



**32.768KHz CRYSTAL OSCILLATOR CHARACTERIZATION REPORT**  
**PREPARED FOR: ATMEL**  
**FEBRUARY 25, 2011**

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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 (INTERNAL CAPACITORS DISABLED)**

- Effective IC and board load capacitance is approx. 20.5pF for all four crystals. The total load capacitance should be reduced by 7.0pF in order to obtain 12.5pF Load Capacitance. \*
- 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: ATXMEGAA1 crystal chara board / ATXMEGA64A1**

- Effective IC and board load capacitance is approx 3.45pF this capacitance should be increased by 9.5pF in order to obtain 12.5pF Load Capacitance.
- All crystals have an allowable Safety factor ( $>5$ ). with the FSRLF crystals having the highest.
- 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: ATXMEGAA1 crystal chara board / ATXMEGA128A1 (low power mode)**

- Effective IC and board load capacitance is approx 4.2pF this capacitance should be increased by 8.3pF in order to obtain 12.5pF Load Capacitance.
- The FX122 is the only crystal without an allowable Safety factor ( $>5$ ). FSRLF has the highest in the test
- FSXLF crystal was only tested on board#1 because board#2 was permanently damaged during testing.
- 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.

\* This result was unexpected, because disabling the internal load capacitors should have lowered load capacitance.

BOARD/MCU : ATmega16/32 TQFP, ATMEGA16L BOARD #1 (INTERNAL CAPACITORS DISABLED)

Crystal Parameters					
Crystal	Freq (MHz)	C0 (pF)	C1(pF)	ESR (OHMS)	Max ESR spec
FSXLF XTAL #1	0.032766	1.04	0.0019538	53,875.28	65000.00
FX135 XTAL#1	0.032764	1.17	0.003282	50,058.59	70000.00
FX122 XTAL #1	0.032761	1.44	0.005880	64,741.46	90000.00
FSRLF XTAL #1	0.032765	1.30	0.002472	18,883.31	50000.00

Measurements					
Crystal	Freq (MHz)	Calculated Board CL (pF)	Oscillator Allowance (Ω) or Neg Res (ohms) <sup>1</sup>	Series Resistor (Ω)	Safety Factor
FSXLF XTAL #1	0.032767	21.4	298,155.28	244,280.00	4.59
FSXLF XTAL #1	0.032768	19.4	401,975.28	348,100.00	6.18
FX135 XTAL#1	0.032766	22.1	344,458.59	294,400.00	4.92
FX135 XTAL#1	0.032767	19.8	398,858.59	348,800.00	5.70
FX122 XTAL #1	0.032765	22.5	309,741.46	245,000.00	3.44
FX122 XTAL #1	0.032765	20.2	384,141.46	319,400.00	4.27
FSRLF XTAL #1	0.032766	22.5	302,333.31	283,450.00	6.05
FSRLF XTAL #1	0.032767	21.0	401,283.31	382,400.00	8.03

2.7V VDD

5.5V VDD

2.7V VDD

5.5V VDD

2.7V VDD

5.5V VDD

2.7V VDD

5.5V VDD

BOARD/MCU : ATmega16/32 TQFP, ATMEGA16L BOARD #2 (INTERNAL CAPACITORS DISABLED)

Crystal Parameters					
Crystal	Freq (MHz)	C0 (pF)	C1(pF)	ESR (OHMS)	Max ESR spec
FSXLF XTAL #2	0.032766	1.09	0.0019648	47,545.98	65000.00
FX135 XTAL#2	0.032764	1.18	0.003065	62,979.96	70000.00
FX122 XTAL #2	0.032761	1.45	0.006063	63,960.65	90000.00
FSRLF XTAL #2	0.032765	1.31	0.002390	18,832.11	50000.00

Measurements					
Crystal	Freq (MHz)	Calculated Board CL (pF)	Oscillator Allowance (Ω) or Neg Res (ohms) <sup>1</sup>	Series Resistor (Ω)	Safety Factor
FSXLF XTAL #2	0.032767	18.8	331,805.98	284,260.00	5.10
FSXLF XTAL #2	0.032767	17.2	437,165.98	389,620.00	6.73
FX135 XTAL#2	0.032766	21.5	341,559.96	278,580.00	4.88
FX135 XTAL#2	0.032767	19.1	426,109.96	363,130.00	6.09
FX122 XTAL #2	0.032765	21.5	343,360.65	279,400.00	3.82
FX122 XTAL #2	0.032766	19.1	421,760.65	357,800.00	4.69
FSRLF XTAL #2	0.032767	21.5	360,312.11	341,480.00	7.21
FSRLF XTAL #2	0.032767	20.1	444,022.11	425,190.00	8.88

2.7V VDD

5.5V VDD

2.7V VDD

5.5V VDD

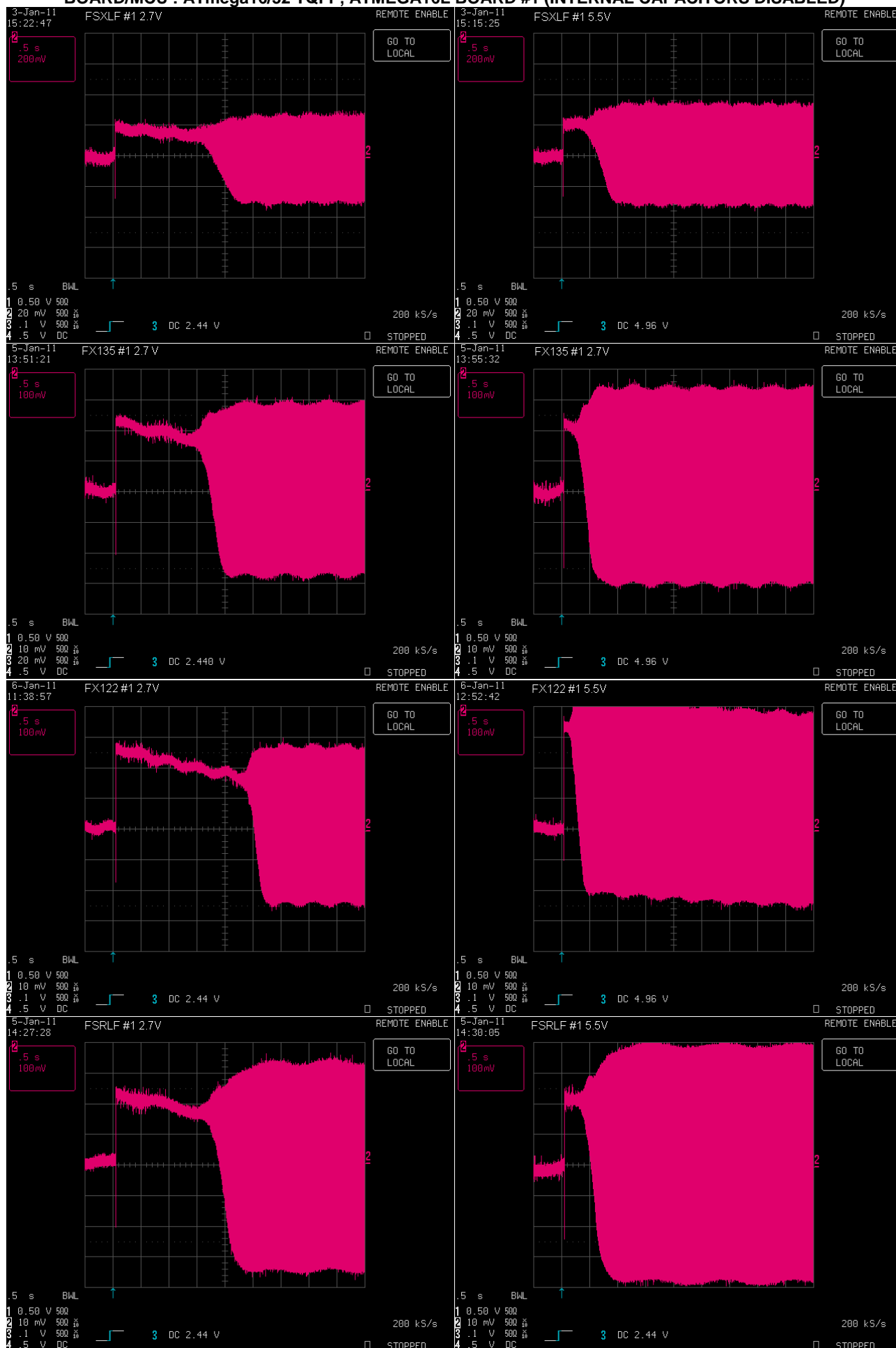
2.7V VDD

5.5V VDD

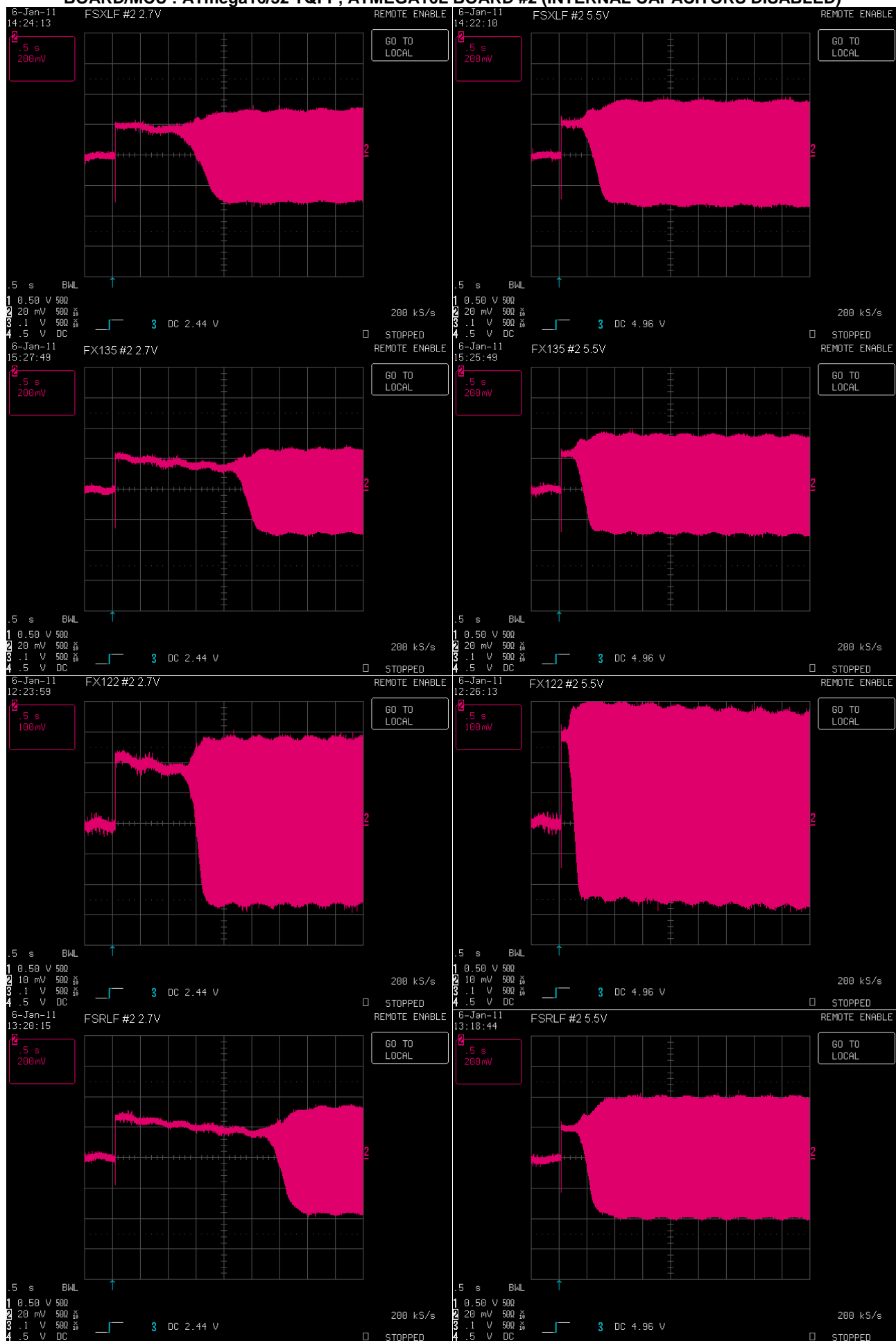
2.7V VDD

5.5V VDD

## BOARD/MCU : ATmega16/32 TQFP, ATMEGA16L BOARD #1 (INTERNAL CAPACITORS DISABLED)



## BOARD/MCU : ATmega16/32 TQFP, ATMEGA16L BOARD #2 (INTERNAL CAPACITORS DISABLED)



## BOARD/MCU : ATxmegaA1 crystal chara board / ATXMEGA64A1 BOARD #1

Crystal Parameters					
Crystal	Freq (MHz)	C0 (pF)	C1(pF)	ESR (OHMS)	Max ESR spec
FSXLF XTAL #5	0.032765	1.06	0.001999	47,744.26	65000.00
FX135 XTAL #5	0.032764	1.21	0.003255	52,579.30	70000.00
FX122 XTAL #5	0.032761	1.46	0.005976	67,049.62	90000.00
FSRLF XTAL #5	0.032765	1.30	0.002572	20,561.14	50000.00

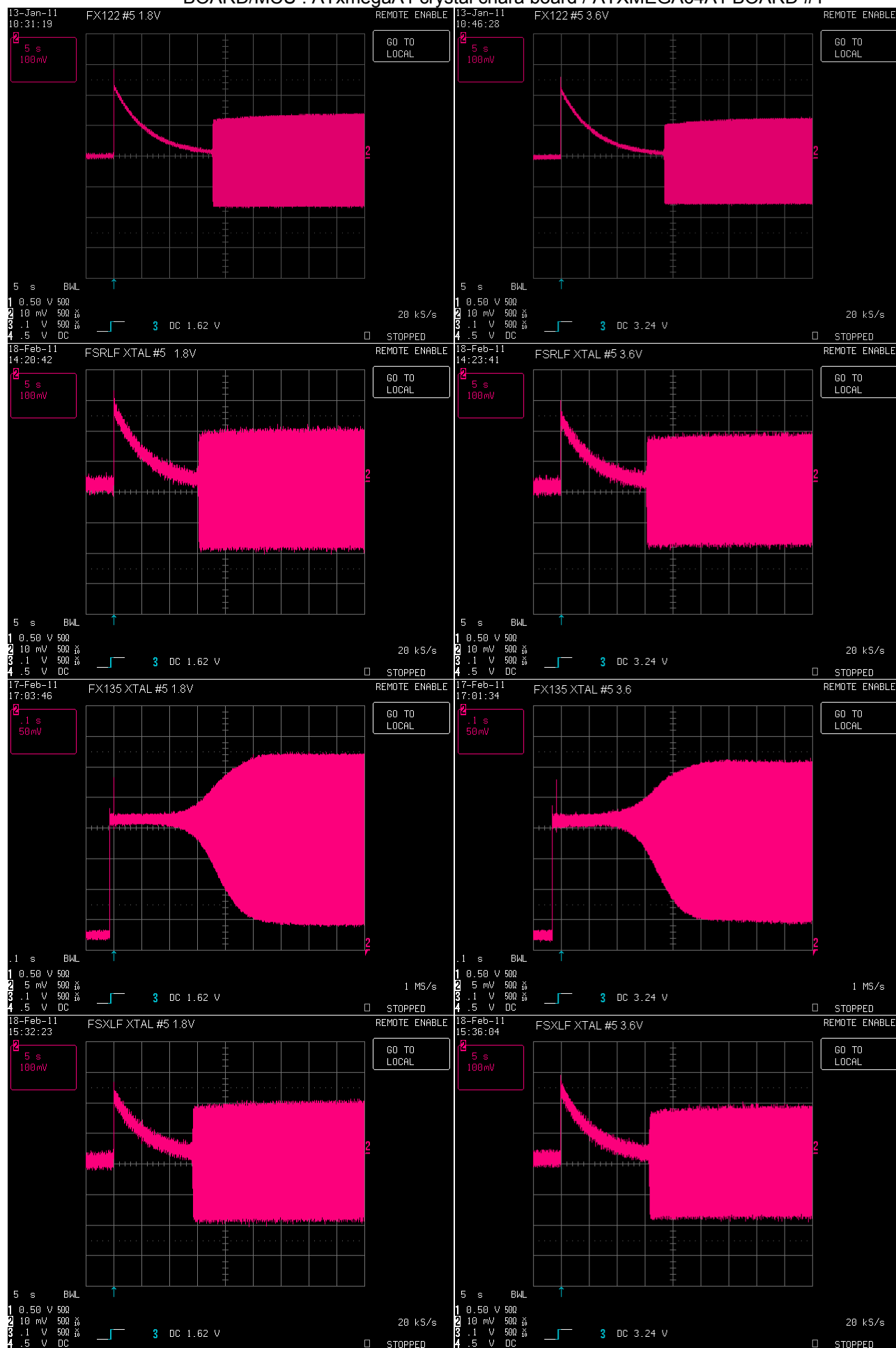
	Measurements					
	Crystal	Freq (MHz)	Calculated Board CL (pF)	Oscillator Allowance (Ω) or Neg Res (ohms) <sup>1</sup>	Series Resistor (Ω)	Safety Factor
1.8V VDD	FSXLF XTAL #5	0.032772	3.5	1,820,344.26	1,772,600.00	28.01
3.6V VDD	FSXLF XTAL #5	0.032773	3.1	1,972,144.26	1,924,400.00	30.34
1.8V VDD	FX135 XTAL #5	0.032776	3.3	1,573,179.30	1,520,600.00	22.47
3.6V VDD	FX135 XTAL #5	0.032775	3.6	1,632,579.30	1,580,000.00	23.32
1.8V VDD	FX122 XTAL #5	0.032781	3.3	2,541,349.62	2,474,300.00	28.24
3.6V VDD	FX122 XTAL #5	0.032783	3.0	2,675,449.62	2,608,400.00	29.73
1.8V VDD	FSRLF XTAL #5	0.032773	3.6	1,631,361.14	1,610,800.00	32.63
3.6V VDD	FSRLF XTAL #5	0.032774	3.3	1,734,961.14	1,714,400.00	34.70

## BOARD/MCU : ATxmegaA1 crystal chara board / ATXMEGA64A1 BOARD #2

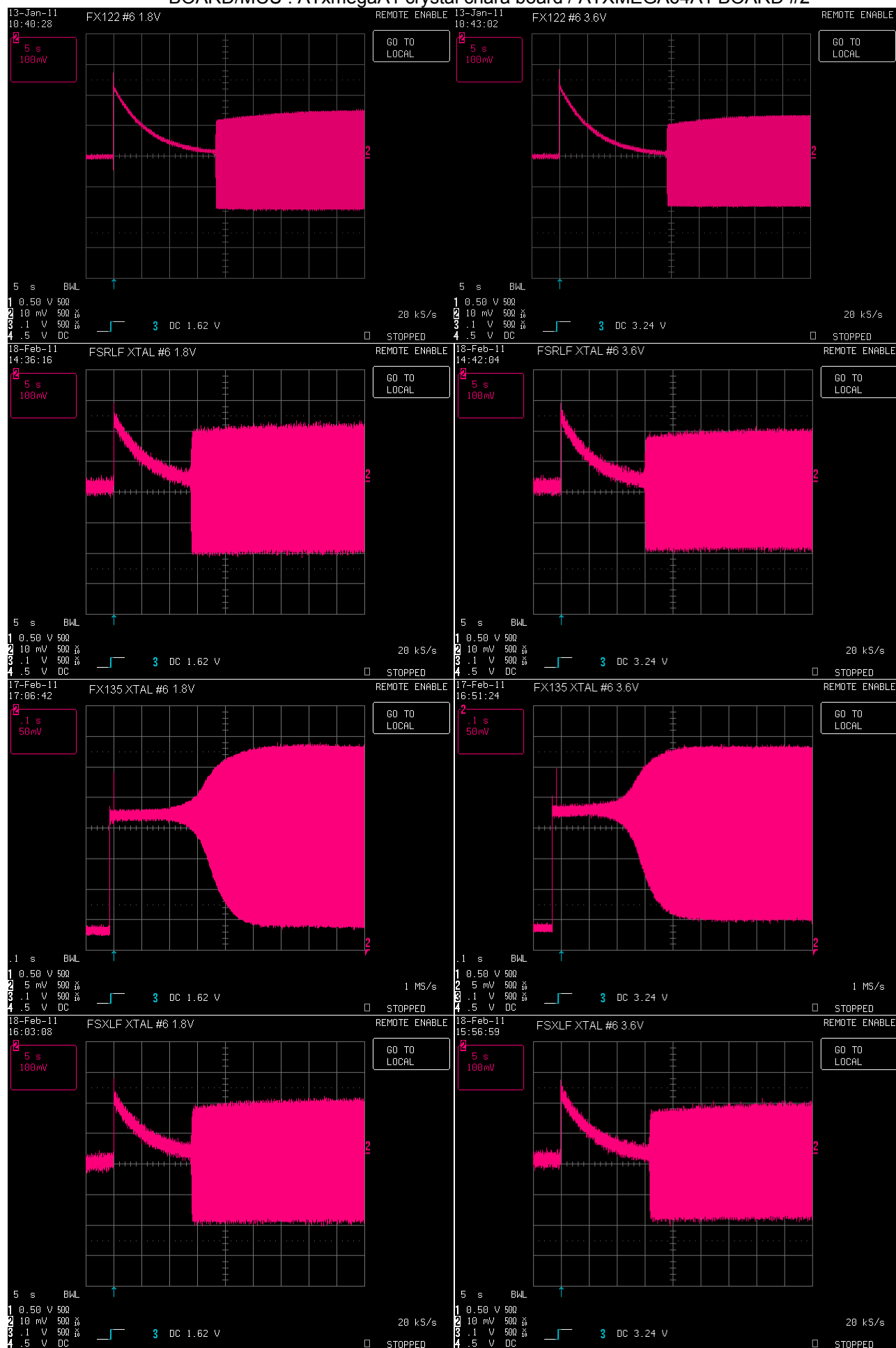
BOARD #001 : ATXMEGA16C1 Crystal Oscillator Board / ATXMEGA16C1 AT BOARD #12						
Crystal Parameters						
	Crystal	Freq (MHz)	C0 (pF)	C1(pF)	ESR (OHMS)	Max ESR spec
1	FSXLF XTAL #6	0.032766	1.12	0.001964	49,522.11	65000.00
2	FX135 XTAL #6	0.032764	1.16	0.003215	53,458.82	70000.00
3	FX122 XTAL #6	0.032761	1.42	0.005731	68,490.89	90000.00
4	FSRLF XTAL #6	0.032765	1.30	0.002414	21,381.65	50000.00

	Measurements					
	Crystal	Freq (MHz)	Calculated Board CL (pF)	Oscillator Allowance (Ω) or Neg Res (ohms) <sup>1</sup>	Series Resistor (Ω)	Safety Factor
1.8V VDD	FSXLF XTAL #6	0.032772	3.6	1,573,522.11	1,524,000.00	24.21
3.6V VDD	FSXLF XTAL #6	0.032773	3.3	1,787,922.11	1,738,400.00	27.51
1.8V VDD	FX135 XTAL #6	0.032774	4.2	1,729,958.82	1,676,500.00	24.71
3.6V VDD	FX135 XTAL #6	0.032774	4.0	1,766,958.82	1,713,500.00	25.24
1.8V VDD	FX122 XTAL #6	0.032783	2.9	2,050,190.89	1,981,700.00	22.78
3.6V VDD	FX122 XTAL #6	0.032782	3.0	2,220,290.89	2,151,800.00	24.67
1.8V VDD	FSRLF XTAL #6	0.032773	3.8	1,946,181.65	1,924,800.00	38.92
3.6V VDD	FSRLF XTAL #6	0.032773	3.4	2,191,281.65	2,169,900.00	43.83

BOARD/MCU : ATxmegaA1 crystal chara board / ATXMEGA64A1 BOARD #1



## BOARD/MCU : ATxmegaA1 crystal chara board / ATXMEGA64A1 BOARD #2



## BOARD/MCU : ATXMEGAA1 crystal chara board / ATXMEGA128A1 BOARD #1 (low power mode)

Crystal Parameters					
Crystal	Freq (MHz)	C0 (pF)	C1(pF)	ESR (OHMS)	Max ESR spec
FSXLF XTAL #3	0.032765	1.33	0.0025652	18,035.41	65000.00
FX135 XTAL #3	0.032764	1.25	0.003291	50,344.74	70000.00
FX122 XTAL #3	0.032761	1.50	0.006120	62,089.75	90000.00
FSRLF XTAL #3	0.032766	1.03	0.001921	52,496.34	50000.00

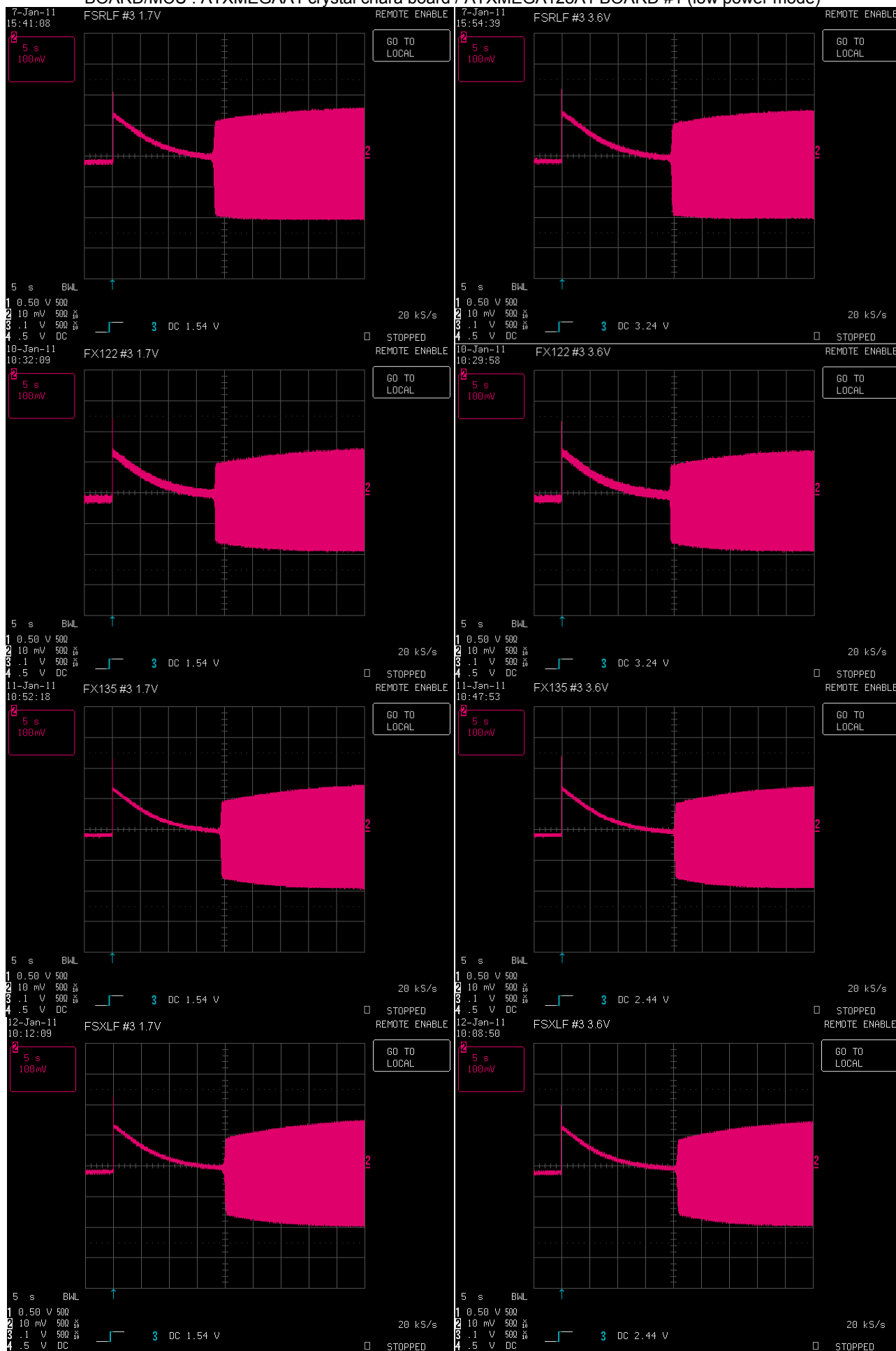
	Measurements					
	Crystal	Freq (MHz)	Calculated Board CL (pF)	Oscillator Allowance ( $\Omega$ ) or Neg Res (ohms) <sup>1</sup>	Series Resistor ( $\Omega$ )	Safety Factor
1.7V VDD	FSXLF XTAL #3	0.032772	4.9	615,835.41	597,800.00	9.47
3.6V VDD	FSXLF XTAL #3	0.032772	4.7	797,235.41	779,200.00	12.27
1.7V VDD	FX135 XTAL #3	0.032774	4.3	798,594.74	748,250.00	11.41
3.6V VDD	FX135 XTAL #3	0.032774	4.0	1,016,144.74	965,800.00	14.52
1.7V VDD	FX122 XTAL #3	0.032778	4.6	385,649.75	323,560.00	4.28
3.6V VDD	FX122 XTAL #3	0.032778	4.3	583,859.75	521,770.00	6.49
1.7V VDD	FSRLF XTAL #3	0.032772	3.8	740,416.34	687,920.00	14.81
3.6V VDD	FSRLF XTAL #3	0.032772	3.6	885,496.34	833,000.00	17.71

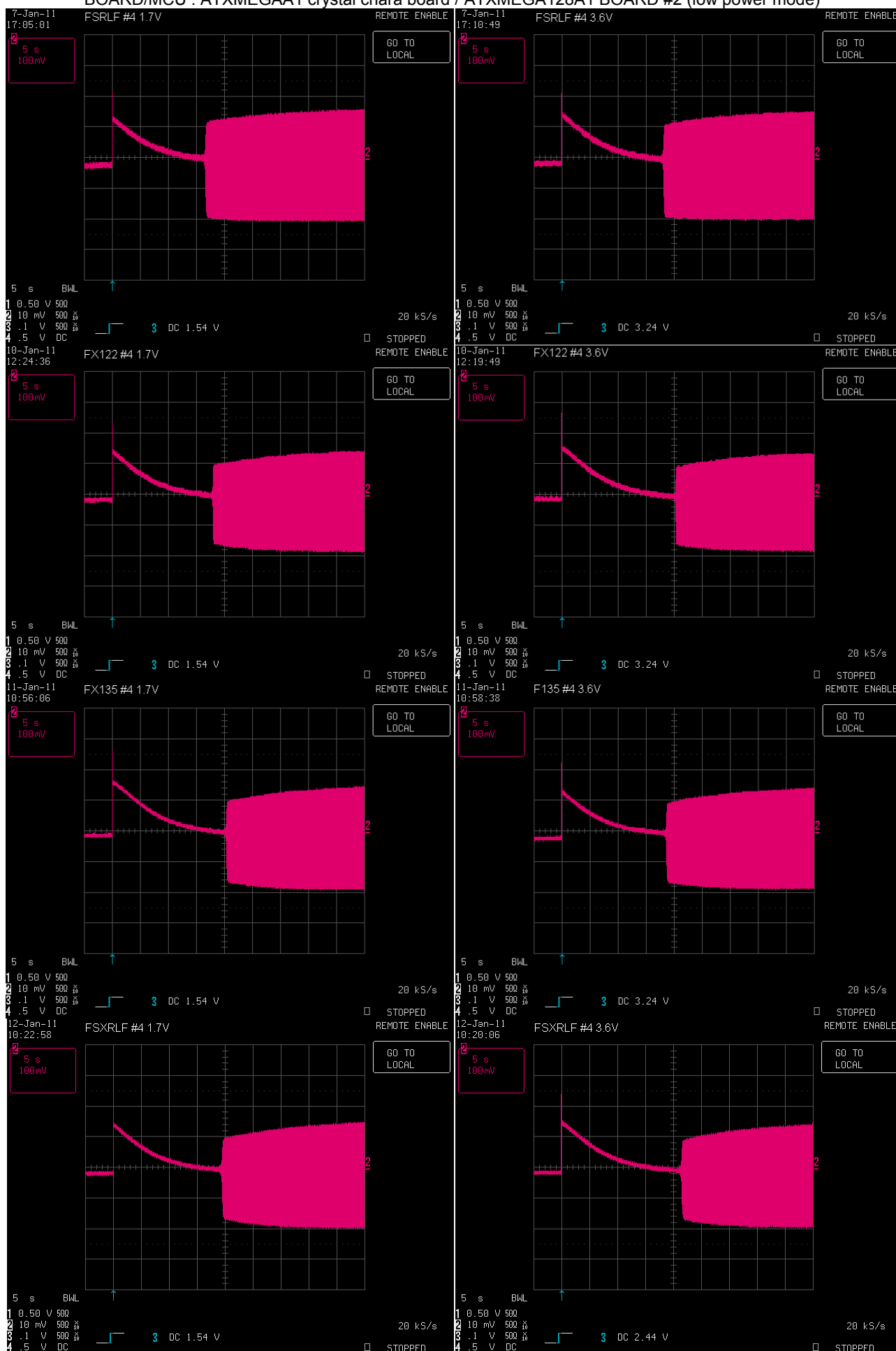
## BOARD/MCU : ATXMEGAA1 crystal chara board / ATXMEGA128A1 BOARD #2 (low power mode)

Crystal Parameters						
	Crystal	Freq (MHz)	C0 (pF)	C1(pF)	ESR (OHMS)	Max ESR spec
1	FSXLF XTAL #4	0.032766	1.04	0.0019794	48,459.99	65000.00
2	FX135 XTAL #4	0.032764	1.14	0.003195	52,854.61	70000.00
3	FX122 XTAL #4	0.032761	1.51	0.006019	64,843.27	90000.00
4	FSRLF XTAL #4	0.032765	1.29	0.002614	17,829.26	50000.00

	Measurements					
	Crystal	Freq (MHz)	Calculated Board CL (pF)	Oscillator Allowance ( $\Omega$ ) or Neg Res (ohms) <sup>1</sup>	Series Resistor ( $\Omega$ )	Safety Factor
1.7V VDD	FSXLF XTAL #4	0.032772	4.2	48,459.99		
3.6V VDD	FSXLF XTAL #4	0.032772	4.0	48,459.99		
1.7V VDD	FX135 XTAL #4	0.032774	4.2	369,144.61	316,290.00	5.27
3.6V VDD	FX135 XTAL #4	0.032775	3.8	666,704.61	613,850.00	9.52
1.7V VDD	FX122 XTAL #4	0.032778	4.3	586,273.27	521,430.00	6.51
3.6V VDD	FX122 XTAL #4	0.032779	4.0	703,193.27	638,350.00	7.81
1.7V VDD	FSRLF XTAL #4	0.032772	4.3	952,729.26	934,900.00	19.05
3.6V VDD	FSRLF XTAL #4	0.032773	4.1	981,929.26	964,100.00	19.64

BOARD/MCU : ATXMEGAA1 crystal chara board / ATXMEGA128A1 BOARD #1 (low power mode)







**32.768KHz CRYSTAL OSCILLATOR CHARACTERIZATION REPORT**  
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**February 25, 2011**

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