	0.032765	0.92	0.001965248	53,881.96	65000.00
2	FX135 XTAL#3	0.032764	1.03	0.003167419	53,569.29	70000.00
3	FX 122 XTAL #2	0.032761	1.34	0.006200265	61,493.10	90000.00
4	FSRLF XTAL #3	0.032765	1.18	0.002511816	20,132.72	50000.00

	Measurements					
	Crystal	Freq (MHz)	Calculated Board CL	Oscillator Allowance (Ω) or Neg Res (ohms) ¹	Series Resistor (Ω)	Safety Factor
2.7V VDD	FSXLF XTAL #2	0.032767	19.4	253,221.96	199,340.00	3.90
5.5V VDD	FSXLF XTAL #2	0.032767	17.7	476,181.96	422,300.00	7.33
2.7V VDD	FX135 XTAL#3	0.032767	21.8	265,199.29	211,630.00	3.79
5.5V VDD	FX135 XTAL#3	0.032767	19.0	465,169.29	411,600.00	6.65
2.7V VDD	FX 122 XTAL #2	0.032765	21.4	264,063.10	202,570.00	2.93
5.5V VDD	FX 122 XTAL #2	0.032766	18.2	478,493.10	417,000.00	5.32
2.7V VDD	FSRLF XTAL #3	0.032767	21.1	272,297.72	252,165.00	5.45
5.5V VDD	FSRLF XTAL #3	0.032767	19.7	510,532.72	490,400.00	10.21

BOARD/MCU: ATmega16/32 TQFP, ATmega16L



BOARD/MCU: ATmega16/32 TQFP, ATmega16L



BOARD/MCU : ATMEGA 169 PART#1

Fundamental

Crystal Parameters					
Crystal	FR	C0 (pF)	C1(pF)	ESR (OHMS)	Max ESR spec
FSXLF XTAL #5	0.032766	0.88	0.001934729	49,355.91	65000.00
FX135 XTAL#6	0.032764	0.93	0.003071743	53,429.87	70000.00
FX 122 XTAL #5	0.032760	1.33	0.006382303	56,665.33	90000.00
FSRLF XTAL #5	0.032765	1.11	0.002342479	19,993.13	50000.00

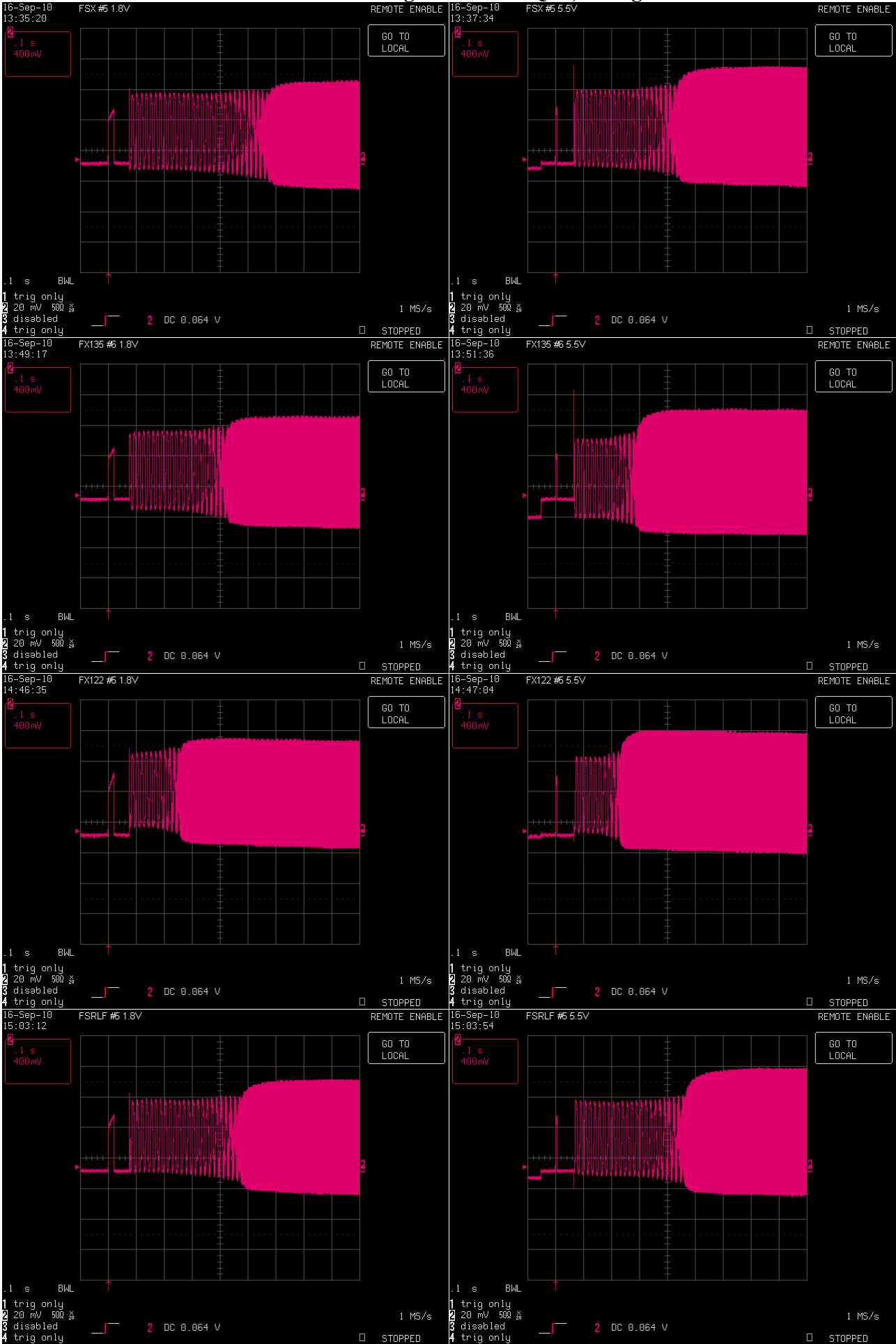
Measurements					
	Freq (MHz)	Calculated Board CL	Oscillator Allowance (Ω) or Neg Res (ohms) ¹	Series Resistor (Ω)	Safety Factor
FSXLF XTAL #5	0.032769	8.5	1,314,855.91	1,265,500.00	20.23
FSXLF XTAL #5	0.032771	5.2	1,457,055.91	1,407,700.00	22.42
FX135 XTAL#6	0.032770	8.5	1,024,729.87	971,300.00	14.64
FX135 XTAL#6	0.032773	5.1	1,220,129.87	1,166,700.00	17.43
FX 122 XTAL #5	0.032771	8.1	765,965.33	709,300.00	8.51
FX 122 XTAL #5	0.032777	4.8	10,431,665.33	10,375,000.00	115.91
FSRLF XTAL #5	0.032768	10.2	845,293.13	825,300.00	16.91
FSRLF XTAL #5	0.032771	5.5	1,408,193.13	1,388,200.00	28.16

BOARD/MCU : ATMEGA 169 PART#2

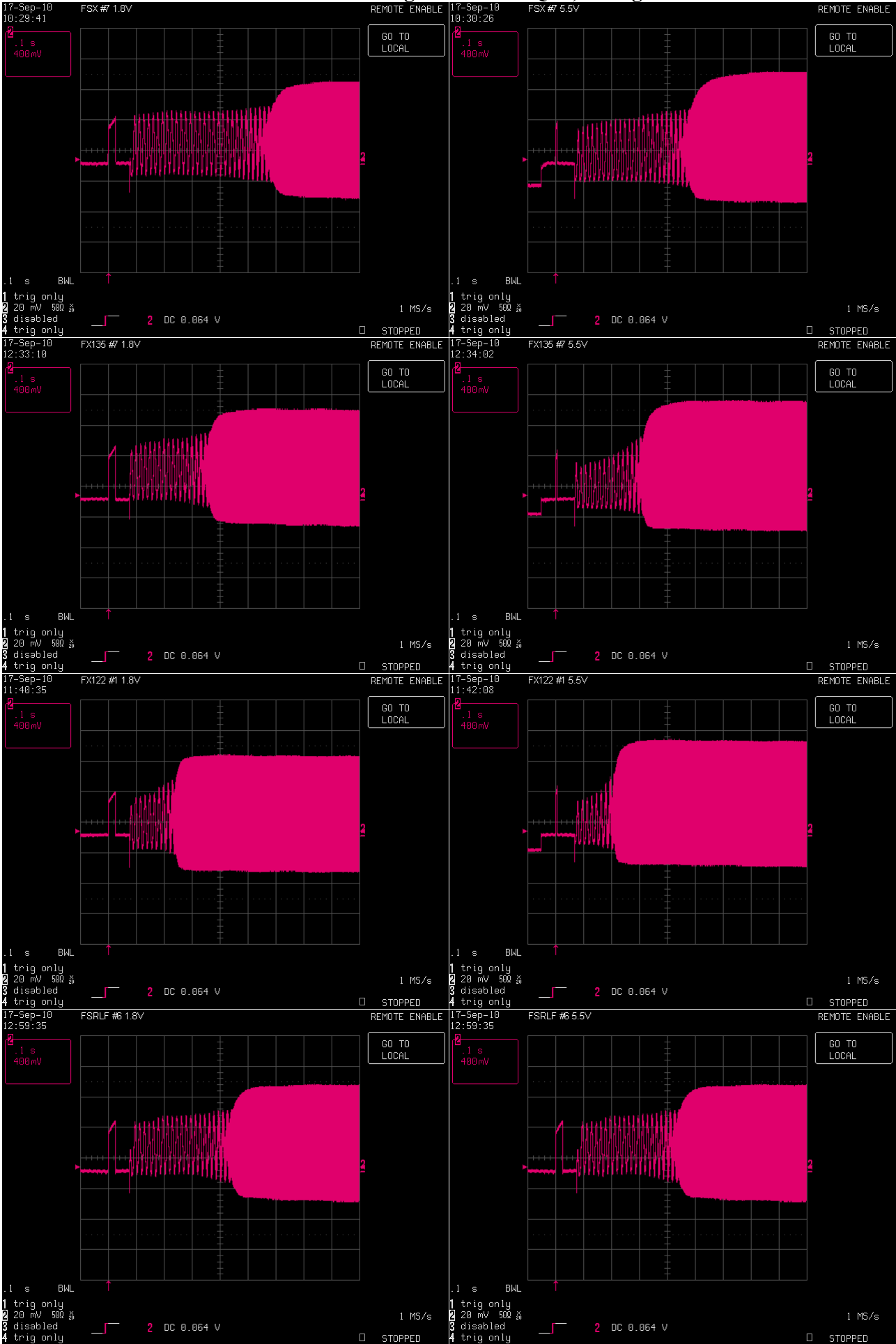
Crystal Parameters					
Crystal	FR	C0 (pF)	C1(pF)	ESR (OHMS)	Max ESR spec
FSXLF XTAL #7	0.032766	0.95	0.001932473	55,583.64	65000.00
FX135 XTAL#7	0.032764	1.00	0.003164797	59,238.12	70000.00
FX122 XTAL #1	0.032761	1.35	0.006114381	71,046.47	90000.00
FSRLF XTAL #6	0.032765	1.13	0.00240517	21,340.62	50000.00

Measurements					
Crystal	Freq (MHz)	Calculated Board CL	Oscillator Allowance (Ω) or Neg Res (ohms) ¹	Series Resistor (Ω)	Safety Factor
FSXLF XTAL #7	0.032769	7.5	925,283.64	869,700.00	14.24
FSXLF XTAL #7	0.032771	4.5	1,202,583.64	1,147,000.00	18.50
FX135 XTAL#7	0.032770	8.0	964,938.12	905,700.00	13.78
FX135 XTAL#7	0.032773	4.6	1,346,638.12	1,287,400.00	19.24
FX122 XTAL #1	0.032774	6.4	820,546.47	749,500.00	9.12
FX122 XTAL #1	0.032780	3.8	1,307,746.47	1,236,700.00	14.53
FSRLF XTAL #6	0.032768	10.0	1,027,140.62	1,005,800.00	20.54
FSRLF XTAL #6	0.032771	5.3	1,478,940.62	1,457,600.00	29.58

BOARD/MCU:ATmega64/128/169TQFP,ATmega169



BOARD/MCU:ATmega64/128/169TQFP,ATmega169



BOARD/MCU : ATMEGA164PA PART#1

Fundamental

Crystal Parameters					
Crystal	FR	C0 (pF)	C1(pF)	ESR (OHMS)	Max ESR spec
FSXLF XTAL #3	0.032765	0.92	0.001944462	51,382.30	65000.00
FX135 XTAL#4	0.032764	1.15	0.003330528	56,535.90	70000.00
FX 122 XTAL #3	0.032761	1.38	0.006384225	74,475.38	90000.00
FSRLF XTAL #3	0.032765	1.18	0.002511816	20,132.72	50000.00

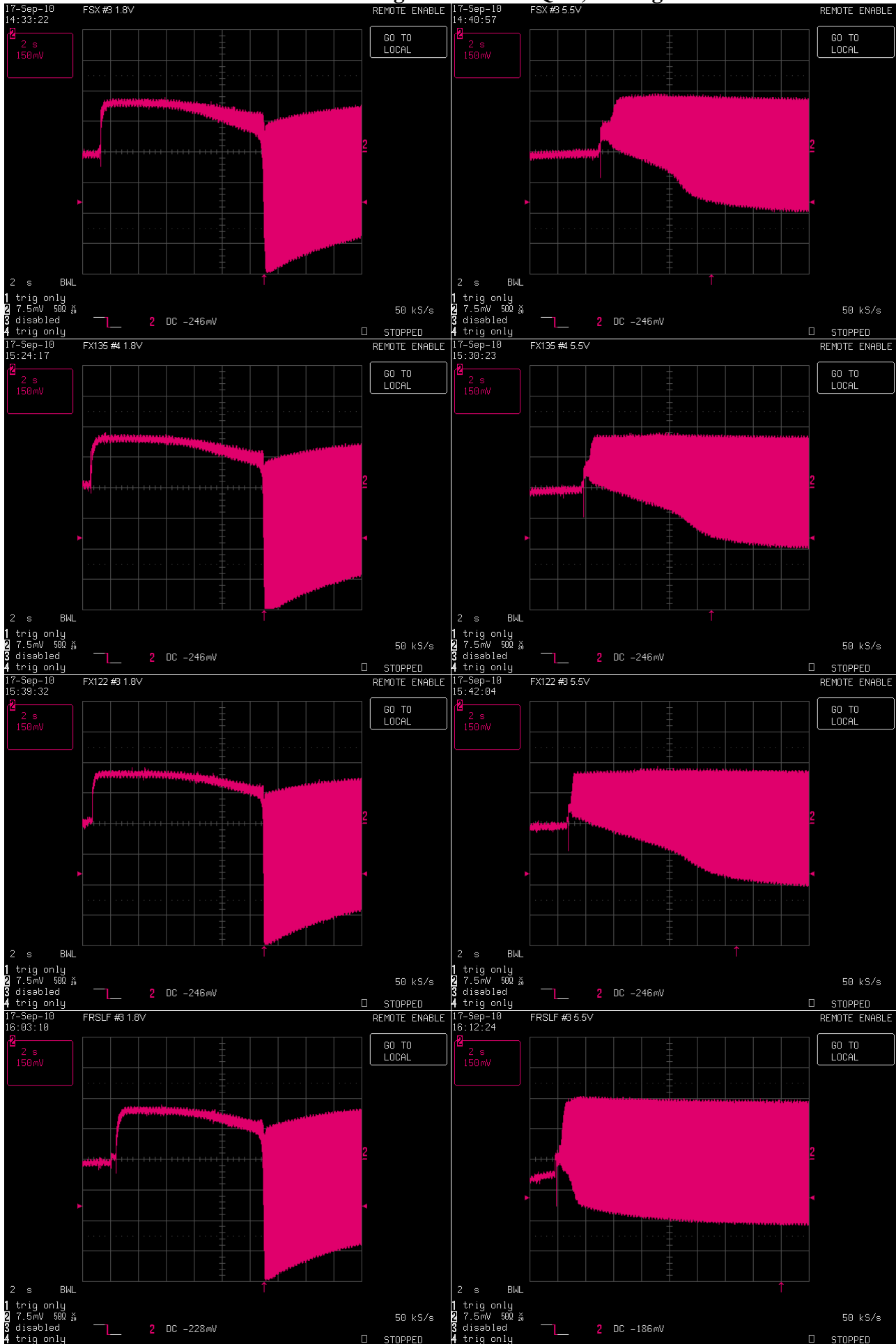
	Measurements					
	Crystal	Freq (MHz)	Calculated Board CL	Oscillator Allowance (Ω) or Neg Res (ohms) ¹	Series Resistor (Ω)	Safety Factor
1.8V VDD	FSXLF XTAL #3	0.032771	4.7	539,782.30	488,400.00	8.30
5.5V VDD	FSXLF XTAL #3	0.032771	4.3	750,282.30	698,900.00	11.54
1.8V VDD	FX135 XTAL#4	0.032773	5.0	470,235.90	413,700.00	6.72
5.5V VDD	FX135 XTAL#4	0.032774	4.4	670,035.90	613,500.00	9.57
1.8V VDD	FX 122 XTAL #3	0.032776	5.3	606,175.38	531,700.00	6.74
5.5V VDD	FX 122 XTAL #3	0.032778	4.7	1,045,375.38	970,900.00	11.62
1.8V VDD	FSRLF XTAL #3	0.032771	5.3	923,832.72	903,700.00	18.48
5.5V VDD	FSRLF XTAL #3	0.032772	4.7	989,932.72	969,800.00	19.80

BOARD/MCU : ATMEGA164PA PART#2

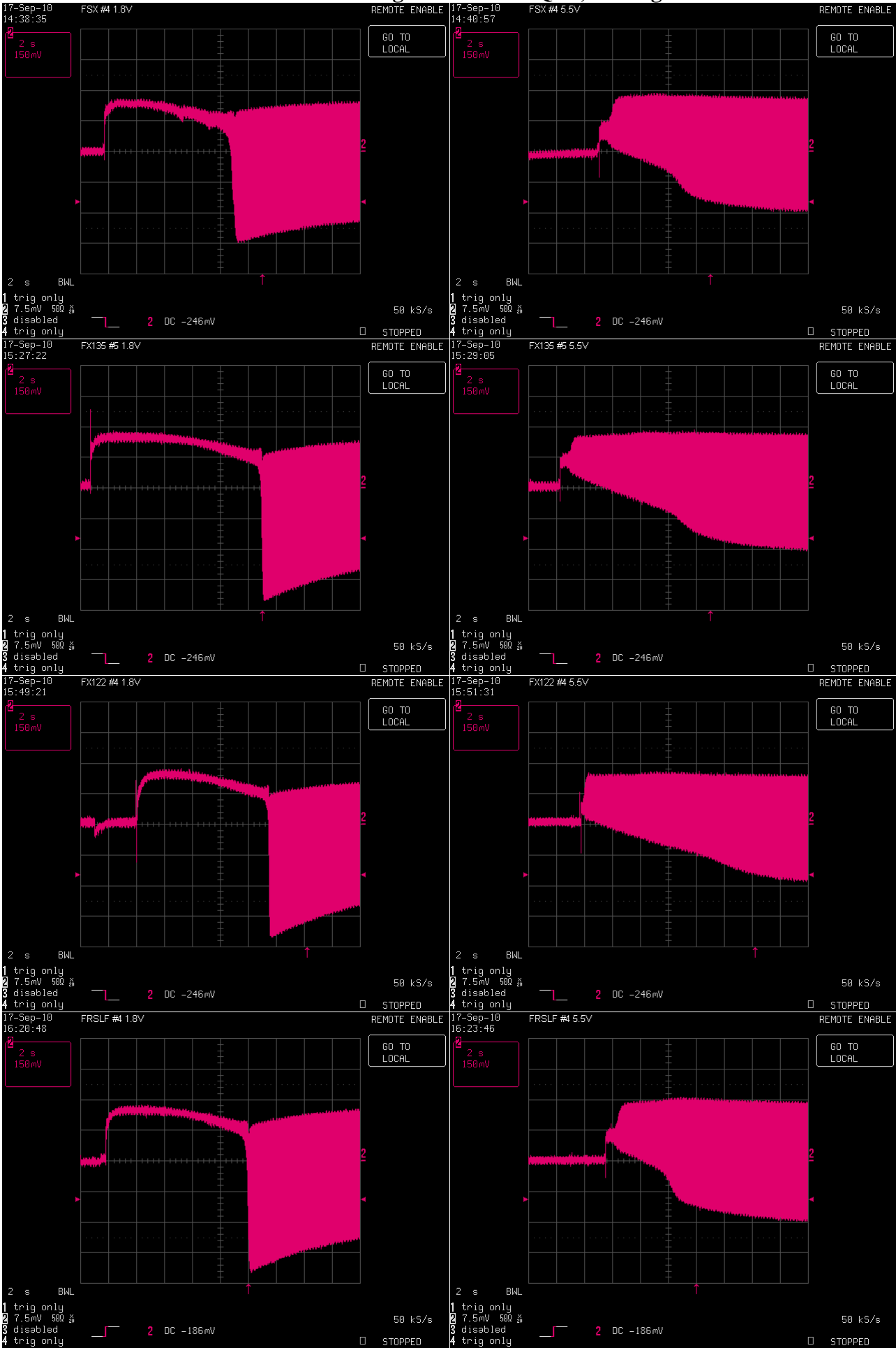
Crystal Parameters					
Crystal	FR	C0 (pF)	C1(pF)	ESR (OHMS)	Max ESR spec
FSXLF XTAL #4	0.032766	0.88	0.001961677	49,156.32	65000.00
FX135 XTAL#5	0.032764	1.03	0.003183966	62,203.16	70000.00
FX 122 XTAL #4	0.032760	1.37	0.006327751	58,624.63	90000.00
FSRLF XTAL #4	0.032765	1.13	0.002381009	19,282.84	50000.00

	Measurements					
	Crystal	Freq (MHz)	Calculated Board CL	Oscillator Allowance (Ω) or Neg Res (ohms) ¹	Series Resistor (Ω)	Safety Factor
	FSXLF XTAL #4	0.032771	5.4	675,256.32	626,100.00	10.39
	FSXLF XTAL #4	0.032771	4.9	922,256.32	873,100.00	14.19
	FX135 XTAL#5	0.032772	5.2	823,503.16	761,300.00	11.76
	FX135 XTAL#5	0.032773	4.6	933,103.16	870,900.00	13.33
	FX 122 XTAL #4	0.032777	4.9	739,524.63	680,900.00	8.22
	FX 122 XTAL #4	0.032778	4.4	874,024.63	815,400.00	9.71
	FSRLF XTAL #4	0.032771	5.4	874,982.84	855,700.00	17.50
	FSRLF XTAL #4	0.032771	4.8	989,382.84	970,100.00	19.79

BOARD/MCU: ATmega164P/324P TQFP, ATmega164PA



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