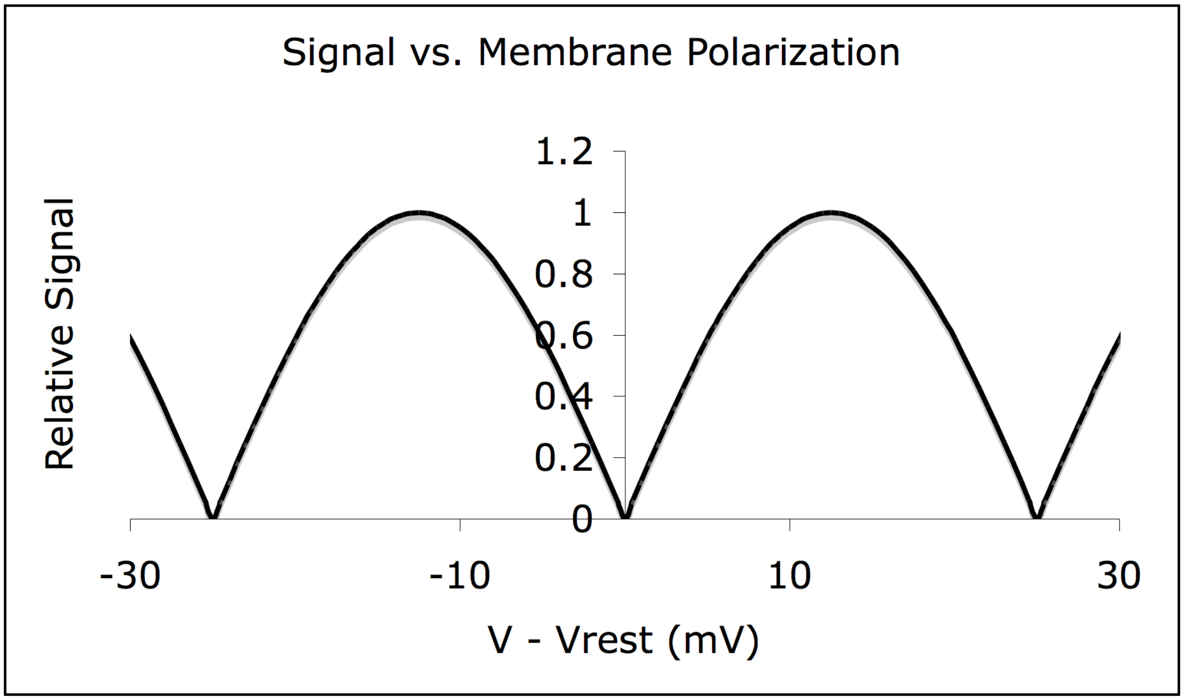
Exam questions

1) In electronically acquired data noise typically produces both positive and negative fluctuations in signal. In many, if not most, imaging methods, the images are treated as positive-only data, requiring a rectification step. Discuss what this does to our ability to make statistical inferences from the data.

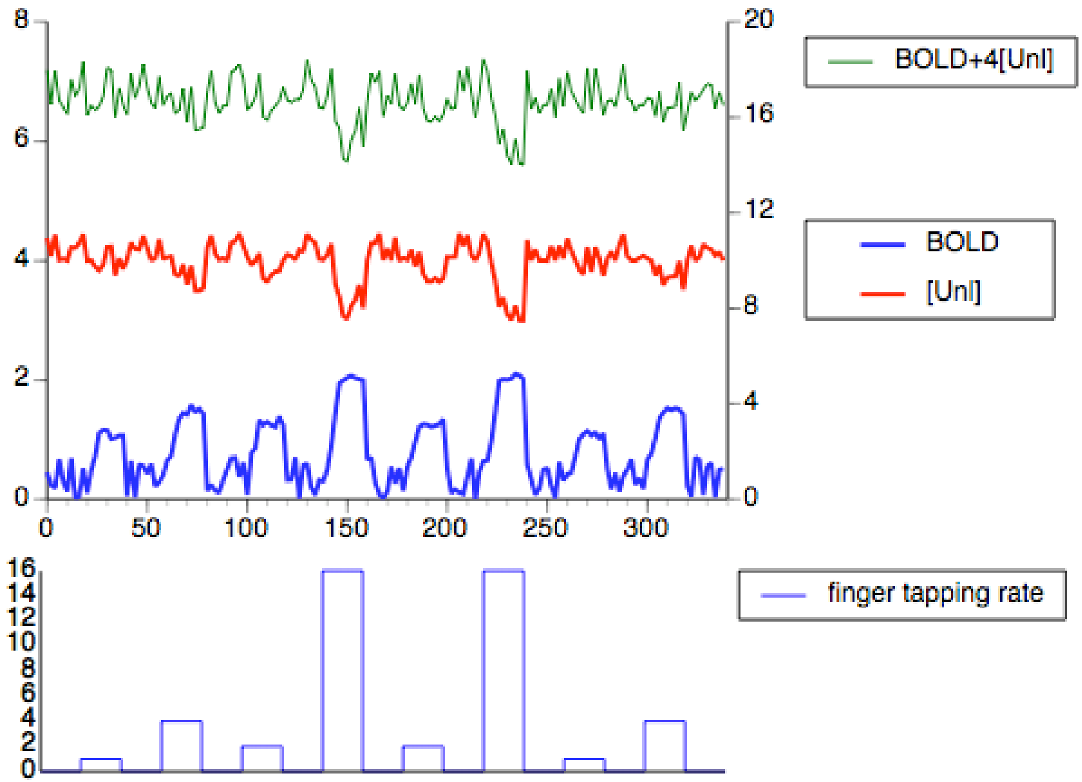
2) A clever UCLA graduate student has just developed a means of observing brain function using an imaging method based on polarized light that can apparently detect changes in neural membrane thickness as the intracellular potential changes. Because of the interferometry based detection means, the input/output relationship of the signal appears to be as follows:



The signal change with membrane potential is estimated to occur in less than 5 msec. The noise has been characterized as having a Gaussian, but non-white spectral distribution. Specifically, the noise has an amplitude of about 50% of the relative signal at frequencies below 20 Hz, but decreases rapidly in amplitude to about 10% relative to the signal at frequencies above 100 Hz, and stays at this level at least up to 100 kHz. The spatial resolution (FWHM) is about 2 mm.

Discuss what you expect to be the advantages and limitations of this new method, considering factors such as: sensitivity, linearity, distortion, etc…

3) A physiologist performs an experiment in which she measured blood oxygen level, by fMRI and extracellular concentration of the metabolite Unlikelium simultaneously, using magnetic resonance spectroscopy. She noticed that the fMRI and MRS signals depended on finger tapping rate in a very non-linear manner. Her data look like this:



She notes that when she adds the MRI BOLD signal to a scaled multiple of the concentration of Unlikelium, the sum is nearly constant. How can she use this information to get a better brain activation measure than she would get from the fMRI or MRS data alone? (Her data appear in the table on the last page).

4) The Kirlian aura may be detected by exposing a photographic plate with a biological sample in the presence of a strong electric field. Recently, scientists at the Nexxus research institute reported that the electrical energies varied in frequency between 1000 and 10000 Hz. They are building a system to detect this digitally and wish to convert the analog electrical signal to digital signals in a way that faithfully reflects the subtle Kirlian aura. The Signal to estimated noise ratio is surprisingly high at 10:1 within this frequency band and the noise appears to be flat with frequency. Compare the following approaches for them:

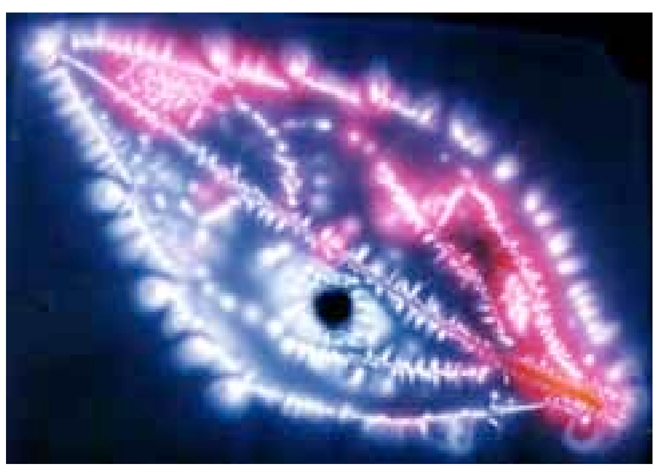


Image from http://www.crystalinks.com/kirlian.html

a) Digitize at a rate of 1,000,000 samples/second using an analog to digital convertor (ADC) that has four bits of accuracy, Fourier transform the signal and throw away signals at frequencies over 10,000 Hz.

b) Build an electrical low pass filter that suppresses signals above 10,000 Hz at a rate of 12 decibels/octave, then digitize at 10,000 Hz, using an ADC with 16 bit accuracy

c) Build an electrical low pass filter that suppresses signals above 10,000 Hz at a rate of 12 decibels/octave, then digitize are a rate of 50,000 Hz with 14 bit accuracy, Fourier transform the signal and throw away signals at frequencies over 10,000 Hz.

time	finger tapping rate	BOLD	[Unl]	BOLD+[Unl]
0	0	0.450147214	4.380870836	17.97363056
2	0	0.23922738	4.078545961	16.55341122
4	0	0.188593535	4.439891079	17.94815785
6	0	0.673080059	4.012966563	16.72494631
8	0	0.304887642	4.030879509	16.42840568
10	0	0.12845209	4.004615507	16.14691412
12	0	0.691016268	4.224357762	17.58844732
14	0	0.022880883	4.215039834	16.88304022
16	0	0.049760436	4.292785769	17.22090351
18	0	0.520236613	4.448464938	18.31409636
20	1	0.103559249	4.000129506	16.10407727
22	1	0.480325148	4.006994921	16.50830483
24	1	0.722650791	3.899952515	16.32246085
26	1	1.108540803	3.840497979	16.47053272
28	1	1.165241362	3.929694678	16.88402008
30	1	1.158891066	4.228595875	18.07327457
32	1	1.012434308	4.237713545	17.96328849
34	1	1.03075465	3.754230835	16.04767799
36	1	1.066870811	4.037639091	17.21742718
38	1	1.066610787	3.863092883	16.51898232
40	0	0.057524509	4.01915815	16.13415711
42	0	0.644071907	4.296810395	17.83131349
44	0	0.033159019	4.196186243	16.81790399
46	0	0.579019545	4.184505464	17.3170414
48	0	0.55598371	4.417121203	18.22446852
50	0	0.434609841	4.204668974	17.25328574
52	0	0.590167886	4.007910351	16.62180929
54	0	0.220047893	4.041705515	16.38686995
56	0	0.290509117	4.353888069	17.70606139
58	0	0.414331487	4.027451174	16.52413618
60	4	0.656360609	4.05792777	16.88807169
62	4	0.727091186	4.071883843	17.01462656
64	4	1.083362242	3.774428529	16.18107636
66	4	1.34585983	3.743064782	16.31811896
68	4	1.442893917	3.939581912	17.20122156
70	4	1.415584318	3.600152597	15.81619471
72	4	1.580423039	3.916185302	17.24516425
74	4	1.456862463	3.501951161	15.46466711

76	4	1.510751368	3.500214899	15.51161096
78	4	1.431312287	3.537928663	15.58302694
80	0	0.138990008	4.223526524	17.0330961
82	0	0.250231162	4.423717035	17.9450993
84	0	0.144142906	4.122269641	16.63322147
86	0	0.113429366	4.015772874	16.17652086
88	0	0.325104527	4.042029448	16.49322232
90	0	0.504884591	4.000007605	16.50491501
92	0	0.690228403	4.295347858	17.87161983
94	0	0.696281448	4.326709876	18.00312095
96	0	0.383161429	4.457591254	18.21352645
98	0	0.613455833	4.253382327	17.62698514
100	2	0.078635368	4.06489546	16.33821721
102	2	0.771676839	3.929380851	16.48920024
104	2	0.861434916	3.998857535	16.85686505
106	2	1.330034968	4.122510574	17.82007727
108	2	1.245655359	3.70158733	16.05200468
110	2	1.294407571	3.646454985	15.88022751
112	2	1.242291993	3.762916326	16.2939573
114	2	1.21168153	3.816057125	16.47591003
116	2	1.381988477	3.830740057	16.7049487
118	2	1.238377773	4.005265126	17.25943828
120	0	0.32530808	4.103965298	16.74116927
122	0	0.329824987	4.075602191	16.63223375
124	0	0.704072631	4.013876019	16.75957671
126	0	0.01839153	4.179543128	16.73656404
128	0	0.564266225	4.15155071	17.17046906
130	0	0.593993526	4.449116609	18.39045996
132	0	0.196925174	4.345509487	17.57896312
134	0	0.07385905	4.29662669	17.26036581
136	0	0.323139146	4.029712286	16.44198829
138	0	0.308566393	4.016024149	16.37266299
140	16	0.499110887	4.102863954	16.9105667
142	16	0.894694075	4.2799784	18.01460767
144	16	1.443181502	3.604475916	15.86108517
146	16	1.946590369	3.397634519	15.53712844
148	16	2	3.066393485	14.26557394
150	16	2.047015849	3.028081881	14.15934337
152	16	2.073579928	3.242844398	15.04495752
154	16	2.039575046	3.346123491	15.42406901
156	16	2.019090302	3.595781183	16.40221503
158	16	2.000023041	3.203419346	14.81370043
160	0	0.664253235	4.002052093	16.67246161
162	0	0.700310733	4.28677307	17.84740301
164	0	0.283328606	4.29667678	17.47003573
166	0	0.083099706	4.454950486	17.90290165
168	0	0.021979318	4.009646144	16.06056389
170	0	0.133715495	4.197355154	16.92313611
172	0	0.551574284	4.004949451	16.57137209
174	0	0.269210934	4.386864769	17.81667001
176	0	0.524434909	4.000010263	16.52447596
178	0	0.138724803	4.045443155	16.32049742
180	2	0.540645618	4.016369841	16.60612498
182	2	0.703463033	4.17765534	17.41408439

184	2	0.967817768	3.904915405	16.58747939
186	2	1.212607141	4.14182335	17.77990054
188	2	1.258349597	3.777614663	16.36880825
190	2	1.248340609	3.655274984	15.86944054
192	2	1.214848889	3.654263323	15.83190218
194	2	1.232875325	3.705318888	16.05415088
196	2	1.257866479	3.648202396	15.85067606
198	2	1.343620811	3.69576575	16.12668381
200	0	0.522816996	4.063659312	16.77745424
202	0	0.106221695	4.062166414	16.35488735
204	0	0.162544276	4.065858141	16.42597684
206	0	0.114100362	4.458991258	17.95006539
208	0	0.09282519	4.251883438	17.10035894
210	0	0.3803507	4.429402024	18.0979588
212	0	0.685460186	4.092868843	17.05693556
214	0	0.007286032	4.00506018	16.02752675
216	0	0.457709496	4.13762754	17.00821966
218	0	0.636389822	4.449056131	18.43261435
220	16	0.646441732	4.321914498	17.93409972
222	16	0.955454085	3.972701588	16.84626044
224	16	1.452915846	3.662230956	16.10183967
226	16	1.992978786	3.226577206	14.89928761
228	16	2.016702901	3.378814169	15.53195958
230	16	2.009860495	3.098535299	14.40400169
232	16	2.028810728	3.010137793	14.0693619
234	16	2.103817267	3.24731704	15.09308543
236	16	2.080384115	3.003665434	14.09504585
238	16	2.022897959	3.000406763	14.02452501
240	0	0.588049561	4.342186277	17.95679467
242	0	0.342407821	4.004637055	16.36095604
244	0	0.080354428	4.183160132	16.81299496
246	0	0.171373423	4.006004635	16.19539196
248	0	0.494267567	4.005029513	16.51438562
250	0	0.526526495	4.000773263	16.52961955
252	0	0.22001072	4.245212431	17.20086044
254	0	0.024103457	4.002675998	16.03480745
256	0	0.622349317	4.249280574	17.61947161
258	0	0.314893529	4.03904609	16.47107789
260	1	0.419595452	4.366114637	17.884054
262	1	0.448128493	4.166280822	17.11325178
264	1	0.71119096	4.013136417	16.76373663
266	1	1.009254241	3.855480062	16.43117449
268	1	1.088508545	3.774746281	16.18749367
270	1	1.143080674	4.227497439	18.05307043
272	1	1.073940295	3.816727104	16.34084871
274	1	1.123311957	4.225637499	18.02586195
276	1	1.004307762	4.034942928	17.14407947
278	1	1.103642819	3.750328393	16.10495639
280	0	0.500323663	4.041483278	16.66625677
282	0	0.169951897	4.148112524	16.76240199
284	0	0.439020062	4.002027648	16.44713065
286	0	0.127916568	4.261377811	17.17342781
288	0	0.39550674	4.448148192	18.18809951
290	0	0.494319554	4.075040179	16.79448027

292	0	0.669190321	4.007383273	16.69872341
294	0	0.253237505	4.001766149	16.2603021
296	0	0.355611382	4.045066784	16.53587852
298	0	0.174303665	4.083520262	16.50838471
300	4	0.667368712	4.036947091	16.81515708
302	4	0.767523845	3.998826939	16.7628316
304	4	1.034835834	3.75668514	16.0615764
306	4	1.350709374	3.93091656	17.07437561
308	4	1.449221564	3.592440306	15.81898279
310	4	1.521731116	3.717932702	16.39346192
312	4	1.490603141	3.732710228	16.42144405
314	4	1.521635408	3.737672101	16.47232381
316	4	1.500509328	3.991836359	17.46785476
318	4	1.415263078	3.511162224	15.45991197
320	0	0.219820988	4.010159228	16.2604579
322	0	0.048412091	4.251402845	17.05402347
324	0	0.706088522	4.000544127	16.70826503
326	0	0.6613726	4.061004606	16.90539102
328	0	0.076082882	4.273640884	17.17064642
330	0	0.550138522	4.214303414	17.40735218
332	0	0.602264718	4.186617123	17.34873321
334	0	0.036401242	4.08873908	16.39135756
336	0	0.492317027	4.138642792	17.04688819
338	0	0.515309797	4.000247319	16.51629907