

~~What is claimed is:~~ CLAIMS:

1. A touch sensitive device comprising:

a touch interface comprising rows and columns;

a signal generator for generating a plurality of unique orthogonal signals on at least a plurality of the rows, respectively;

a frequency converter that:

receives a first touch signal present on at least one of the plurality of columns, the first touch signal having a first center frequency,

combines the first touch signal with a second signal, the second signal having a second center frequency, and

outputs a lower frequency touch signal, the lower frequency touch signal having a center frequency that is lower than the center frequency of the first touch signal;

a touch processor for identifying touch on the touch interface by processing the lower frequency touch signal and outputting touch event data.

2. The touch sensitive device of claim 1, wherein the frequency converter and the touch processor are part of the same hardware processor.

~~3. The touch sensitive device of claim 1, wherein the frequency converter and the touch processor are different hardware processors.~~

~~4. The touch sensitive device of claim 1, wherein the orthogonal signals are orthogonal in frequency.~~

~~5. The touch sensitive device of claim 1, wherein the orthogonal signals are orthogonal in time.~~

~~6. The touch sensitive device of claim 1, wherein the orthogonal signals are orthogonal in code.~~

~~7. The touch sensitive device of claim 1, wherein the orthogonal signals are orthogonal with respect to at least two selected from the group consisting of: time, frequency, and code.~~

~~8. The touch sensitive device of claim 4, wherein the lower frequency touch signal has frequency bins which have been aligned by the frequency converter, thereby facilitating processing of the lower frequency touch signal by the touch processor.~~

~~9. The touch sensitive device of claim 7, wherein the lower frequency touch signal has frequency bins which have been aligned by the frequency converter, thereby facilitating processing of the lower frequency touch signal by the touch processor.~~

~~10. The touch sensitive device of claim 4, wherein the orthogonal signals have a preselected spacing in frequency, and wherein the frequency converter provides a preselected frequency offset between the first touch signal and the lower frequency touch signal, thereby facilitating processing of the lower frequency touch signal by the touch processor.~~

~~11. The touch sensitive device of claim 7, wherein the lower frequency touch signal has frequency bins which have been aligned by the frequency converter, thereby facilitating processing of the lower frequency touch signal by the touch processor.~~

~~12. The touch sensitive device of claim 4, wherein the touch processor comprises a processor configured to perform spectral analysis.~~

~~13. The touch sensitive device of claim 7, wherein the touch processor comprises a processor configured to perform spectral analysis.~~

~~14. The touch sensitive device of claim 6, wherein the touch processor comprises a processor configured to perform cross correlation using a Fourier transform.~~

~~15. The touch sensitive device of claim 7, wherein the touch processor comprises a processor configured to perform cross correlation using a Fourier transform.~~

~~16. The touch sensitive device of claim 12, wherein the touch processor comprises a processor configured to perform spectral analysis using a Fourier transform.~~

~~17. The touch sensitive device of claim 13, wherein the touch processor comprises a processor configured to perform spectral analysis using a Fourier transform.~~

~~18. The touch sensitive device of claim 16, configured to perform the spectral analysis digitally such that a spectrum of each column is analyzed to determine which and how much of a signal of interest from each row of the touch interface is present on each column of the touch interface.~~

~~19. The touch sensitive device of claim 17, configured to perform the spectral analysis digitally such that a spectrum of each column is analyzed to determine which and how much of a signal of interest from each row of the touch interface is present on each column of the touch interface.~~

~~20. The touch sensitive device of claim 14, configured to perform the cross correlation digitally such that the signal of each column is analyzed to determine which and how much of a signal of interest from each row of the touch interface is present on each column of the touch interface.~~

~~21. The touch sensitive device of claim 15, configured to perform the cross-correlation digitally such that the signal of each column is analyzed to determine which and how much of a signal of interest from each row of the touch interface is present on each column of the touch interface.~~

~~22. The touch sensitive device of claim 1, wherein the touch processor further comprises an analog-to-digital converter.~~

~~23. The touch sensitive device of claim 1, further comprising an analog-to-digital converter configured to convert the lower frequency touch signal to a digital signal;~~

~~i) for processing by the touch processor;~~

~~ii) for processing by the touch processor, the touch processor being optimized for the second center frequency to lower power consumption of the analog-to-digital converter; and/or~~

~~iii) for processing by the touch processor, the touch processor being optimized for the second center frequency to lower circuit-design complexity of the analog-to-digital converter.~~

~~24. The touch sensitive device of claim 1, further comprising an analog-to-digital converter configured to convert the lower frequency touch signal to a digital signal for processing by the touch processor, the touch processor being optimized for the second center frequency to lower power consumption of the analog-to-digital converter.~~

~~25. The touch sensitive device of claim 1, further comprising an analog-to-digital converter configured to convert the lower frequency touch signal to a digital signal for processing by the touch processor, the touch processor being optimized for the second center frequency to lower circuit-design complexity of the analog-to-digital converter.~~

~~264.~~ The touch sensitive device of claim 1, further comprising a sigma-delta analog-to-digital converter or a continuous time sigma-delta analog-to-digital converter configured to convert the lower frequency touch signal to a digital signal for processing by the touch processor.

~~27. The touch sensitive device of claim 1, further comprising a continuous time sigma-delta analog-to-digital converter configured to convert the lower frequency touch signal to a digital signal for processing by the touch processor.~~

~~285.~~ A touch sensitive device comprising:

a touch interface comprising rows and columns;

a signal generator for generating a plurality of unique orthogonal signals on at least a plurality of the rows, respectively;

a frequency converter that:

receives a first touch signal present on at least one of the plurality of columns, the first touch signal having a first center frequency,

converts the first touch signal to a second signal having a second center frequency,
and

outputs the second signal having the second center frequency;

a touch processor for identifying touch on the touch interface by processing the second signal having the second center frequency and outputting touch event data.

~~296.~~ The touch sensitive device of either claim 1 or 285, wherein the orthogonal signals are orthogonal in frequency, time or code.

~~30. The touch sensitive device of claim 28, wherein the orthogonal signals are orthogonal in time.~~

~~31. The touch sensitive device of claim 28, wherein the orthogonal signals are orthogonal in code.~~

~~327.~~ The touch sensitive device of either claim 1 or 285, wherein the orthogonal signals are orthogonal with respect to at least two selected from ~~the a~~ group consisting of: time, frequency, and code.

~~33. The touch sensitive device of claim 29, wherein the second signal having the second center frequency has frequency bins which have been aligned by the frequency converter, thereby facilitating processing of the second signal by the touch processor.~~

~~34. The touch sensitive device of claim 32, wherein the second signal having the second center frequency has frequency bins which have been aligned by the frequency converter, thereby facilitating processing of the second signal by the touch processor.~~

~~35. The touch sensitive device of claim 29, wherein the orthogonal signals have a preselected spacing in frequency, and wherein the frequency converter provides a preselected frequency offset between the first touch signal and the second signal, thereby facilitating processing of the second signal by the touch processor.~~

~~36. The touch sensitive device of claim 32, wherein the second signal having the second center frequency has frequency bins which have been aligned by the frequency converter, thereby facilitating processing of the second signal by the touch processor.~~

~~378.~~ The touch sensitive device of either claim 1 or 295, wherein the touch processor comprises a processor configured to perform spectral analysis.

~~38. The touch sensitive device of claim 32, wherein the touch processor comprises a processor configured to perform spectral analysis.~~

~~39. The touch sensitive device of claim 31, wherein the touch processor comprises a processor configured to perform cross-correlation using a Fourier transform.~~

~~40. The touch sensitive device of claim 32, wherein the touch processor comprises a processor configured to perform cross-correlation using a Fourier transform.~~

~~41. The touch sensitive device of claim 37, wherein the touch processor comprises a processor configured to perform spectral analysis using a Fourier transform.~~

~~42. The touch sensitive device of claim 38, wherein the touch processor comprises a processor configured to perform spectral analysis using a Fourier transform.~~

~~43. The touch sensitive device of claim 41, configured to perform the spectral analysis digitally such that a spectrum of each column is analyzed to determine which and how much of a signal of interest from each row of the touch interface is present on each column of the touch interface.~~

~~44. The touch sensitive device of claim 42, configured to perform the spectral analysis digitally such that a spectrum of each column is analyzed to determine which and how much of a signal of interest from each row of the touch interface is present on each column of the touch interface.~~

~~45. The touch sensitive device of claim 39, configured to perform the cross-correlation digitally such that the signal of each column is analyzed to determine which and how much of a signal of interest from each row of the touch interface is present on each column of the touch interface.~~

~~46. The touch sensitive device of claim 40, configured to perform the cross-correlation digitally such that the signal of each column is analyzed to determine which and how much of a signal of interest from each row of the touch interface is present on each column of the touch interface.~~

~~479.~~ The touch sensitive device of claim 285, wherein the second center frequency is lower than the first center frequency.

~~4810.~~ The touch sensitive device of claim 285, wherein the second center frequency is higher than the first center frequency.

~~49. The touch sensitive device of claim 28, wherein the touch processor further comprises an analog-to-digital converter.~~

~~5011.~~ The touch sensitive device of claim 285, further comprising an analog-to-digital converter configured to convert the second signal to a digital signal:

i) for processing by the touch processor;

ii) for processing by the touch processor, the touch processor being optimized for the second center frequency to lower power consumption of the analog-to-digital converter; and/or

iii) for processing by the touch processor, the touch processor being optimized for the second center frequency to lower circuit-design complexity of the analog-to-digital converter.

~~51. The touch sensitive device of claim 28, further comprising an analog-to-digital converter configured to convert the second signal to a digital signal for processing by the touch processor, the touch processor being optimized for the second center frequency to lower power consumption of the analog-to-digital converter.~~

~~52. The touch sensitive device of claim 28, further comprising an analog-to-digital converter configured to convert the second signal to a digital signal for processing by the touch processor, the touch processor being optimized for the second center frequency to lower circuit design complexity of the analog-to-digital converter.~~

5312. The touch sensitive device of claim 285, further comprising a sigma-delta analog-to-digital converter or a continuous time sigma-delta analog-to-digital converter configured to convert the second signal to a digital signal for processing by the touch processor.

~~54. The touch sensitive device of claim 28, further comprising a continuous time sigma-delta analog-to-digital converter configured to convert the second signal to a digital signal for processing by the touch processor.~~

5513. A touch sensitive device comprising:

a touch interface comprising rows and columns;

a signal generator for generating a plurality of unique orthogonal signals on at least a plurality of the rows, respectively;

a local oscillator generating a second signal, the second signal having a second center frequency;

a heterodyning frequency mixer configured to receive a first touch signal present on at least one of the plurality of columns, the first touch signal having a first center frequency, and the second signal, and to output a heterodyned signal based upon the first touch signal and the

second signal, the heterodyned signal having a center frequency that is different than the center frequency of the first touch signal;

a touch processor for identifying touch on the touch interface by processing the heterodyned signal and outputting touch event data.

~~56~~14. The touch sensitive device of claim ~~55~~13, wherein the frequency mixer comprises a quadrature frequency mixer.

~~—57. The touch sensitive device of claim 55, wherein the quadrature frequency mixer employs first and second frequency mixers driven from the local oscillator, one of the first and second frequency mixers being fed with a copy of a signal from the local oscillator that has been shifted by 90 degrees.~~

~~58~~15. The touch sensitive device of claim ~~55~~13, wherein the touch processor is configured to perform spectral analysis and/or cross-correlation.

~~—59. The touch sensitive device of claim 55, wherein the touch processor is configured to perform spectral analysis using a Fourier transform.~~

~~60~~16. The touch sensitive device of claim ~~55~~13, wherein the touch processor is configured to perform cross-correlation.

~~—61. The touch sensitive device of claim 60, wherein the touch processor is configured to perform cross-correlation using a Fourier transform as a step of the cross-correlation.~~

~~62. The touch sensitive device of claim 59, wherein an in-phase output of the frequency mixer is fed into a real input of the Fourier transform and a quadrature output of the frequency mixer is fed into an imaginary input of the Fourier transform.~~

~~63. The touch sensitive device of claim 61, wherein an in phase output of the frequency mixer is fed into a real input of the Fourier transform and a quadrature output of the frequency mixer is fed into an imaginary input of the Fourier transform.~~

~~6417.~~ The touch sensitive device of claim ~~5513~~, further comprising a bandpass filter configured:

~~i) to filter the first touch signal prior to mixing of the first touch signal with the second signal;~~

~~ii) to filter out a sum component of an output of the mixer and allow a difference component to pass; or~~

~~iii) to filter out a difference component of an output of the mixer and allow a sum component to pass.~~

~~65. The touch sensitive device of claim 55, further comprising a bandpass filter configured to filter out a sum component of an output of the mixer and allow a difference component to pass.~~

~~66. The touch sensitive device of claim 55, further comprising a bandpass filter configured to filter out a difference component of an output of the mixer and allow a sum component to pass.~~

~~6718.~~ The touch sensitive device of claim ~~5513~~, wherein the signal generator is configured:

~~i) to perform frequency division multiplexing;~~

~~ii) to perform time division multiplexing;~~

~~iii) to perform a simultaneous mixture of frequency division multiplexing and time division multiplexing;~~

iv) to perform code division multiplexing;

v) to perform a simultaneous mixture of code division multiplexing and time division multiplexing.

~~68. The touch sensitive device of claim 67, wherein the frequency generator is configured to allocate frequencies such that there is a gap in frequency coverage, the gap coinciding with a set of unusable frequencies near DC in the heterodyned signal.~~

~~69. The touch sensitive device of claim 55, wherein the signal generator is configured to perform time division multiplexing.~~

~~70. The touch sensitive device of claim 56, wherein the quadrature frequency mixer is configured to shift the center frequency of the first touch signal down to a position in baseband.~~

~~71. The touch sensitive device of claim 55, wherein the signal generator is configured to perform a simultaneous mixture of frequency division multiplexing and time division multiplexing.~~

~~72. The touch sensitive device of claim 55, wherein the signal generator is configured to perform code division multiplexing.~~

~~73. The touch sensitive device of claim 55, wherein the signal generator is configured to perform a simultaneous mixture of code division multiplexing and time division multiplexing.~~

74~~19~~. The touch sensitive device of claim 55~~13~~, wherein the signal generator is configured;

i) to perform a simultaneous mixture of code division multiplexing and frequency division multiplexing; or

ii) to perform a simultaneous mixture of frequency division multiplexing, time division multiplexing, and code division multiplexing.

~~75. The touch sensitive device of claim 55, wherein the signal generator is configured to perform a simultaneous mixture of frequency division multiplexing, time division multiplexing, and code division multiplexing.~~

~~76~~20. The touch sensitive device of any one of claims 1, 5 and 5513, wherein the touch processor comprises a processor configured to perform spectral analysis.

~~77. The touch sensitive device of claim 76, wherein the touch processor comprises a processor configured to perform spectral analysis using a Fourier transform.~~

~~78~~21. The touch sensitive device of any one of claims 551, 2 and 13, wherein the touch processor comprises a processor configured to perform cross-correlation.

~~79. The touch sensitive device of claim 78, wherein the touch processor comprises a processor configured to perform cross-correlation using a Fourier transform as a step of the cross-correlation.~~

~~80~~22. The touch sensitive device of claim 5513, wherein a bandpass filter is applied to the first signal prior to heterodyning the first touch signal.

~~81~~23. The touch sensitive device of claim 5513, wherein a bandpass filter is applied to the second signal after heterodyning.

~~8224.~~ The touch sensitive device of claim ~~5513~~, wherein a low-pass filter is applied to the second signal after heterodyning.

~~8325.~~ The touch sensitive device of any one of claims 551, 5 and 13, wherein the touch processor further comprises an analog-to-digital converter.

~~84.~~ The touch sensitive device of claim ~~83~~, wherein the second signal is amplified before digitization by an analog-to-digital converter.

~~85.~~ The touch sensitive device of claim ~~83~~, wherein the analog-to-digital converter is a sigma-delta analog-to-digital converter.

~~86.~~ The touch sensitive device of claim ~~83~~, wherein the analog-to-digital converter is a continuous time sigma-delta analog-to-digital converter.

~~87.~~ The touch sensitive device of claim ~~76~~, configured to perform the spectral analysis digitally such that a spectrum of each column is analyzed to determine which and how much of a signal of interest from each row of the touch interface is present on each column of the touch interface.

~~88.~~ The touch sensitive device of claim ~~78~~, configured to perform the cross-correlation analysis digitally such that the signal from each column is analyzed to determine which and how much of a signal of interest from each row of the touch interface is present on each column of the touch interface.