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TLSI W614 Laser Characterization

Kansas City Division

M. N. Rector

KCP-613-5397

Published August 1994

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TLSI W614 LASER CHARACTERIZATION

M. N. Rector

Published August 1994

**Technical Communications
Kansas City Division**

Contents

<i>Section</i>	<i>Page</i>
Abstract	1
Summary	1
Discussion	2
Scope and Purpose	2
Activity	2
Trimming Discontinuities	2
Kerf Craters	2
Optimization for Thick Film Resistors	3
Visual Criteria for Thick Film Resistors	3
Optimization for Thin Film Resistors	5
Visual Criteria for Thin Film Resistors	6
W614 Laser Trim System Calibration	6
Optimum Settings	7
Accomplishments	7
Appendices	
A. Equipment Used	8
B. Resistor Test Patterns	10
C. Trim Increment Start Positioning	13
D. Focal Point	15
E. Thick Film Characterization Data	18
F. Thin Film Characterization Data	67

Tables

<i>Number</i>		<i>Page</i>
1	Laser Settings for Thick Film Characterization	4
2	Laser Settings for Thin Film Characterization	5
3	Optimum Laser Trim Settings	7

Abstract

The TLSI W614 Laser Trim System, which is a part of the TE5599 Tester, was characterized to find the optimum operating conditions for production trimming of thick and thin film resistors. Operating variables include average laser power, Q-rate, bite size, laser beam focal point, and trim increment start conditions. Operating conditions were found that support a life-stable resistance and a predictable trimming process.

Summary

In order to characterize the trimming process on the TLSI W614 Laser Trim System, thick and thin film resistors were trimmed while average laser power at the trim surface, Q-rate, and bite size were varied.

The resistance drift was monitored to find the conditions that resulted in the most stable trimmed resistors. The optimum operating conditions were found and recorded.

A larger sample was trimmed at the optimum operating conditions to verify the results and study the effect of a varying focus. Resistors trimmed within the ± 34 mil depth of focus did not exhibit significant variation in drift.

Trim increment start conditions were studied to find the best settings for a continuous, and thus predictable, trimming process as well as to reduce craters in the resistor trim kerfs.

Discussion

Scope and Purpose

The results of this experiment are specific only to the TLSI W614 Laser Trim System and the resistance films used. The goals of this experiment were (1) to find the best trim increment start conditions; (2) to optimize laser power, bite size, and Q-rate by looking at relative resistance drift; and (3) to study the effect of a varying focus. Absolute resistance drifts are dependent on resistor geometry, trim geometry, and resistance film, which were held constant. An attempt was made to use worst case geometries.

Activity

The resistors trimmed for this characterization were on 3.75 in. x 4.5 in. substrates in a repetitive test pattern (see Appendix A for resistance films used and Appendix B for test patterns). Trim increment start positioning (see Appendix C) was studied first so that any changes made as a result of the findings could be completed before proceeding to the optimization study. The focal point and associated error (see Appendix D) were found last. However, this study shows that the focal error effects are insignificant.

Trimming Discontinuities

Discontinuities of the trimmed variable versus programmed trim increment length were found to correspond to discontinuities in the actual trim increment length. Whether or not these discontinuities occurred was dependent on the method of determining the start position of each trim increment. A calculated start position is simply the stop position of the previous

increment specified by the software. An "as-read" start position is the stop position of the previous increment as read by the galvo sensors. The stop position is always calculated.

When calculated rather than as-read start positions were used, discontinuities were significantly reduced. The discontinuities of the as-read method are caused by a random over-travel of the galvos at the end of the previous increment. Using a calculated start and stop position reduces the discontinuities, but the as-read start position should be used after long increments (> 150 mils) because of the potential for physically disconnected increments ("gaps"). See Appendix C for a plot that compares the discontinuities of the two methods.

Notice that there are still discontinuities using the calculated start position. These only occur when switching to or from the smallest increment length (0.5 mils). During normal production trimming, the increment length only sequentially decreases, resulting in undershooting, which is recoverable. Overshooting is potentially unrecoverable but will not occur during normal trimming.

Kerf Craters

Craters in the trim kerfs were virtually eliminated by using a trim increment "start delay" of 2 ms. Start delays as long as 15 ms were used without a problem, but with significantly longer start delays, there is a risk that increments will not be physically connected, thereby defeating the precaution of overlapping increments. Lag factor is defined in the W614 software as

the "time period at the end of a laser trim during which the laser will continue to fire and the beam continue to move." Any lag-factor greater than zero caused increasingly large errors in increment length.

Optimization for Thick Film Resistors

All thick film resistors were two-square resistors, 100 x 50 mils, made from 10, 100, 1000 and 10,000 $\Omega/\square$ films. L-cuts were made penetrating 66% of the 50 mil dimension. See Appendix B for drawings of resistor test patterns. The second leg of the L-cut was made as a series of increments of decreasing length. The increment length was decreased by 50% each time until it was 0.5 mils. The final increment length was repeated so that the last two increments were 0.5 mils.

Three resistors were trimmed at each recipe. Of the three resistors, each was on a different substrate and in a different geometric orientation on the substrate so these effects could be averaged out. Average laser power at the trim surface was varied from the level that barely cleaned out the kerf (found by isolation resistance) to the level that caused excessive heat-affected zone (defined as 2 mils each side of the kerf after swabbing with alcohol). This was done at various Q-rates and bite sizes. The conditions used are listed in Table 1.

Bite size can be translated to trim speed by the following formula.

$$\text{Trim Speed} = \text{Bite Size} \cdot \text{Q-rate}$$

Immediately after the trimming, the resistance values were measured and saved. Resistance was measured again 24 hours later and again after 10 temperature cycles from -40 to +125°C. Temperature cycling accelerates resistor drift caused by mechanical stress

(temperature coefficient of expansion). Resistance drift, defined as change in percent of initial resistance, was plotted as averages of the three samples versus laser power and bite size at each Q-rate to find the window of minimum drift (maximum stability). The data in Appendix E show that a Q-rate of 3 kHz, a bite size of 0.122 mils, and a laser power of 1.4 watts is well within the optimum operating window for all resistance films. The films used are named in Appendix A, along with other equipment used in the project.

The optimum operating window had no upper power limit, which provides additional confidence. The absolute drifts are dependent on resistor geometry, trim geometry, and resistance film, which were all held constant. The intent of this experiment was to look at only relative drift so that laser power, bite size, and Q-rate could be optimized.

Next, the optimum operating condition noted above was used to trim 24 resistors at nominal focus, -20 mils, and +20 mils. The plot of kerf width versus Z-height in Appendix D shows that the nominal focus was off by -11.8 mils during this experiment (independent of the type of resistor). The data and histograms in Appendix E show that resistor drift is not adversely affected (<1% difference in drift) by a focal error of 31.8 mils below focus (20 mils below nominal is 31.8 mils below focus because of the -11.8 mil error). The trend suggests that within the ± 34 mil depth of focus, variances would be insignificant. Depth of focus is defined as the two points where the spot size increases by 10% from the spot size at focus. The direction of focal error is irrelevant.

Visual Criteria for Thick Film Resistors

Visual criteria are evaluated by the correlation between discernible visual

Table 1. Laser Settings for Thick Film Characterization

Q-rate (kHz)	Bite Size (mils)	Laser Power Levels (watts)
2	0.080	0.18, 0.46, 0.76, 1.06, and, 1.36
2	0.122	0.31, 0.8, 1.3, 1.78, and 2.27
2	0.180	0.3, 0.81, 1.36, 1.9, and 2.44
2	0.250	0.37, 1.03, 1.72, 2.41, and 3.1
3	0.080	0.22, 0.6, 0.97, 1.35, and 1.72
3	0.122	0.31, 0.70, 1.10, 1.49 and 1.88
3	0.180	0.42, 0.96, 1.5, 2.05, and 2.6
3	0.250	0.56, 1.16, 1.76, 2.36, and 2.96
4	0.080	0.21, 0.57, 0.94, 1.3, and 1.66
4	0.122	0.31, 0.81, 1.3, 1.83, and 2.36
4	0.180	0.43, 1.07, 1.69, 2.33, and 2.97
4	0.250	0.57, 1.36, 2.16, 2.96, and 3.76

characteristics of a trimmed resistor and the quality of the trim. Resistance film in the kerf (dirty kerfs) and excessive heat-affected zone as visual criteria are associated with insufficient and excessive levels of energy per unit length of trim, respectively. A clean kerf is defined here as being greater than 1.3 mils wide at the bottom of the resistance film. If the kerf was clean, the resistor was within the window of acceptable stability. Dirty kerfs were also accompanied by a lack of isolation resistance, that is, a resistance less than 32 M Ω when trimmed completely in half.

If the heat-affected zone adjacent to the kerf was greater than 2 mils on each side of the kerf, it was considered excessive. To make a more objective determination of the heat-affected zone, it was measured after the resistor was swabbed with alcohol to remove any potentially deceptive blow

off. Resistors that were trimmed with excessive heat-affected zone did not exhibit significant instability, but the visual criterion is given here so that an upper limit on energy can be established.

More simply stated:

1. If the kerf is dirty, the energy level was insufficient and the resistor *may* be unstable.
2. If the heat-affected zone is excessive, the energy level was excessive and the resistor *may* be unstable.
3. If neither of the above conditions is present, the resistor will be stable within the window of acceptable stability.

Optimization for Thin Film Resistors

All thin film resistors were top hat resistors, 200 x 20 mils, made from 100 $\Omega/\square$ film. Plunge cuts were made along the 200 mil dimension to 10 mils from the end. See Appendix B for drawings of resistor test patterns. Each cut was made as a series of increments of decreasing length. The increment length was decreased by 50% each time until it was 0.5 mils. The final increment length was repeated so that the last two increments were 0.5 mils.

Three resistors were trimmed at each recipe. Of the three resistors, each was in a different geometric orientation on the substrate to average out the effect. Average laser power at the trim surface was to be varied from the level that barely cleaned out the kerf (found by isolation resistance) to the level that caused excessive heat-affected zone. However, isolation resistance occurred at very low power levels and an excessive heat-affected zone could not be easily discerned, so a power level range was selected to be at least a factor of three above and below the current level. The power levels used are listed in Table 2 below.

Immediately after trimming, resistance values were measured and saved. Resistance was measured again 24 hours later and again after 200 hours of life testing at +150°C. Theoretically, life testing accelerates resistor drift caused by chemical processes (mostly oxidation of

tantalum). Resistance drift, defined as drift percentage from initial resistance, was plotted as averages of the three samples at each Q-rate to find the window of minimum drift (maximum stability). The data in Appendix F show that a Q-rate of 3 kHz, a bite size of 0.122 mils, and a laser power of 0.4 watts is well within the optimum operating window.

Next, the optimum operating condition above was used to trim 48 resistors at nominal focus, -20 mils, +20 mils, and +40 mils. The data and histograms in Appendix F show that resistor stability is not adversely affected (<1% difference in drift) by a focal error of 51.8 mils below focus (40 mils below nominal is 51.8 mils below focus because of the -11.8 mil error mentioned above). The first histograms are bimodal. This is because of the dependence on trim geometry. Resistors that were trimmed vertically were trimmed differently enough from those that were trimmed horizontally to see a 0.5% difference in drift.

The histograms of resistors trimmed with common geometric orientation (vertical) are not bimodal. In contrast to thick film, the mean improves as the focal error moves to 51.8 mils below the focal point. This is probably caused by a decreased energy per unit length of trim associated with a larger spot size. Less energy would theoretically reduce the drift as illustrated in the three-dimensional plot of drift at 3 kHz. Thick film 3-D plots are flatter and therefore would not suggest the same dependence on spot size. Depth of focus

Table 2. Laser Settings for Thin Film Characterization

Q-rate (kHz)	Bite Size (mils)	Laser Power Levels (watts)
2, 3, and 4	0.08, 0.122, 0.18, and 0.25	0.10, 0.24, 0.366, 0.90, and 1.5

is defined as the two points where spot size increases by 10% from the spot size at focus. The direction of focal error is irrelevant.

The difference between the average drift of untrimmed resistors and vertically trimmed resistors with these parameters is 0.5%. This does not satisfy the 0.1% absolute drift requirement because worst case geometries were used and the intent of this experiment was only to optimize laser power, bite size, and Q-rate. Only relative drifts need to be considered to find the optimum settings.

Visual Criteria for Thin Film Resistors

Visual criteria are evaluated by the correlation between discernible visual characteristics of a trimmed resistor and the quality of the trim. Resistance film in the kerf (dirty kerfs) and excessive heat-affected zone as visual criteria are associated with insufficient and excessive levels of energy per unit length of trim, respectively. If the kerf appeared dirty (resistance film not completely removed), the resistor was outside of the window of acceptable stability. Dirty kerfs were also accompanied by a lack of isolation resistance, that is, a resistance less than 32 M Ω when trimmed completely in half.

A heat-affected zone could not be easily discerned for thin film resistors without special efforts. For this reason, the depth of the kerf in thin film resistors can be used as a visual criterion for excessive level of energy per unit length of trim.

It was found that the drifts of thin film resistors with kerf depths of 0.2 mils were only 0.3% larger than optimum. Note that 0.2 mils is two orders of magnitude thicker than the thin film resistors which are roughly 500 Å. This depth corresponds to a Q-rate of 3 kHz, a bite size of 0.122 mils, and a laser power of 1 watt. From this we

can safely define 0.2 mils kerf depth as a visual criterion for excessive energy. More conservative visual criteria than those described above are a "slight flowing of the substrate material" and no groove in the substrate at all.

More simply stated:

1. If the kerf is dirty, the energy level was insufficient and the resistor *may* be unstable.
2. If the kerf depth is greater than 0.2 mils, the energy level was excessive and the resistor *may* be unstable.
3. If neither of the above conditions is present, the resistor will be stable within the window of acceptable stability.

W614 Laser Trim System Calibration

This characterization was done after successful calibration in accordance with two procedures and during one calibration interval for each. One procedure calibrates power, Q-rate, and bite size. Absolute accuracies for these parameters are pertinent. The other procedure calibrates the HP3458A for measuring resistance.

Resistance drift measurements are more accurate than reported in the tester CP because only repeatability (not accuracy) is relevant and because this entire characterization was done during one calibration interval. The inaccuracies of the laser step attenuators ($\pm 10\%$ worst case) need to be considered when looking at laser power levels specified in the plots of resistor drift versus power level and bite size. The power levels that were used to trim large samples at the optimum settings were not affected by the inaccuracies of the laser step attenuators.

Optimum Settings

The optimum settings are listed in Table 3 below. Optimum settings for laser power, Q-rate, and bite size have not changed from those that have been in use on the TE5599. However, prior to this study, the TE5599 had been using an "as-read" start position and a start delay of 0 ms. The optimum settings for these variables have changed to those in Table 3.

Accomplishments

The optimal operating parameters for the TLSI W614 Laser Trim System were found for production trimming of thick film and thin film resistors. The effects of focus were verified to be insignificant within the ± 34 mil depth of focus. Increment start parameters were established for a predictable trimming process and reduced cratering.

Table 3. Optimum Laser Trim Settings

System Variables	Optimum Settings
Average Laser Power at the Trim Surface	1.4 Watts for Thick Film; 0.4 Watts for Thin Film
Q-rate	3 kHz
Bite Size	0.122 mils
Start Delay	2 ms
Lag Factor	0 ms
Start Position	Calculated (as-read after > 150 mil trims)

Appendix A

Equipment Used

EQUIPMENT USED

TLSI W614 Laser Trim System

1. Hitachi monitor
2. Laser power supply
3. Laser trimmer (see TE5599 top drawing for details)
4. Computer
 - a. PC386 compatible (WYSE-386, P/N 3016SX-01)
 - b. Coprocessor
 - c. Dual 90 MB Bernoulli removable disk drive (Iomega S0700425)
 - d. 5.25 in. floppy drive
 - e. DOS 5.0
 - f. Microsoft C, programming language

TE5599 Tester

1. HP3458A Multimeter with 4-wire ohms capability
2. HP3488 Scanner
3. TE5599-W98 Cable
4. TE5599-W99 Cable

Probe Cards

1. Thick film: MRSI, 103720 Rev. 2 with Kelvin probes
2. Thin film: Teledyne TAC, C103720 Rev. 2 with Kelvin probes

Thick Film Resistors

1. Two-square
2. 50 x 100 mils
3. 10 $\Omega/\square$; Du Pont Number 1610
4. 100 $\Omega/\square$; Du Pont Number 1421
5. 1000 $\Omega/\square$; Du Pont Number 1431
6. 10,000 $\Omega/\square$; Du Pont Number 1441
7. Screen printed on 25 mil alumina substrate

Thin Film Resistors

1. Top hat
2. 20 x 200 mils
3. 100 $\Omega/\square$; tantalum nitride
4. Deposited on 25 mil alumina substrate

Appendix B

Resistor Test Patterns

f

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Thick Film Resistors, 2-Square
Medium sized, 50x100 resistors used for characterization

Thin Film Resistors, Top Hat

Appendix C

Trim Increment Start Positioning

Effect of Start Position on Resistance vs. Programmed Trim Increments

Appendix D

Focal Point

Trim Width vs. z-height

Curve Fit to Average of Kerf Width vs. Table Height

Appendix E

Thick Film Characterization Data

24 Hour Resistance Drift (Q-rate = 2 kHz, 10,000 ohms/sq)

19

Resistance Drift (% of R_{trim})

Post Cycle Resistance Drift (Q-rate = 2 kHz, 10,000 ohms/sq)

24 Hour Resistance Drift (Q-rate = 3 kHz, 10,000 ohms/sq)

21

Resistance Drift (% of R_{trim})

Post Cycle Resistance Drift (Q-rate = 3 kHz, 10,000 ohms/sq)

24 Hour Resistance Drift (Q-rate = 4 kHz, 10,000 ohms/sq)

Post Cycle Resistance Drift (Q-rate = 4 kHz, 10,000 ohms/sq)

24

Resistance Drift (% of R_{trim})

24 Hour Resistance Drift (Q-rate = 4 kHz, 10,000 ohms/sq, 1 Sport Removed)

Post Cycle Resistance Drift (Q-rate = 4 kHz, 10,000 ohms/sq, 1 Sport Removed)

26

Resistance Drift (% of R_{trim})

Percent of 4 W
(not all to scale)

Bite Size (mils)

24 Hour Resistance Drift (Q-rate = 2 kHz, 1000 ohms/sq, 11/18/93)

24 Hour Resistance Drift (Q-rate = 3 kHz, 1000 ohms/sq, 11/18/93)

24 Hour Resistance Drift (Q-rate = 4 kHz, 1000 ohms/sq, 11/18/93)

Post Cycle Resistance Drift (Q-rate = 2 kHz, 1000 ohms/sq, 11/18/93)

Post Cycle Resistance Drift (Q-rate = 3 kHz, 1000 ohms/sq, 11/18/93)

Post Cycle Resistance Drift (Q-rate = 4 kHz, 1000 ohms/sq, 11/18/93)

24 Hour Resistance Drift (Q-rate = 2 kHz, 100 ohms/sq, 11/18/93)

24 Hour Resistance Drift (Q-rate = 3 kHz, 100 ohms/sq, 11/18/93)

24 Hour Resistance Drift (Q-rate = 4 kHz, 100 ohms/sq, 11/18/93)

Post Cycle Resistance Drift (Q-rate = 2 kHz, 100 ohms/sq, 11/18/93)

Post Cycle Resistance Drift (Q-rate = 3 kHz, 100 ohms/sq, 11/18/93)

Post Cycle Resistance Drift (Q-rate = 4 kHz, 100 ohms/sq, 11/18/93)

24 Hour Resistance Drift (Q-rate = 2 kHz, 10 ohms/sq)

24 Hour Resistance Drift (Q-rate = 3 kHz, 10 ohms/sq)

24 Hour Resistance Drift (Q-rate = 4 kHz, 10 ohms/sq)

24 Hour Resistance Drift (Q-rate = 4 kHz, 10 ohms/sq.
questionable data points removed)

Post Cycle Resistance Drift (Q-rate = 2 kHz, 10 ohms/sq)

43

Resistance Drift (% of
 R_{trim})

Post Cycle Resistance Drift (Q-rate = 3 kHz, 10 ohms/sq)

Post Cycle Resistance Drift (Q-rate = 4 kHz, 10 ohms/sq)

Post Cycle Resistance Drift, Magnitude (Q-rate = 2 kHz, 10 ohms/sq)

Post Cycle Resistance Drift, Magnitude (Q-rate = 3 kHz, 10 ohms/sq)

Post Cycle Resistance Drift, Magnitude (Q-rate = 4 kHz, 10 ohms/sq)

Post Cycle Resistance Drift, Magnitude (Q-rate = 4 kHz, 10 ohms/sq, questional data points removed)

HERMAN TYPE: THICK FILM												
HERMAN S/N:		406 & 407										
RESISTANCE PASTE:		10000										
DATE: 12/08/93												
TIME: 14:41:31												
EXPERIMENT #: 2												
R	R_trim	z_ofst	R_24	R_post	R_24_drift	R_24_avg	R_post_drif	R_post_avg	bin_range	Bin	Frequency	
A1	66880.27	20	67029.04	67098.03	0.222443	0.134151	0.325601	0.216322	0	0	0	
A2	61911.66	20	61993.45	62048.29	0.132119		0.22069		0.06	0.06	0	
A3	55706.99	20	55791.86	55843.95	0.152361		0.245859		0.12	0.12	7	
A4	57630.74	20	57708.85	57762.74	0.135533		0.229038		0.18	0.18	10	
B1	62999.85	20	63085.5	63145.13	0.135965		0.230605		0.24	0.24	5	
B2	56728.84	20	56813.65	56863.96	0.149496		0.238183		0.3	0.3	2	
B3	54893.74	20	54970.52	55035.74	0.139875		0.258683		0.36	0.36	0	
B4	63954.63	20	64057.18	64141.01	0.160343		0.291416		0.42	0.42	0	
C1	59089.71	20	59179.89	59198.91	0.15262		0.184808		0.48	0.48	0	
C2	48815.57	20	48873.35	48914.53	0.118372		0.202738		0.54	0.54	0	
C3	57870.89	20	57938.75	58012.88	0.117261		0.245355		0.6	0.6	0	
C4	78744.56	20	78917.35	79011.89	0.219432		0.339497		0.66	0.66	0	
A1	77356.9	20	77523.3	77574.78	0.21511		0.281658		0.72	0.72	0	
A2	62098.7	20	62172.46	62194.35	0.118776		0.154031		0.78	0.78	0	
A3	58146.34	20	58215.18	58241.44	0.118379		0.163552		0.84	0.84	0	
A4	64476.8	20	64585.6	64620	0.168747		0.222092		0.9	0.9	0	
B1	71045.66	20	71114.07	71155.54	0.096292		0.154666		0.96	0.96	0	
B2	59345.02	20	59437.1	59464.2	0.155158		0.200833		1.02	1.02	0	
B3	57858.54	20	57915.84	57941.41	0.099031		0.143232		1.08	1.08	0	
B4	71684.29	20	71777.81	71831.59	0.130457		0.20549		1.14	1.14	0	
C1	65575.2	20	65624.21	65679.14	0.074738		0.158498					
C2	52646.68	20	52677.43	52722.42	0.058403		0.143866					
C3	61623.84	20	61664.99	61719.6	0.066778		0.155405					
C4	86636.98	20	86707.95	86806.73	0.081923		0.195939					
D1	49826.1	0	49879.55	49918.22	0.107275	0.131357	0.184894	0.21014		Bin	Frequency	
D2	52967.72	0	53023.59	53068.89	0.105479		0.19101			0	0	
D3	57055.96	0	57159.36	57212.43	0.181241		0.274247			0.06	0	
D4	69879.38	0	70120.83	70216.7	0.345515		0.48271			0.12	9	

LASR0238.CSV

E1	55856.01	0	55917.71	55959.39	0.110475		0.185097			0.18	11
E2	59756.26	0	59815.55	59876.98	0.099221		0.20202			0.24	1
E3	50232.95	0	50288.81	50338.11	0.111194		0.209348			0.3	1
E4	59836.09	0	59965.77	60024.54	0.216735		0.314951			0.36	1
F1	62473.25	0	62532.31	62597.77	0.094542		0.199317			0.42	0
F2	62878.94	0	62932.29	62997.73	0.084846		0.18891			0.48	1
F3	49231.07	0	49300.43	49338.16	0.140887		0.217511			0.54	0
F4	57901.47	0	57955.98	58001.53	0.094158		0.172824			0.6	0
D1	53403.51	0	53445.45	53488.14	0.078549		0.158475			0.66	0
D2	57070.95	0	57102.8	57142.48	0.055814		0.125336			0.72	0
D3	66909.02	0	66952.18	67021.99	0.064503		0.168829			0.78	0
D4	74239.5	0	74296.47	74363.35	0.076738		0.166829			0.84	0
E1	58124.16	0	58179.59	58206.05	0.095359		0.140884			0.9	0
E2	62788.65	0	62871.48	62910.66	0.131922		0.194314			0.96	0
E3	59017.35	0	59111.96	59143.03	0.16032		0.212961			1.02	0
E4	64881.12	0	65098.61	65135.24	0.335223		0.391669			1.08	0
F1	67315.01	0	67393.33	67427.45	0.116347		0.167035			1.14	0
F2	63759.53	0	63817.68	63849.01	0.091205		0.140333				
F3	57137.04	0	57189.5	57218.57	0.091814		0.142687				
F4	65766.99	0	65874.33	65905.87	0.163215		0.211162				
G1	53454.79	-20	53537.98	53625	0.155632	0.155621	0.318425	0.24909		Bin	Frequency
G2	67048.09	-20	67193.84	67261.3	0.21738		0.317995			0	0
G3	59421.53	-20	59501.76	59571.15	0.135035		0.251803			0.06	0
G4	58083.05	-20	58183.21	58237.38	0.172451		0.265712			0.12	1
H1	52221.82	-20	52281.04	52343.26	0.113406		0.232556			0.18	12
H2	62466.86	-20	62547.19	62603.58	0.128602		0.218867			0.24	6
H3	63238.34	-20	63347.39	63423.13	0.172445		0.292209			0.3	3
H4	58082.64	-20	58163.57	58210.35	0.139339		0.219883			0.36	1
I1	48278.2	-20	48377.09	41295.25	0.204846					0.42	0
I2	58408.73	-20	58478.63	58537.21	0.119662		0.219964			0.48	0
I3	63507.07	-20	63613.04	63704.7	0.166861		0.311192			0.54	0
I4	69209.92	-20	69304.67	69405.48	0.136908		0.282561			0.6	0
G1	54894.75	-20	54972.61	55017.21	0.141835		0.223077			0.66	0
G2	65066.74	-20	65187.88	65231.33	0.18617		0.252944			0.72	0
G3	66843.63	-20	66935.52	66987.22	0.137471		0.214809			0.78	0
G4	64914.48	-20	65004.83	65054.72	0.139192		0.216046			0.84	0

LASR0238.CSV

H1	53735.73	-20	53791.67	53824.9	0.104107		0.165948			0.9	0
H2	62982.63	-20	63058.5	63107.47	0.120463		0.198215			0.96	0
H3	71659.11	-20	71801.91	71860.87	0.199278		0.281556			1.02	0
H4	64586.12	-20	64678.68	64726.64	0.14332		0.217568			1.08	0
I1	49730.38	-20	49787.59	49829.24	0.115044		0.198792		0.48271	1.14	0
I2	58625.88	-20	58725.43	58755.79	0.169796		0.22159				
I3	76282.01	-20	76385.3	76445.12	0.135405		0.213826				
I4	72378.99	-20	72581.83	72663.83	0.280249		0.393536

LASR0231.CSV

HERMAN TYPE: THICK FILM											
HERMAN S/N: 306 & 307											
RESISTANCE PASTE: 1000											
DATE: 12/07/93											
TIME: 16:32:02											
EXPERIMENT #: 2											
R	R_trim	z_ofst	R_24	R_post	R_24_drift	R_24_avg	R_post_drif	R_post_avg	bin_range	Bin	Frequency
A1	6241.061	20	6246.599	6256.58	0.088734	0.089793	0.248661	0.22303	0	0	0
A2	5069.25	20	5079.605	5094.049	0.204269		0.489196		0.06	0.06	1
A3	4900.588	20	4904.413	4909.742	0.078046		0.1868		0.12	0.12	6
A4	6078.236	20	6082.46	6086.607	0.069493		0.137723		0.18	0.18	9
B1	5837.659	20	5843.103	5850.799	0.093262		0.225095		0.24	0.24	5
B2	4645.33	20	4648.244	4654.151	0.062731		0.189894		0.3	0.3	1
B3	4773.604	20	4776.418	4783.995	0.058951		0.217669		0.36	0.36	0
B4	6545.919	20	6554.758	6561.757	0.135031		0.241959		0.42	0.42	1
C1	5523.293	20	5526.509	5532.256	0.058221		0.162271		0.48	0.48	1
C2	4145.564	20	4147.381	4152.042	0.043819		0.156267		0.54	0.54	0
C3	4964.992	20	4968.436	4975.936	0.069369		0.220432		0.6	0.6	0
C4	7836.492	20	7844.014	7852.825	0.095988		0.208425		0.66	0.66	0
A1	5888.003	20	5897.285	5914.692	0.157646		0.453274		0.72	0.72	0
A2	5193.179	20	5199.114	5209.687	0.114281		0.317876		0.78	0.78	0
A3	5248.171	20	5252.513	5262.12	0.082727		0.265781		0.84	0.84	0
A4	5628.092	20	5632.068	5638.446	0.070642		0.183962		0.9	0.9	0
B1	5327.044	20	5331.204	5336.166	0.078097		0.171247		0.96	0.96	0
B2	5136.715	20	5141.233	5150.825	0.087948		0.274697		1.02	1.02	0
B3	5164.901	20	5170.571	5177.542	0.109781		0.244741		1.08	1.08	0
B4	6098.186	20	6101.685	6106.059	0.057374		0.129097		1.14	1.14	0
C1	5566.889	20	5570.872	5576.974	0.071556		0.181163				
C2	4579.027	20	4581.361	4583.012	0.050964		0.087017				
C3	5327.053	20	5332.476	5338.261	0.101793		0.210391				
C4	6980.315	20	6988.293	6990.721	0.114298		0.14907				
D1	4278.598	0	4282.042	4294.451	0.080487	0.140496	0.370515	0.524357		Bin	Frequency
D2	4170.427	0	4174.924	4186.081	0.107832		0.375356	0.385379		0	0
D3	4887.696	0	4895.835	4917.87	0.166514		0.617352			0.06	0
D4	5810.071	0	5817.323	5823.877	0.124824		0.237617			0.12	0

LASR0231.CSV

E1	4758.147	0	4765.533	4776.423	0.155219		0.384091			0.18	2
E2	4650.959	0	4660.033	4676.586	0.195102		0.551008			0.24	6
E3	4011.001	0	4016.226	4057.164	0.13026		1.150907			0.3	2
E4	4938.493	0	4945.202	4966.671	0.135842		0.570578			0.36	3
F1	5340.933	0	5352.966	5369.336	0.225296		0.531808			0.42	1
F2	5037.007	0	5041.793	5049.153	0.095011		0.241144			0.48	3
F3	3863.383	0	3870.432	3907.824	0.182448		1.150302			0.54	3
F4	5006.606	0	5012.438	5023.482	0.116494		0.337065			0.6	1
D1	4102.007	0	4106.582	4113.611	0.111525		0.282884			0.66	0
D2	4364.812	0	4370.109	4378.802	0.121348		0.320522			0.72	0
D3	4884.471	0	4900.546	4991.461	0.329102		2.190405			0.78	0
D4	5726.464	0	5732.252	5739.556	0.101066		0.228626			0.84	0
E1	4426.654	0	4431.712	4437.908	0.114267		0.254241			0.9	0
E2	5129.161	0	5135.241	5142.836	0.118544		0.266618			0.96	0
E3	4110.075	0	4113.015	4129.918	0.071537		0.482782			1.02	0
E4	4822.587	0	4830.917	4850.791	0.172728		0.584824			1.08	0
F1	5041.097	0	5049.014	5065.594	0.157047		0.485942			1.14	2
F2	5313.014	0	5320.191	5326.203	0.135081		0.248242			2.5	1
F3	4166.629	0	4169.671	4178.108	0.073001		0.275504				
F4	4913.847	0	4921.283	4935.775	0.151333		0.446243				
G1	4814.839	-20	4822.374	4834.872	0.156494	0.148927	0.416078	0.396211		Bin	Frequency
G2	5762.378	-20	5769.295	5778.278	0.120036		0.275926			0	1
G3		-20	4858.818	4871.967						0.06	0
G4	5130.601	-20	5143.769	5158.623	0.256656		0.546174			0.12	0
H1	4480.554	-20	4484.998	4496.589	0.099183		0.357872			0.18	0
H2	5260.671	-20	5265.446	5278.262	0.090763		0.334396			0.24	3
H3	4884.861	-20	4894.229	4912.352	0.191774		0.562773			0.3	6
H4	5004.437	-20	5011.181	5023.888	0.134756		0.388677			0.36	4
I1	3992.421	-20	3997.41	4006.762	0.124954		0.359204			0.42	4
I2	5114.991	-20	5118.712	5129.915	0.072738		0.291768			0.48	2
I3	5101.229	-20	5109.472	5136.823	0.161588		0.697756			0.54	2
I4	5956.857	-20	5968.885	5986.823	0.201913		0.503045			0.6	0
G1	1917.139	-20	1917.303	1917.778	0.008574		0.033337			0.66	1
G2	5959.545	-20	5971.82	5980.38	0.205973		0.349604			0.72	0
G3	5026.332	-20	5038.356	5051.589	0.239218		0.502486			0.78	0

LASR0231.CSV

G4	5331.687	-20	5338.719	5345.206	0.131894		0.253562			0.84	0
H1	4386.694	-20	4394.64	4403.942	0.181142		0.393194			0.9	0
H2	5517.153	-20	5526.053	5536.046	0.16132		0.342439			0.96	0
H3	5352.471	-20	5360.348	5373.646	0.147168		0.395604			1.02	0
H4	5080.443	-20	5090.756	5104.758	0.202987		0.478599			1.08	0
I1	4016.457	-20	4022.849	4034.413	0.159137		0.447071			1.14	0
I2	4905.663	-20	4910.428	4921.188	0.097129		0.316468				
I3	5329.585	-20	5336.662	5353.316	0.132778		0.445274				
I4	5732.41	-20	5740.845	5756.575	0.147143		0.421544

HERMAN TYPE: THICK FILM											
HERMAN S/N: 211 & 218											
RESISTANCE PASTE: 100											
DATE: 12/06/93											
TIME: 17:08:55											
EXPERIMENT #: 2											
R	R_trim	z_ofst	R_24	R_post	R_24_drift	R_24_avg	R_post_drif	R_post_avg	bin_range	Bin	Frequency
A1	499.24	20	500.1436	501.4422	0.180987	0.110131	0.439183	0.267643	0	0	0
A2	387.872	20	388.2001	389.3325	0.084598		0.375137		0.06	0.06	0
A3	336.215	20	336.4745	337.0896	0.077187		0.259447		0.12	0.12	5
A4	417.077	20	417.3742	417.682	0.071254		0.144836		0.18	0.18	6
B1	481.807	20	482.5662	483.5273	0.157564		0.355775		0.24	0.24	4
B2	370.561	20	370.9273	371.4225	0.098837		0.23194		0.3	0.3	5
B3	337.568	20	337.8593	338.1371	0.086293		0.1683		0.36	0.36	3
B4	453.403	20	453.9061	454.4767	0.110959		0.236256		0.42	0.42	1
C1	462.304	20	462.8386	463.5662	0.115627		0.272274		0.48	0.48	0
C2	347.837	20	348.0853	348.3358	0.071385		0.143209		0.54	0.54	0
C3	350.134	20	350.4793	350.7946	0.098609		0.188319		0.6	0.6	0
C4	523.556	20	524.1534	525.2958	0.11411		0.331206		0.66	0.66	0
A1	490.766	20	491.6358	492.4812	0.17723		0.34828		0.72	0.72	0
A2	413.567	20	414.0608	414.8441	0.11941		0.307855		0.78	0.78	0
A3	346.898	20	347.253	347.6376	0.102332		0.212761		0.84	0.84	0
A4	393.316	20	393.7295	394.4529	0.10512		0.288214		0.9	0.9	0
B1	477.744	20	478.1581	478.7456	0.086671		0.209208		0.96	0.96	0
B2	397.449	20	398.0786	398.9269	0.158406		0.370469		1.02	1.02	0
B3	340.359	20	340.7808	341.334	0.123937		0.28564		1.08	1.08	0
B4	430.897	20	431.2649	432.2182	0.085391		0.305673		1.14	1.14	0
C1	451.324	20	451.7425	452.1076	0.092736		0.173328				
C2	381.345	20	381.6195	382.0242	0.071974		0.177789				
C3	372.594	20	373.1605	373.9712	0.152032		0.368272				
C4	481.601	20	482.0849	482.7116	0.100487		0.230073				
D1	397.148	0	397.8344	398.4628	0.172839	0.135012	0.329959	0.361222		Bin	Frequency
D2	388.482	0	388.8506	390.16	0.094883		0.430083			0	0
D3	391.799	0	392.049	393.0343	0.0638		0.314292			0.06	0
D4	441.052	0	443.5305	444.7513	0.561961		0.831766			0.12	1

LASR0220.CSV

E1	425.915	0	426.2922	427.8579	0.088564		0.454094			0.18	1
E2	414.151	0	414.6249	415.7301	0.114416		0.379826			0.24	4
E3	367.633	0	367.9024	368.8037	0.073268		0.317422			0.3	10
E4	398.082	0	398.3396	400.3214	0.064717		0.55939			0.36	3
F1	456.897	0	457.7836	458.3627	0.194039		0.319764			0.42	2
F2	407.695	0	407.8758	408.4633	0.044337		0.1881			0.48	1
F3	347.342	0	347.6174	348.2212	0.079281		0.252481			0.54	1
F4	409.693	0	410.5431	411.0726	0.207502		0.335612			0.6	0
D1	408.694	0	409.1631	410.0568	0.114785		0.332351			0.66	0
D2	367.396	0	368.1793	369.3889	0.213212		0.539522			0.72	0
D3	392.316	0	392.5279	392.9734	0.054008		0.167285			0.78	1
D4	478.087	0	478.7987	479.6071	0.148869		0.31695			0.84	0
E1	435.186	0	435.7585	437.0173	0.131549		0.419041			0.9	0
E2	407.24	0	407.721	408.274	0.118116		0.253273			0.96	0
E3	355.164	0	355.5644	356.4784	0.112747		0.36872			1.02	0
E4	426.594	0	427.3145	428.0175	0.168892		0.332574			1.08	0
F1	479.856	0	480.376	481.1139	0.108364		0.261455			1.14	0
F2	418.893	0	419.4585	420.109	0.135002		0.289445				
F3	346.949	0	347.1768	348.0537	0.065658		0.317397				
F4	413.592	0	414.0448	415.0802	0.109476		0.35854				
G1	420.148	-20	420.8765	421.4951	0.173394	0.149359	0.319593	0.35174		Bin	Frequency
G2	452.229	-20	452.8247	453.6427	0.131716		0.311637			0	0
G3	370.829	-20	371.3264	372.5827	0.134143		0.470677			0.06	0
G4	395.954	-20	396.4951	397.0282	0.136655		0.270551			0.12	0
H1	410.981	-20	411.3431	412.1803	0.088094		0.290962			0.18	3
H2	437.432	-20	437.9361	439.3246	0.115233		0.430803			0.24	4
H3	387.308	-20	387.761	388.659	0.11697		0.347606			0.3	10
H4	398.548	-20	399.0345	399.6458	0.122073		0.274681			0.36	1
I1	392.116	-20	392.7636	393.4739	0.165159		0.345095			0.42	5
I2	401.694	-20	402.497	403.3945	0.199915		0.421559			0.48	0
I3	395.625	-20	396.648	398.2807	0.258581		0.666797			0.54	0
I4	440.584	-20	441.4248	442.694	0.190828		0.476632			0.6	0
G1	414.433	-20	415.1305	415.881	0.1683		0.348169			0.66	1
G2	468.559	-20	469.2741	470.074	0.152621		0.3223			0.72	0
G3	394.602	-20	395.0845	395.9131	0.122281		0.33115			0.78	0

LASR0220.CSV

G4	407.801	-20	408.59	409.1893	0.193488		0.339289			0.84	0
H1	398.823	-20	399.4417	400.1827	0.155132		0.339762			0.9	0
H2	450.409	-20	450.9812	451.7471	0.127037		0.296215			0.96	0
H3	414.45	-20	415.0031	415.9302	0.133449		0.355887			1.02	0
H4	403.04	-20	403.5152	403.8415	0.117893		0.198467			1.08	0
I1	384.807	-20	385.3239	385.7181	0.134332		0.236216			1.14	0
I2	422.173	-20	422.6048	423.1122	0.102287		0.221981				
I3	428.532	-20	429.1138	430.1875	0.135772		0.384832				
I4	443.519	-20	444.4471	445.4832	0.209264		0.440907

LASR0218.CSV

HERMAN TYPE: THICK_FILM											
HERMAN S/N: 109 & 110											
RESISTANCE PASTE: 10											
DATE: 12/06/93											
TIME: 15:24:37											
EXPERIMENT #: 2											
R	R_trim	z_ofst	R_24	R_post	R_24_drift	R_24_avg	R_post_drif	R_post_avg	bin_range	Bin	Frequency
A1	65.436	20	65.48939	65.49212	0.081585	0.038515	0.085682	0.044897	0	0	0
A2	53.942	20	53.95926	53.98401	0.031997		0.077827		0.06	0.06	0
A3	52.06	20	52.06479	52.06839	0.009207		0.016121		0.12	0.12	5
A4	63.451	20	63.47761	63.4585	0.041941		0.011812		0.18	0.18	6
B1	62.152	20	62.20583	62.20336	0.086605		0.082563		0.24	0.24	4
B2	51.537	20	51.54922	51.57607	0.023701		0.075752		0.3	0.3	5
B3	54.778	20	54.78621	54.79096	0.014979		0.023652		0.36	0.36	3
B4	65.904	20	65.93044	65.9157	0.04012		0.017754		0.42	0.42	1
C1	59.806	20	59.85678	59.85337	0.084903		0.079142		0.48	0.48	0
C2	49.08	20	49.09473	49.11607	0.030012		0.073434		0.54	0.54	0
C3	57.012	20	57.01032	57.02022	0.002943		0.014409		0.6	0.6	0
C4	71.953	20	71.97584	71.96363	0.031744		0.014771		0.66	0.66	0
A1	69.867	20	69.92795	69.93251	0.087243		0.093672		0.72	0.72	0
A2	54.633	20	54.63586	54.66143	0.005239		0.052011		0.78	0.78	0
A3	50.722	20	50.72281	50.71945	0.001591		0.00503		0.84	0.84	0
A4	60.316	20	60.34341	60.32685	0.045446		0.017984		0.9	0.9	0
B1	65.083	20	65.1388	65.13769	0.085731		0.083954		0.96	0.96	0
B2	51.748	20	51.75512	51.77789	0.013757		0.057722		1.02	1.02	0
B3	52.329	20	52.32732	52.32536	0.003203		0.006951		1.08	1.08	0
B4	63.853	20	63.88448	63.86686	0.049298		0.021708		1.14	1.14	0
C1	61.859	20	61.91105	61.91175	0.084135		0.085194				
C2	49.605	20	49.61584	49.63341	0.021861		0.05724				
C3	54.355	20	54.35381	54.35428	0.002189		0.001325				
C4	70.801	20	70.83281	70.81644	0.044923		0.021808				
D1	53.982	0	54.03048	54.02726	0.089804	0.041274	0.083773	0.048155		Bin	Frequency
D2	49.481	0	49.48953	49.51791	0.017247		0.074529			0	0
D3	55.592	0	55.58707	55.59477	0.008861		0.004975			0.06	0
D4	63.234	0	63.26711	63.25143	0.052353		0.027552			0.12	1

LASR0218.CSV

E1	57.284	0	57.33973	57.33496	0.097284		0.088878			0.18	1
E2	53.582	0	53.59542	53.62177	0.025042		0.07416			0.24	4
E3	50.933	0	50.93686	50.94433	0.007584		0.022246			0.3	10
E4	59.341	0	59.36705	59.35321	0.043904		0.020565			0.36	3
F1	62.102	0	62.14936	62.15622	0.076254		0.087229			0.42	2
F2	54.434	0	54.45567	54.48187	0.039817		0.087859			0.48	1
F3	49.918	0	49.91835	49.92063	0.000693		0.00527			0.54	1
F4	58.165	0	58.19162	58.17511	0.045759		0.01738			0.6	0
D1	55.616	0	55.66359	55.66404	0.08556		0.086302			0.66	0
D2	50.828	0	50.83952	50.85933	0.022661		0.061605			0.72	0
D3	53.676	0	53.67156	53.67434	0.008272		0.003091			0.78	1
D4	60.252	0	60.2746	60.26163	0.037514		0.015982			0.84	0
E1	57.817	0	57.8729	57.87791	0.096688		0.105239			0.9	0
E2	55.136	0	55.14937	55.17387	0.024244		0.068632			0.96	0
E3	49.169	0	49.1737	49.17269	0.009565		0.007504			1.02	0
E4	55.308	0	55.32653	55.31391	0.033509		0.010684			1.08	0
F1	62.319	0	62.36703	62.36921	0.077078		0.080501			1.14	0
F2	57.554	0	57.58247	57.61087	0.049465		0.098719				
F3	48.316	0	48.31254	48.31222	0.007172		0.007828				
F4	53.682	0	53.70038	53.69018	0.034241		0.015228				
G1	63.217	-20	63.28374	63.29423	0.105573	0.057586	0.122016	0.072504		Bin	Frequency
G2	60.582	-20	60.61118	60.63759	0.048171		0.091677			0	0
G3	51.135	-20	51.14615	51.15297	0.021813		0.035122			0.06	0
G4	54.487	-20	54.52454	54.51842	0.068901		0.057637			0.12	0
H1	60.602	-20	60.66665	60.67989	0.106686		0.128365			0.18	3
H2	57.269	-20	57.29063	57.31831	0.037764		0.086025			0.24	4
H3	52.948	-20	52.95224	52.96067	0.008004		0.023918			0.3	10
H4	58.078	-20	58.11823	58.10847	0.069265		0.052433			0.36	1
I1	56.768	-20	56.82552	56.82854	0.101325		0.106526			0.42	5
I2	51.569	-20	51.58562	51.61275	0.032221		0.084756			0.48	0
I3	54.966	-20	54.96798	54.9788	0.003604		0.023274			0.54	0
I4	66.302	-20	66.356	66.3545	0.081446		0.079127			0.6	0
G1	62.489	-20	62.55601	62.56775	0.107232		0.125868			0.66	1
G2	62.925	-20	62.95419	62.97817	0.046385		0.084431			0.72	0
G3	49.277	-20	49.29696	49.30149	0.040512		0.049668			0.78	0

LASR0218.CSV

G4	51.508	-20	51.53879	51.52964	0.059771		0.041989			0.84	0
H1	60.932	-20	61.00324	61.01265	0.116919		0.132191			0.9	0
H2	58.514	-20	58.54143	58.56456	0.046883		0.086334			0.96	0
H3	51.322	-20	51.32373	51.32877	0.003375		0.01318			1.02	0
H4	53.187	-20	53.21151	53.20316	0.046088		0.030365			1.08	0
I1	57.497	-20	57.56314	57.57149	0.11503		0.129382			1.14	0
I2	53.377	-20	53.39667	53.42225	0.036853		0.084706				
I3	53.205	-20	53.21126	53.21458	0.011762		0.017995				
I4	61.836	-20	61.87711	61.86887	0.066484		0.053122				

Appendix F

Thin Film Characterization Data

24 Hour Resistance Drift (Q-rate = 2 kHz, Thin Film)

24 Hour Resistance Drift (Q-rate = 3 kHz, Thin Film)

24 Hour Resistance Drift (Q-rate = 4 kHz, Thin Film)

Post Life Test Resistance Drift (Q-rate = 2 kHz, Thin Film)

Post Life Test Resistance Drift (Q-rate = 3 kHz, Thin Film)

Post Life Test Resistance Drift (Q-rate = 4 kHz, Thin Film)

LASR0247.CSV

HERMAN TYPE: THIN FILM											
HERMAN S/N: 106											
RESISTANCE PASTE: 100											
DATE: 12/09/93											
TIME: 14:48:30											
EXPERIMENT #: 2											
R_num	R_trim	focus	R_24	R_post_cyc	R_drift_cyc	R_post_life	R_drift_life	average	vert_avg	Bin	Frequency
A1	4274.921	20	4282.87	4286.334	0.266976	4299.931	0.585032	0.70657	0.55483	0	0
A2	4057.338	20	4064.08	4066.822	0.233749	4077.488	0.49664			0.05	0
A3	4120.573	20	4128.621	4132.102	0.279791	4145.094	0.595098		horiz_avg	0.1	0
A4	4237.94	20	4249.098	4254.378	0.387877	4273.197	0.831947		0.8583	0.15	0
A5	4167.624	20	4178.67	4183.68	0.385255	4201.749	0.818821			0.2	0
A6	4317.595	20	4331.121	4337.298	0.456342	4359.891	0.97963			0.25	0
A7	3922.216	20	3929.713	3932.597	0.264672	3943.842	0.551379			0.3	0
A8	3904.335	20	3911.141	3913.992	0.24734	3924.52	0.516998			0.35	0
A9	4003.142	20	4010.496	4013.481	0.258272	4024.881	0.543055			0.4	0
A10	4320.164	20	4333.62	4339.591	0.449682	4362.605	0.982382			0.45	3
A11	4191.012	20	4202.248	4207.214	0.386589	4225.327	0.818783			0.5	10
A12	4240.815	20	4252.087	4257.23	0.387072	4276.149	0.833194			0.55	8
B1	3869.654	20	3876.09	3878.817	0.236791	3888.726	0.492872			0.6	1
B2	3837.057	20	3843.494	3846.11	0.235936	3856.237	0.499853			0.65	2
B3	3747.548	20	3754.343	3756.973	0.251498	3767.35	0.528392			0.7	1
B4	3941.528	20	3952.174	3956.407	0.377493	3972.912	0.796237			0.75	8
B5	3987.278	20	3997.902	4002.301	0.376773	4019.077	0.797518			0.8	6
B6	4190.709	20	4203.235	4208.525	0.425131	4228.602	0.90421			0.85	3
B7	3838.18	20	3845.357	3848.367	0.265412	3859.437	0.553831			0.9	1
B8	3840.886	20	3847.607	3850.525	0.250958	3860.96	0.522632			0.95	4
B9	3930.262	20	3937.089	3940.107	0.250492	3950.925	0.525732			1	0
B10	4129.403	20	4140.716	4145.702	0.394706	4163.759	0.831986			1.05	1
B11	4039.041	20	4049.446	4054.008	0.370558	4070.718	0.784273			1.1	0
B12	3987.331	20	3997.571	4001.896	0.365282	4018.211	0.774441				
C1	3876.605	20	3883.366	3886.246	0.248697	3896.298	0.507995				
C2	3766.914	20	3773.401	3776.001	0.241232	3786.145	0.51052				
C3	3715.806	20	3722.295	3724.837	0.243043	3734.789	0.510874				
C4	3877.595	20	3887.461	3891.585	0.360791	3907.605	0.773944				

LASR0247.CSV

C5	3999.745	20	4010.143	4014.948	0.380099	4031.623	0.797011				
C6	4283.85	20	4297.578	4303.972	0.469718	4326.606	0.998074				
C7	3967.645	20	3975.477	3978.899	0.283644	3991.147	0.592337				
C8	3930.054	20	3937.158	3940.186	0.257808	3951.644	0.549354				
C9	4051.276	20	4058.913	4062.292	0.271914	4073.995	0.56079				
C10	4185.503	20	4197.64	4203.082	0.419997	4222.34	0.880105				
C11	4086.063	20	4097.432	4102.465	0.401413	4120.599	0.84521				
C12	3974.35	20	3984.46	3988.839	0.364563	4004.117	0.748974				
D1	4064.832	20	4072.295	4075.667	0.266555	4087.25	0.551508				
D2	3956.221	20	3963.003	3966.121	0.250239	3976.926	0.523363				
D3	4046.705	20	4054.989	4058.788	0.298589	4072.837	0.645757				
D4	4234.132	20	4246.177	4251.598	0.412505	4272.165	0.898256				
D5	4398.686	20	4412.313	4418.55	0.451589	4442.142	0.987942				
D6	4692.086	20	4707.762	4715.333	0.495451	4742.943	1.083895				
D7	4491.928	20	4501.767	4506.067	0.314765	4522.181	0.673507				
D8	4533.649	20	4543.473	4548.062	0.317912	4564.45	0.679396				
D9	4521.833	20	4530.693	4534.496	0.280041	4548.916	0.598949				
D10	4537.885	20	4551.06	4556.966	0.420482	4578.152	0.887358				
D11	4313.515	20	4324.764	4329.67	0.374521	4347.182	0.780496				
D12	4185.156	20	4195.851	4200.43	0.364957	4217.156	0.764609		vert avg		
E1	4054.304	0	4062.017	4065.31	0.271465	4078.295	0.591729	0.77768	0.58584	Bin	Frequency
E2	4076.266	0	4084.413	4087.869	0.284648	4101.098	0.60918			0	0
E3	4075.27	0	4083.87	4087.642	0.303587	4102.177	0.660245		horiz avg	0.05	0
E4	4268.237	0	4282.018	4288.857	0.483103	4314.028	1.072834		0.96952	0.1	0
E5	4304.068	0	4317.458	4324.543	0.475713	4350.048	1.068294			0.15	0
E6	4473.017	0	4487.437	4494.988	0.49119	4521.729	1.08902			0.2	0
E7	4520.364	0	4529.663	4533.988	0.301392	4551.043	0.67868			0.25	0
E8	4540.824	0	4549.995	4554.087	0.292084	4569.93	0.640974			0.3	0
E9	4596.128	0	4605.036	4608.953	0.279039	4624.53	0.617945			0.35	0
E10	4427.159	0	4441.294	4448.291	0.477326	4473.445	1.045496			0.4	0
E11	4264.219	0	4276.559	4282.637	0.43192	4304.804	0.951763			0.45	0
E12	4129.149	0	4141.117	4146.839	0.428418	4168.072	0.942647			0.5	3
F1	3865.849	0	3873.113	3876.196	0.267651	3888.166	0.577292			0.55	14
F2	3832.661	0	3839.729	3842.742	0.263029	3854.187	0.561649			0.6	5
F3	3896.096	0	3903.695	3907.124	0.283053	3919.717	0.606264			0.65	2

LASR0247.CSV

F4	3982.4	0	3994.726	4000.522	0.455052	4021.964	0.993474			0.7	0
F5	4065.309	0	4078.943	4085.734	0.502422	4109.268	1.081328			0.75	1
F6	4159.344	0	4173.059	4179.833	0.492602	4204.233	1.079226			0.8	0
F7	4077.639	0	4085.754	4089.348	0.287151	4103.179	0.626344			0.85	3
F8	3971.606	0	3978.83	3981.926	0.259845	3994.66	0.580476			0.9	7
F9	4026.529	0	4033.956	4037.122	0.26308	4049.762	0.57699			0.95	6
F10	4102.284	0	4115.316	4121.649	0.472054	4145.009	1.041493			1	2
F11	3998.973	0	4010.974	4016.723	0.443864	4038.01	0.976166			1.05	5
F12	3917.816	0	3929.334	3934.635	0.429295	3954.722	0.941997			1.1	0
G1	3852.758	0	3860.465	3863.457	0.277697	3875.098	0.579833				
G2	3830.012	0	3837.165	3839.998	0.26073	3851.342	0.556929				
G3	3831.235	0	3838.87	3841.865	0.277456	3854.043	0.595314				
G4	3907.425	0	3918.906	3923.695	0.416387	3943.26	0.917112				
G5	3900.059	0	3911.363	3916.187	0.413532	3936.248	0.927906				
G6	4005.245	0	4017.438	4022.715	0.436178	4043.569	0.956839				
G7	3924.96	0	3932.244	3935.288	0.263136	3947.274	0.568507				
G8	3893.66	0	3900.853	3903.949	0.26425	3915.699	0.56603				
G9	3897.886	0	3904.875	3907.778	0.253779	3918.771	0.535797				
G10	3947.84	0	3959.458	3964.681	0.426588	3983.928	0.914128				
G11	3908.949	0	3919.989	3925.001	0.410647	3943.588	0.886157				
G12	3906.614	0	3917.91	3922.714	0.412122	3941.444	0.891571				
H1	4177.637	0	4185.546	4188.768	0.266442	4201.216	0.564407				
H2	4123.008	0	4130.97	4134.258	0.272859	4146.878	0.578943				
H3	4115.759	0	4123.524	4126.618	0.26384	4138.554	0.553845				
H4	4185.509	0	4197.824	4203.362	0.426543	4224.778	0.938211				
H5	4128.141	0	4140.619	4146.219	0.437921	4167.909	0.963346				
H6	4175.981	0	4189.006	4194.937	0.453929	4217.663	0.998143				
H7	3936.91	0	3944.619	3947.268	0.2631	3958.888	0.558259				
H8	3936.05	0	3943.568	3946.392	0.262751	3957.597	0.547418				
H9	3970.979	0	3978.514	3981.199	0.257367	3991.91	0.527087				
H10	4008.662	0	4020.394	4025.431	0.418319	4044.5	0.894006				
H11	3973.117	0	3983.573	3988.049	0.375826	4004.345	0.785981				
H12	4127.264	0	4139.277	4144.693	0.422289	4164.873	0.911241		vert avg		
I1	4323.652	-20	4330.787			4345.671	0.509278	0.65524	0.50734	Bin	Frequency
I2	4338.135	-20	4345.26			4360.268	0.510191			0	0

LASR0247.CSV

I3	4315.641	-20	4322.69			4337.845	0.51449		horiz avg	0.05	0
I4	4333.48	-20	4344.445			4369.512	0.831471		0.80314	0.1	0
I5	4212.805	-20	4222.852			4246.453	0.798704			0.15	0
I6	4238.217	-20	4248.692			4273.549	0.833649			0.2	0
I7	4182.894	-20	4189.924			4204.431	0.514893			0.25	0
I8	4132.58	-20	4139.24			4152.645	0.485538			0.3	0
I9	4221.334	-20	4228.073			4241.192	0.470431			0.35	0
I10	4060.767	-20	4069.806			4089.417	0.705535			0.4	0
I11	4078.127	-20	4087.222			4107.236	0.713773			0.45	10
I12	4280.839	-20	4291.006			4313.757	0.76896			0.5	12
J1	4041.526	-20	4048.29			4061.63	0.497446			0.55	2
J2	4064.611	-20	4071.279			4084.851	0.497959			0.6	0
J3	4036.174	-20	4042.963			4056.941	0.514514			0.65	0
J4	4077.606	-20	4087.709			4111.589	0.833415			0.7	2
J5	4070.886	-20	4080.806			4104.178	0.81781			0.75	6
J6	4115.65	-20	4125.88			4149.443	0.821073			0.8	16
J7	4095.965	-20	4102.367			4115.931	0.487449			0.85	0
J8	4047.318	-20	4053.751			4066.933	0.484641			0.9	0
J9	4126.6	-20	4133.203			4146.527	0.4829			0.95	0
J10	4018.303	-20	4027.994			4049.219	0.769378			1	0
J11	4014.195	-20	4023.889			4046.013	0.79265			1.05	0
J12	4039.46	-20	4049.331			4071.123	0.783835			1.1	0
K1	4043.281	-20	4050.144			4063.949	0.511158				
K2	4053.447	-20	4060.151			4073.697	0.499568				
K3	4037.719	-20	4044.475			4058.231	0.508021				
K4	4086.307	-20	4096.55			4119.59	0.814497				
K5	4134.761	-20	4145.125			4168.299	0.81113				
K6	4204.01	-20	4214.564			4238.351	0.816851				
K7	4190.426	-20	4197.244			4211.513	0.503212				
K8	4157.226	-20	4164.002			4177.622	0.490627				
K9	4180.804	-20	4187.94			4202.257	0.513126				
K10	4136.776	-20	4147.208			4170.773	0.821834				
K11	4080.739	-20	4090.881			4114.555	0.828683				
K12	4080.088	-20	4090.336			4113.492	0.818698				
L1	4223.554	-20	4230.932			4245.321	0.515361				
L2	4209.405	-20	4216.256			4230.247	0.495118				

LASR0247.CSV

L3	4218.774	-20	4225.868			4240.612	0.517627				
L4	4315.879	-20	4326.89			4352.281	0.843435				
L5	4413.73	-20	4424.2			4449.083	0.800984				
L6	4552.583	-20	4563.671			4590.259	0.827575				
L7	4693.076	-20	4701.467			4719.287	0.558495				
L8	4678.911	-20	4687.081			4704.33	0.543259				
L9	4692.669	-20	4701.172			4718.518	0.55083				
L10	4527.451	-20	4538.493			4564.441	0.817025				
L11	4383.049	-20	4393.841	~		4418.34	0.805172				
L12	4306.106	-20	4316.837			4340.525	0.799302				
M1	4433.45	-40	4440.144			4454.49	0.474583	0.54352	0.47344	Bin	Frequency
M2	4546.412	-40	4553.57			4568.474	0.485268			0	0
M3	4580.694	-40	4587.492			4602.967	0.486234			0.05	0
M4	4670.051	-40	4678.876			4700.731	0.556954		0.61361	0.1	0
M5	4785.954	-40	4794.818			4817.578	0.660767			0.15	0
M6	4952.18	-40	4961.479			4985.827	0.679447			0.2	0
M7	5146.403	-40	5154.427			5174.086	0.537919			0.25	0
M8	4982.86	-40	4990.763			5009.219	0.528987			0.3	0
M9	4902.826	-40	4910.371			4927.252	0.498193			0.35	0
M10	4801.937	-40	4810.903			4833.221	0.651485			0.4	2
M11	4599.7	-40	4607.983			4627.843	0.611848			0.45	20
M12	4487.089	-40	4495.007			4513.551	0.58974			0.5	2
N1	4230.695	-40	4236.963			4249.85	0.452758			0.55	8
N2	4298.101	-40	4304.389			4317.945	0.461698			0.6	12
N3	4303.863	-40	4310.306			4324.141	0.471151			0.65	4
N4	4358.916	-40	4367.019			4385.887	0.618756			0.7	0
N5	4378.229	-40	4386.157			4404.734	0.605389			0.75	0
N6	4445.601	-40	4453.92			4473.229	0.621475			0.8	0
N7	4522.648	-40	4529.567			4544.588	0.485112			0.85	0
N8	4376.634	-40	4383.163			4397.286	0.47188			0.9	0
N9	4353.966	-40	4360.538			4373.806	0.455667			0.95	0
N10	4301.063	-40	4308.771			4326.336	0.587588			1	0
N11	4233.135	-40	4240.981			4258.428	0.597491			1.05	0
N12	4194.916	-40	4202.314			4218.603	0.564651			1.1	0
O1	4242.807	-40	4249.243			4262.039	0.453279				

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O2	4324.728	-40	4331.147			4344.131	0.448658				
O3	4338.902	-40	4345.267			4359.102	0.465562				
O4	4374.091	-40	4382.327			4401.532	0.627351				
O5	4336.748	-40	4344.768			4363.296	0.612172				
O6	4325.701	-40	4333.484			4351.335	0.592592				
O7	4414.974	-40	4421.501			4435.624	0.467732				
O8	4271.719	-40	4278.028			4291.136	0.454538				
O9	4239.462	-40	4245.5			4257.824	0.433128				
O10	4176.912	-40	4184.094			4200.037	0.553644				
O11	4173.711	-40	4181.374			4198.151	0.585563				
O12	4195.161	-40	4202.556			4218.594	0.558563				
P1	4537.567	-40	4544.369			4558.908	0.470327				
P2	4625.105	-40	4632.381			4647.627	0.486945				
P3	4699.852	-40	4707.16			4722.873	0.489817				
P4	4619.036	-40	4628.168			4649.051	0.64981				
P5	4511.151	-40	4519.529			4539.722	0.633334				
P6	4455.653	-40	4463.97			4483.226	0.618838				
P7	4402.243	-40	4408.803			4422.799	0.46694				
P8	4306.595	-40	4313.073			4326.151	0.454083				
P9	4294.582	-40	4301.211			4314.427	0.462084				
P10	4435.515	-40	4444.238			4463.238	0.625029				
P11	4414.901	-40	4423.157			4441.909	0.611745				
P12	4497.394	-40	4505.825			4524.935	0.612374				

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