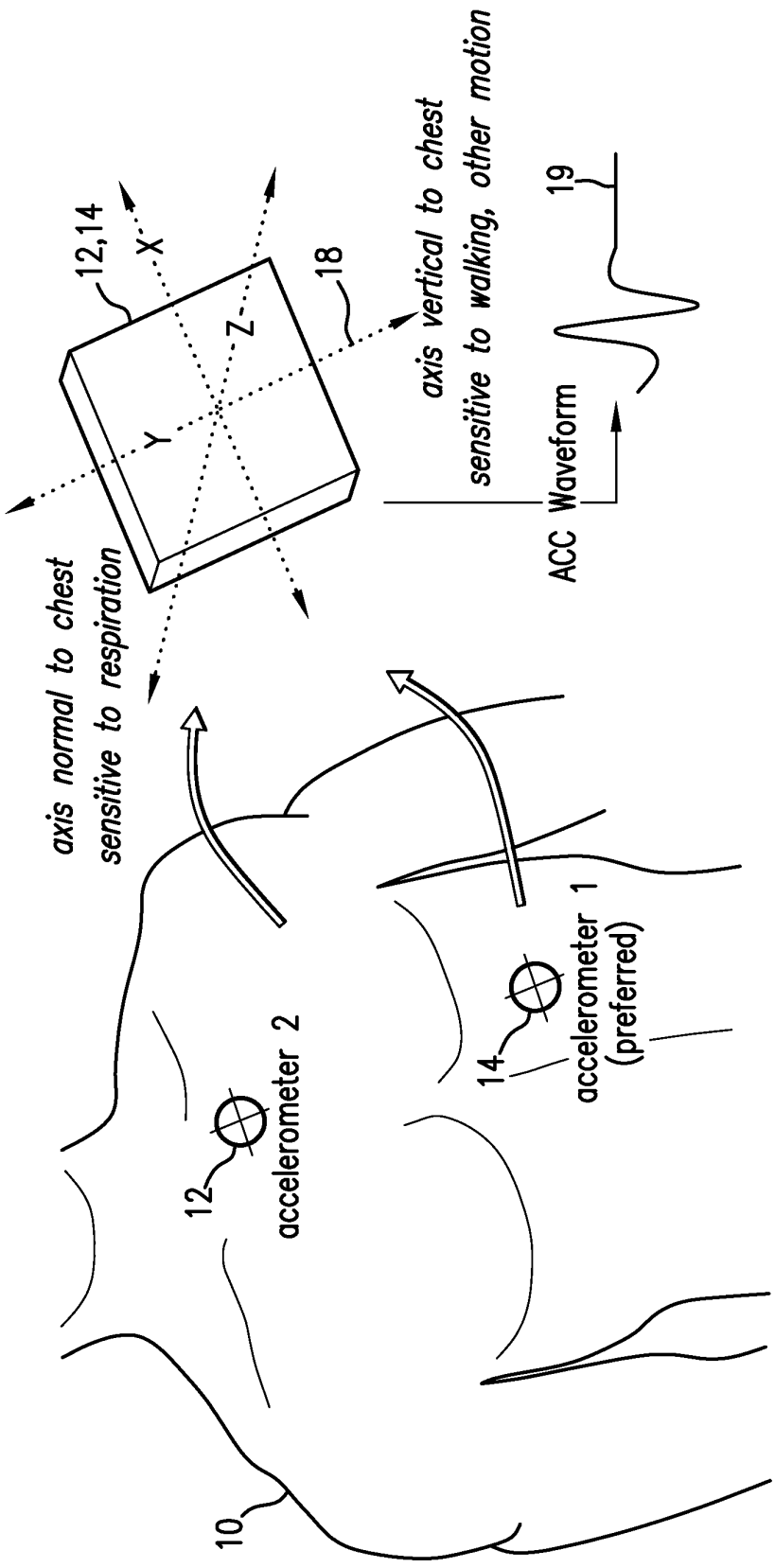

12,14
X
Z
Y
18
axis vertical to chest
sensitive to walking, other motion
19
ACC Waveform
axis normal to chest
sensitive to respiration
12
accelerometer 2
14
accelerometer 1
(preferred)
10

FIG.1A

FIG.1B

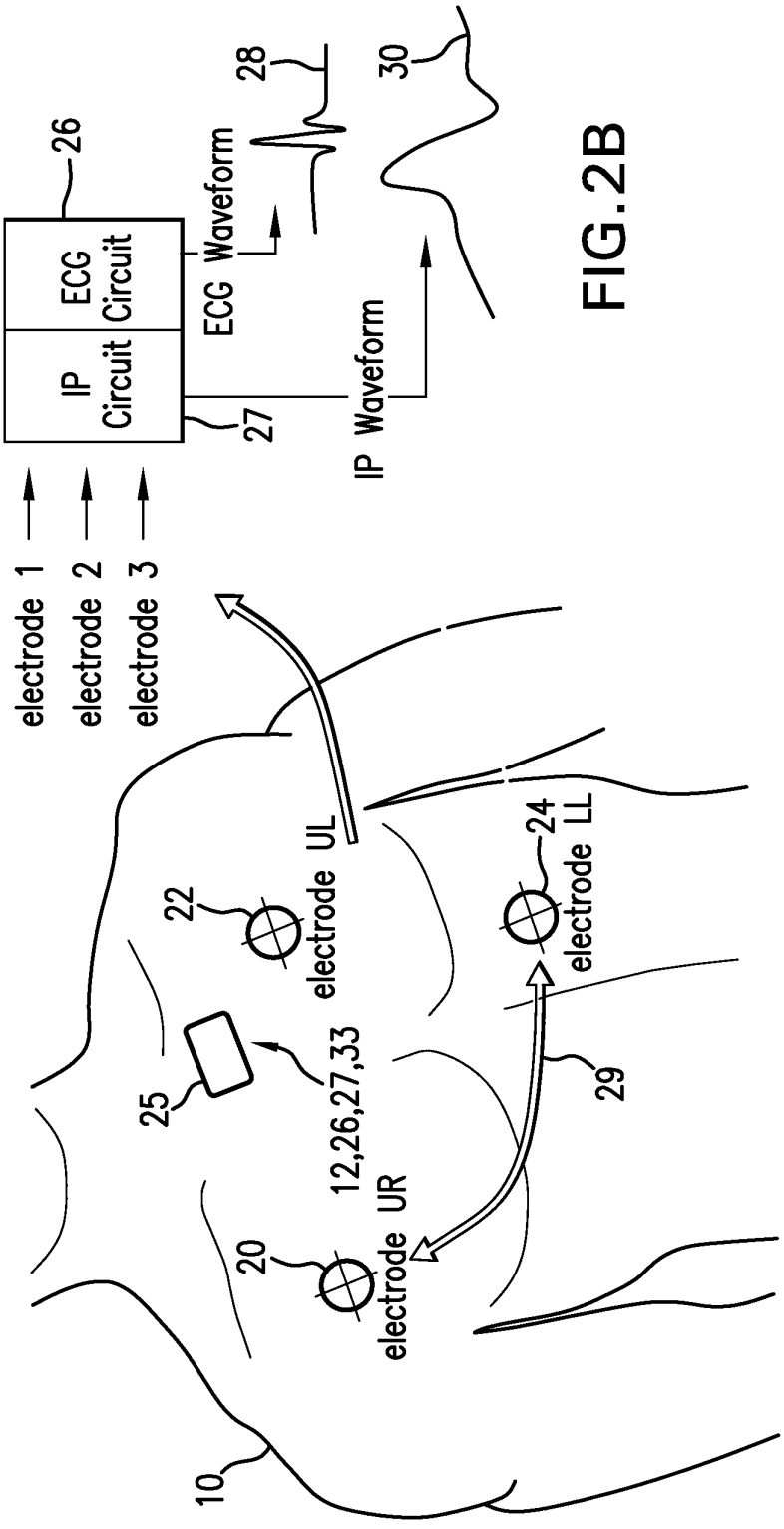

electrode 1
electrode 2
electrode 3
IP Circuit
ECG Circuit
26
27
ECG Waveform
28
IP Waveform
30
electrode UL
22
electrode UR
20
12,26,27,33
25
electrode LL
24
29
10

FIG.2A

FIG.2B

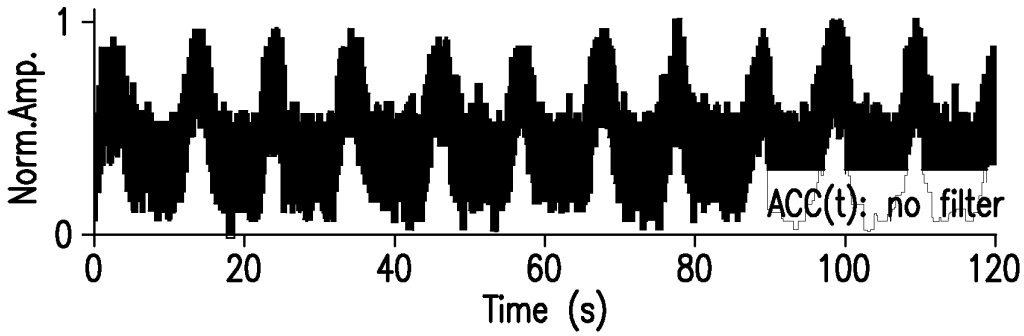


FIG.3A

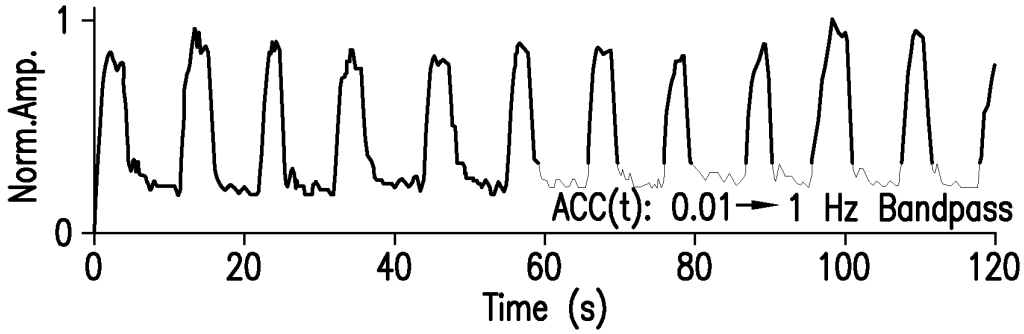


FIG.3B

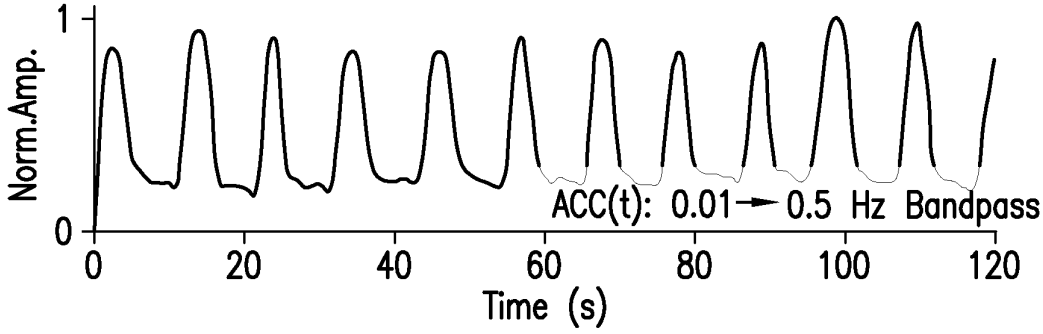


FIG.3C

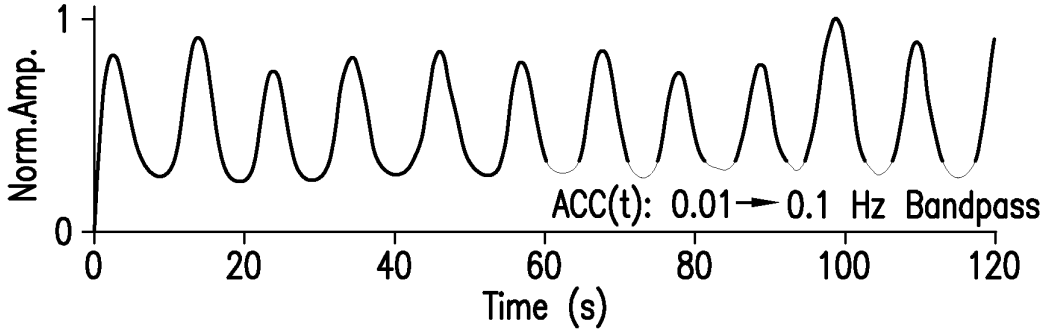


FIG.3D

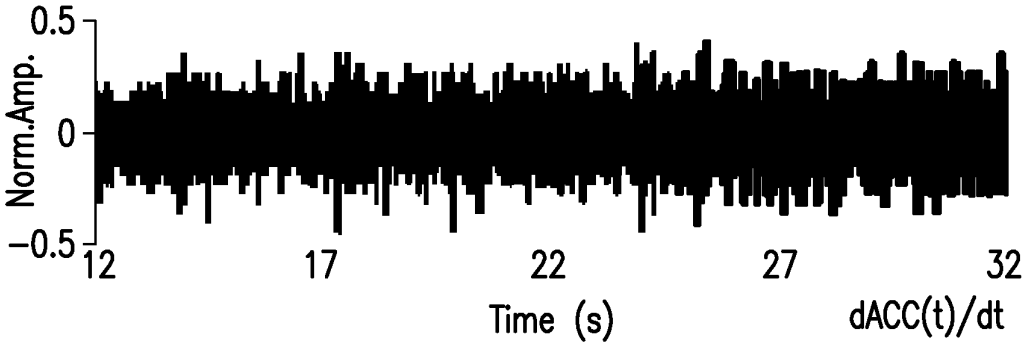


FIG.3E

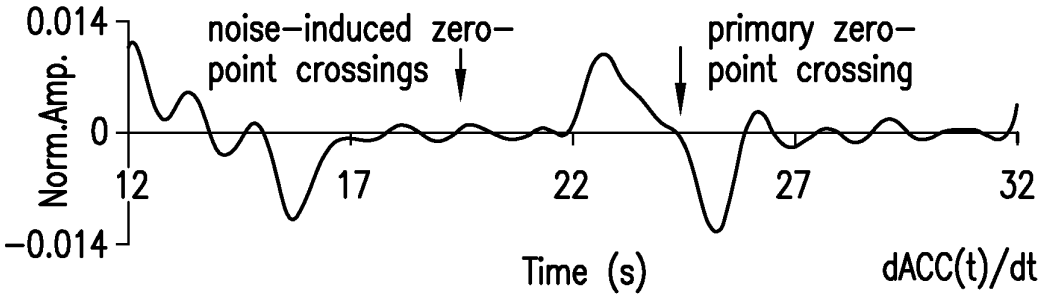


FIG.3F

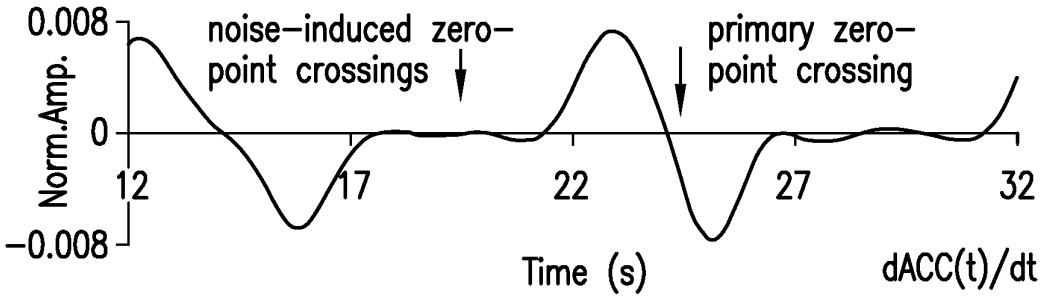


FIG.3G

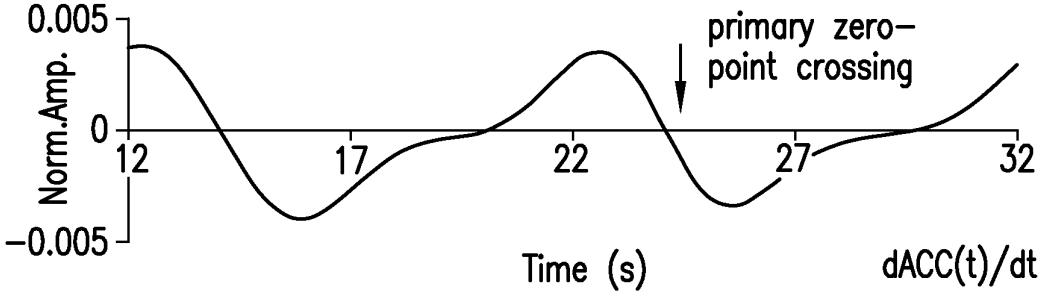


FIG.3H

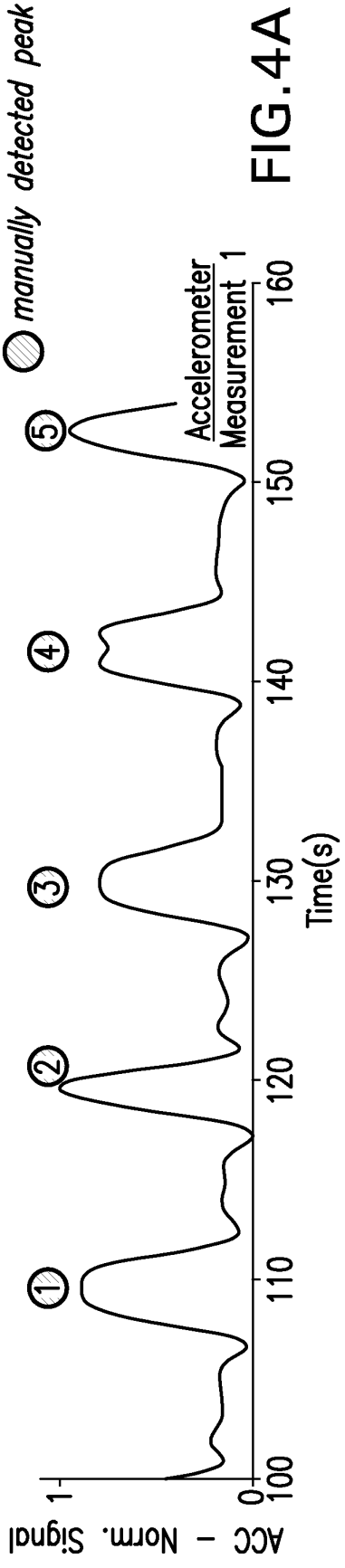


FIG.4A

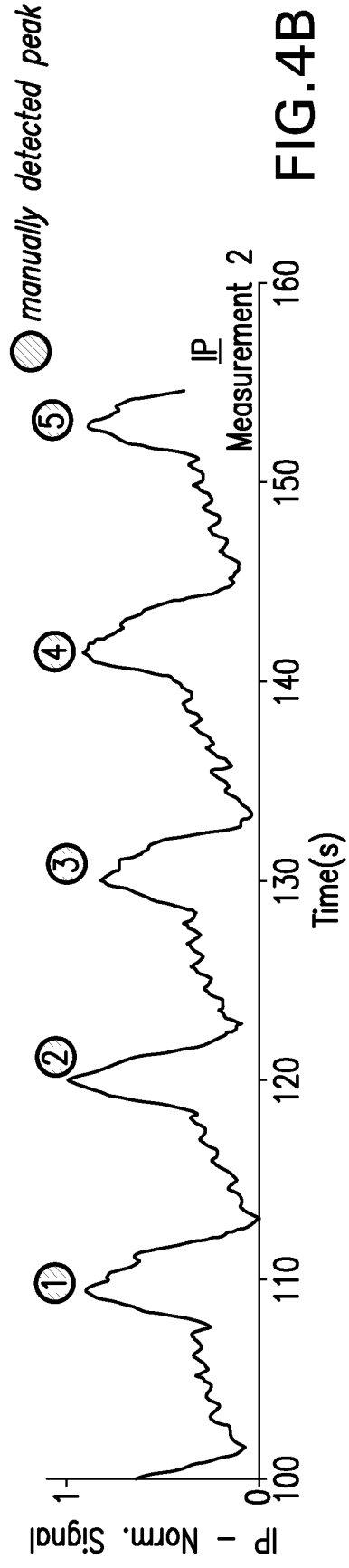


FIG.4B

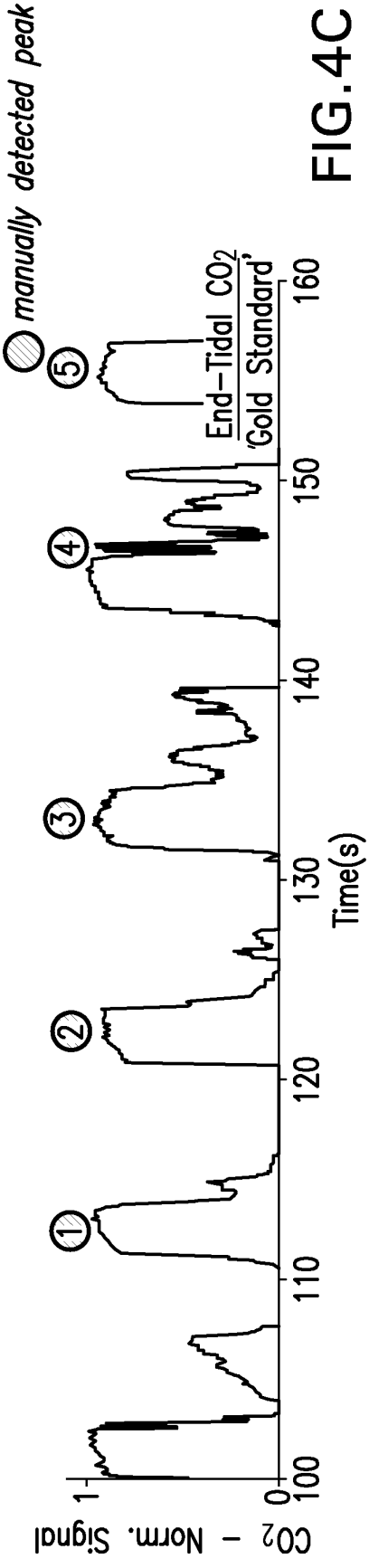


FIG.4C

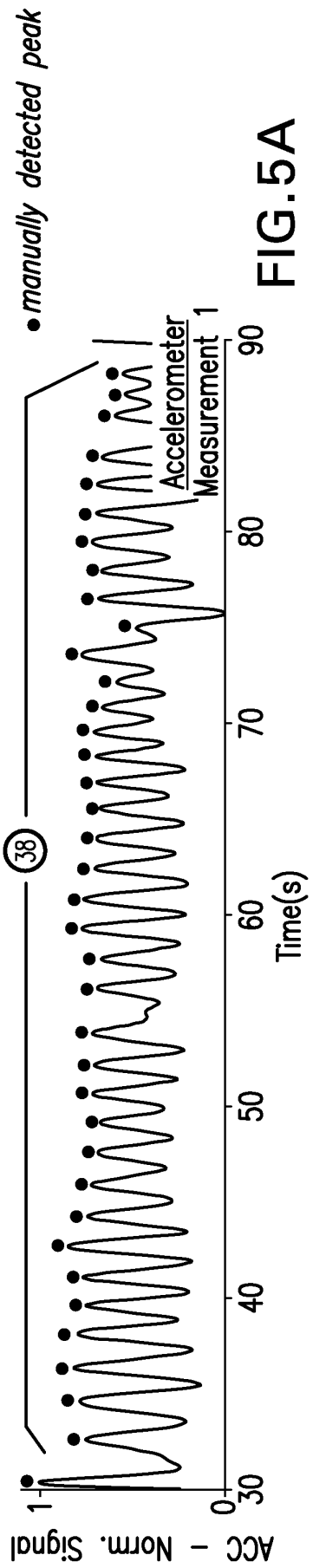


FIG.5A

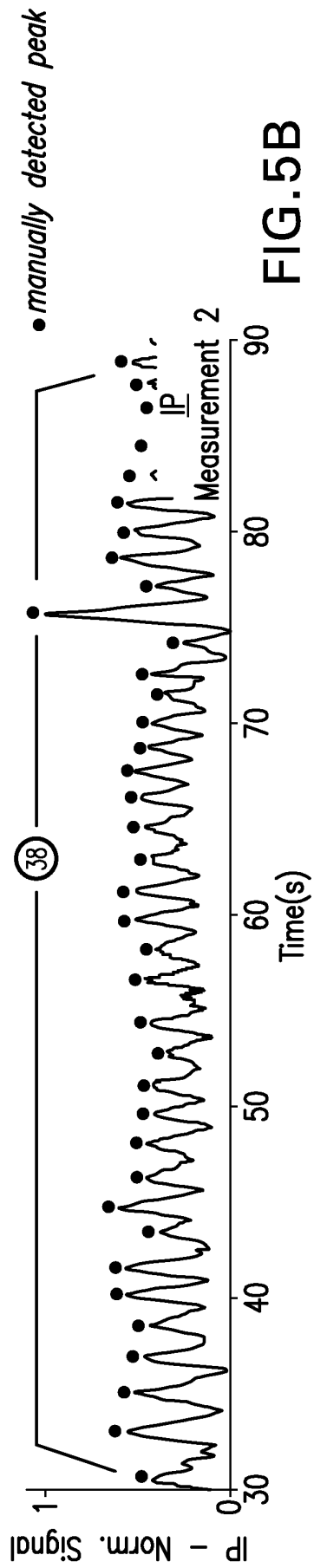


FIG.5B

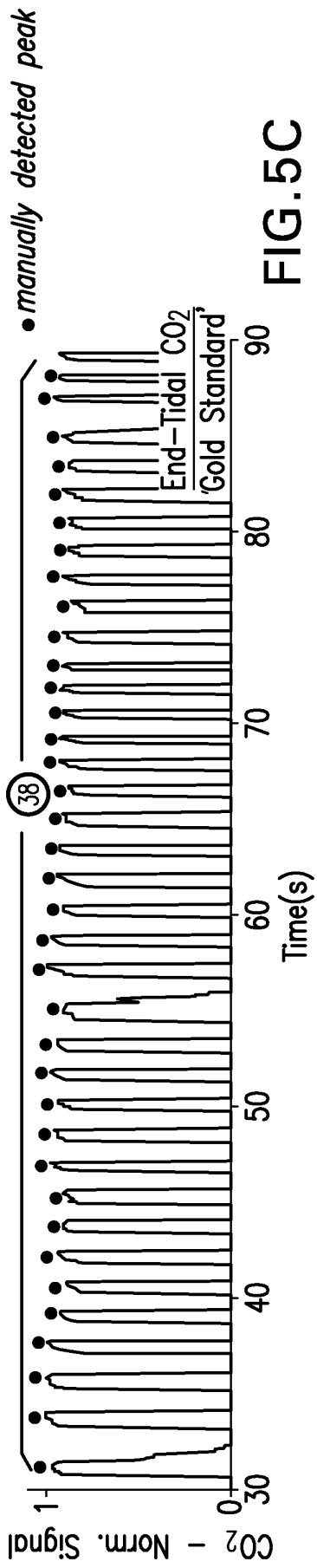


FIG.5C

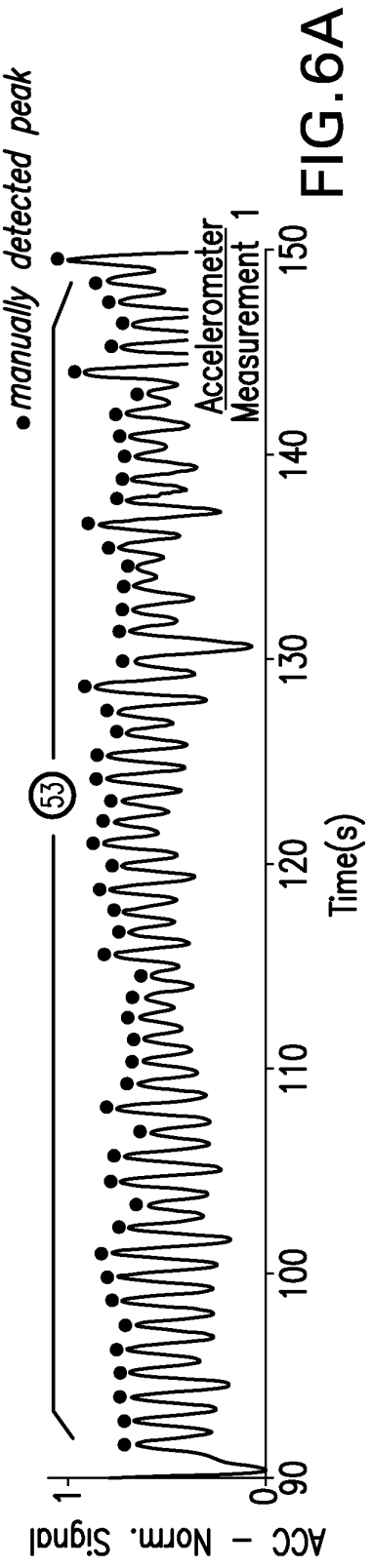


FIG.6A

FIG.6B

FIG.6C

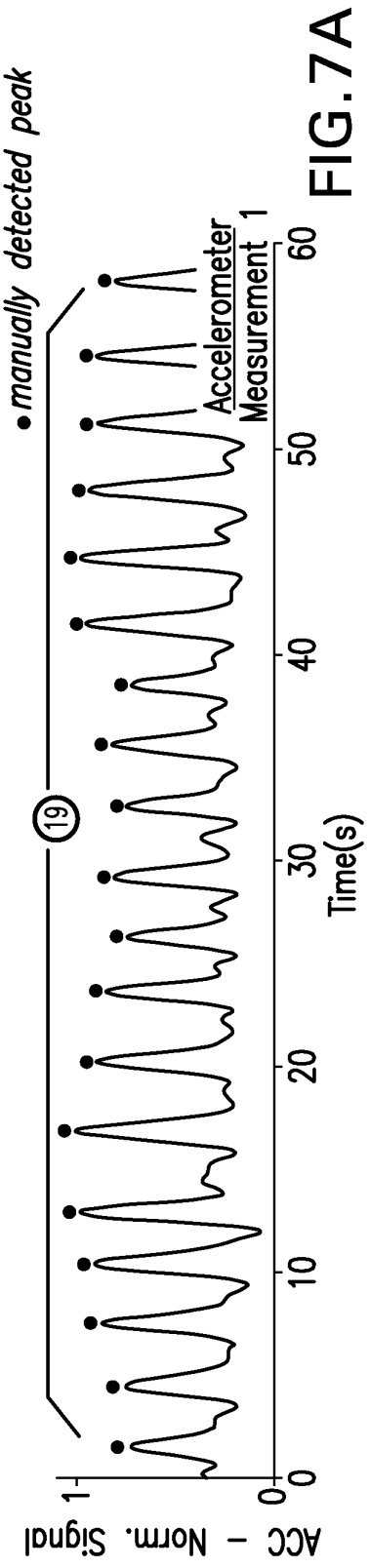


FIG.7A

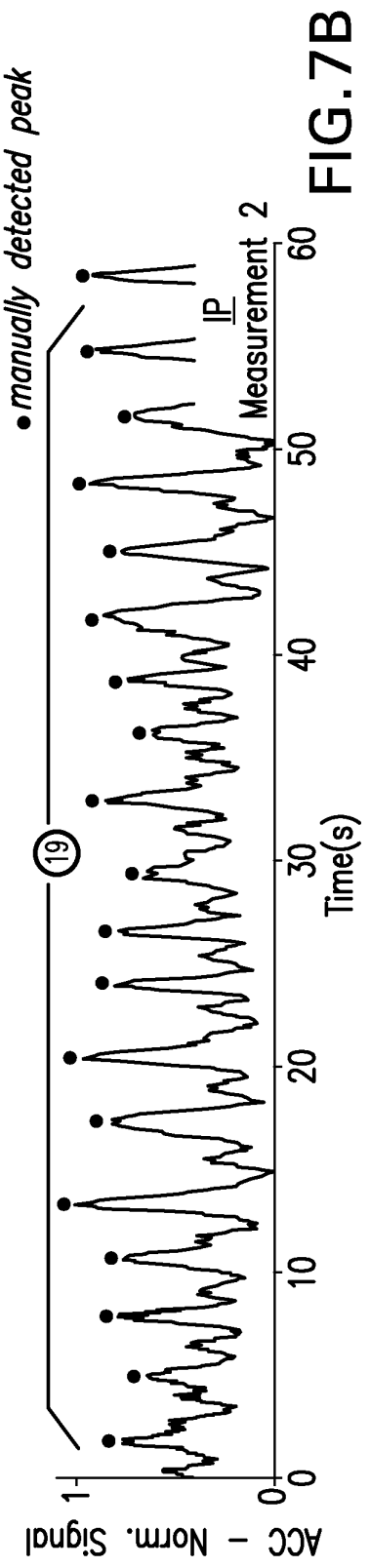


FIG.7B

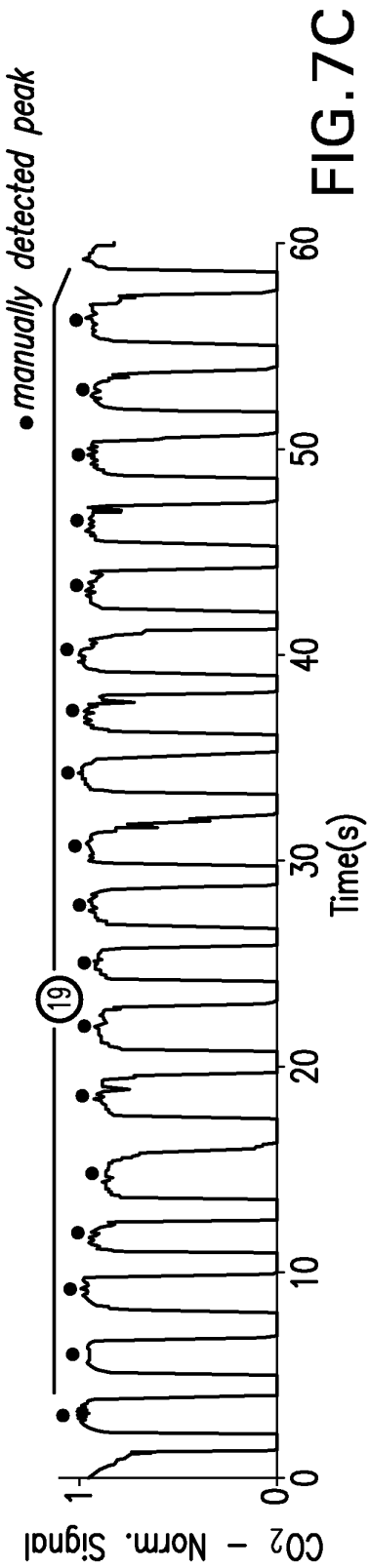


FIG.7C

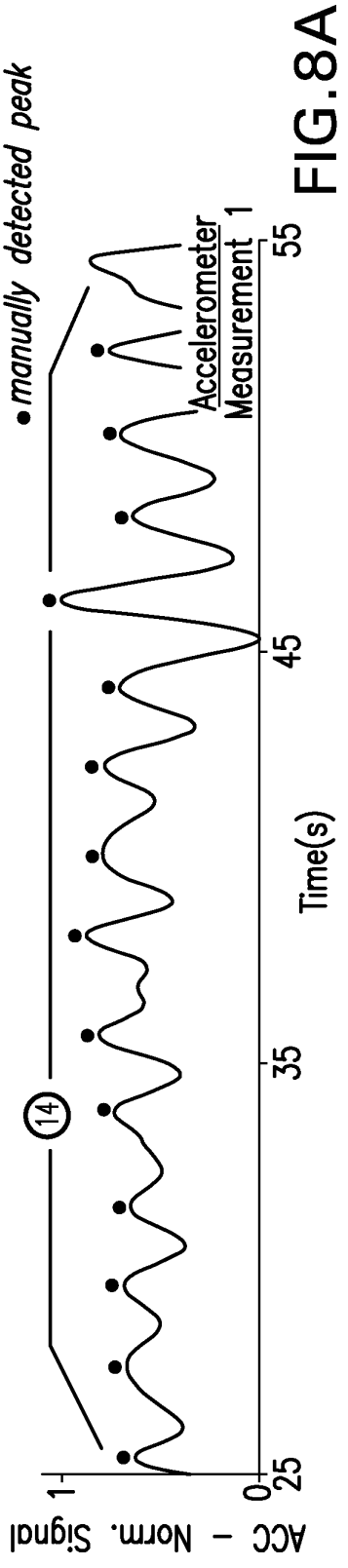


FIG.8A

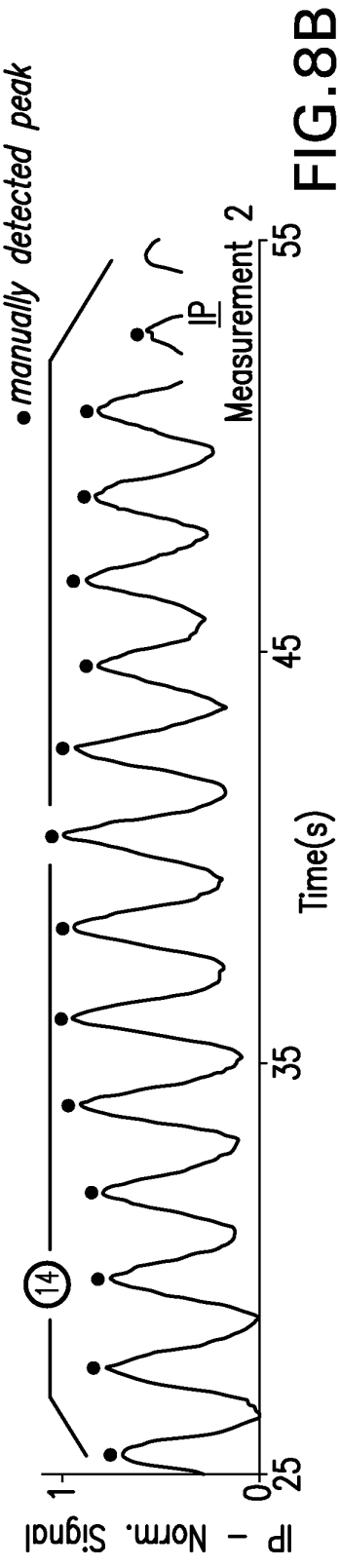


FIG.8B

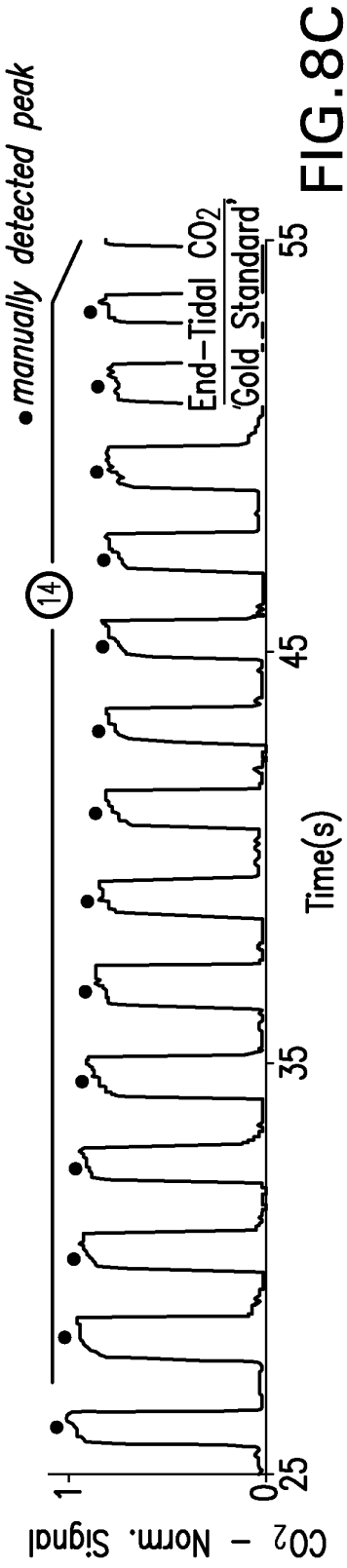


FIG.8C

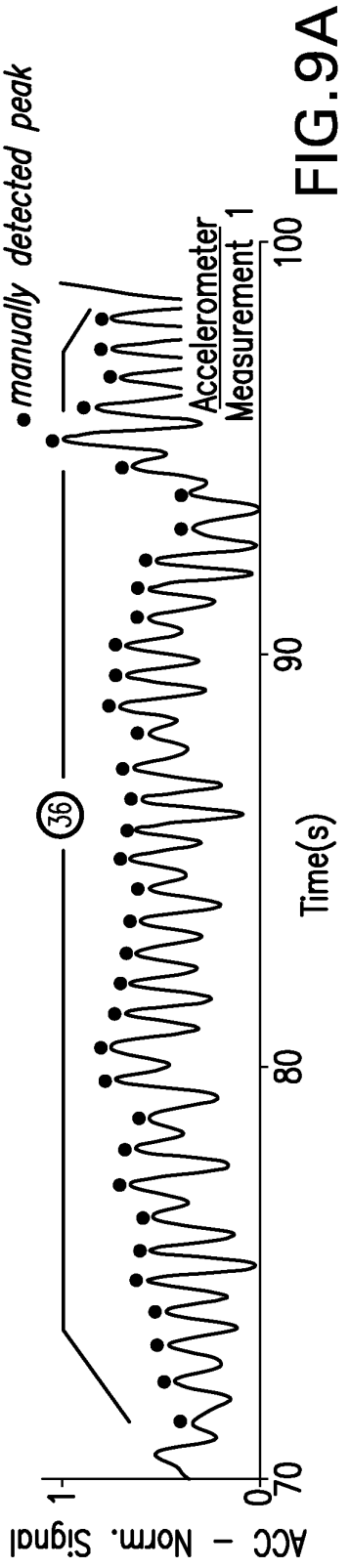


FIG.9A

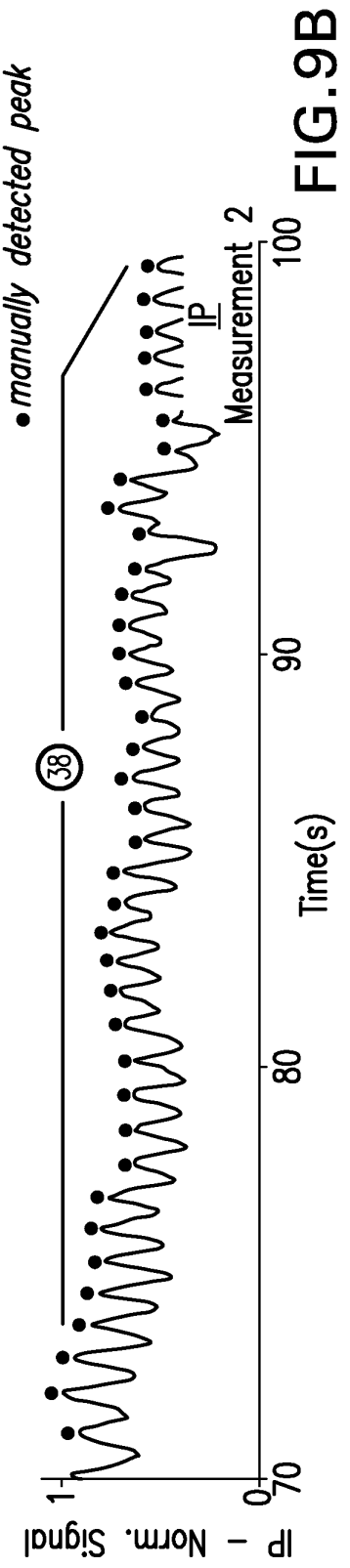


FIG.9B

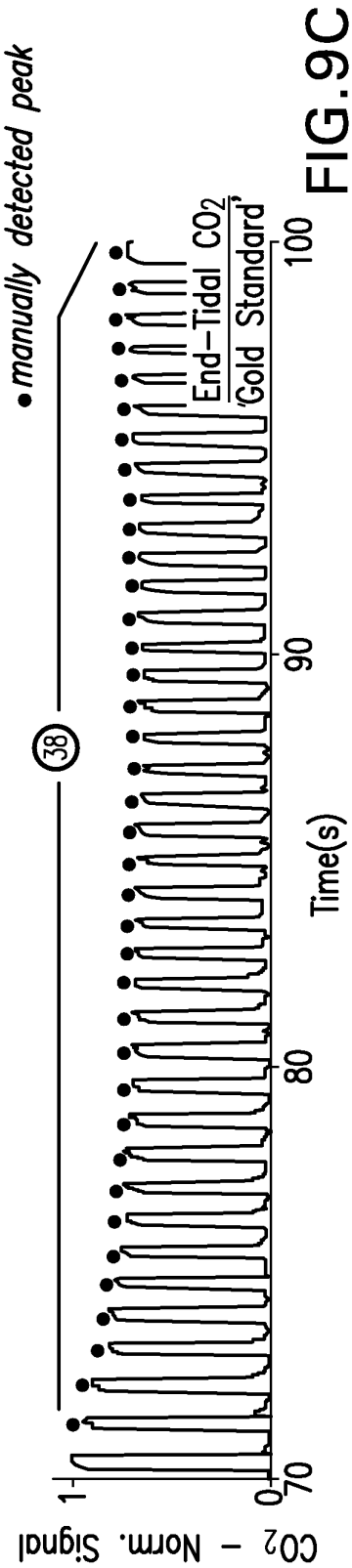


FIG.9C

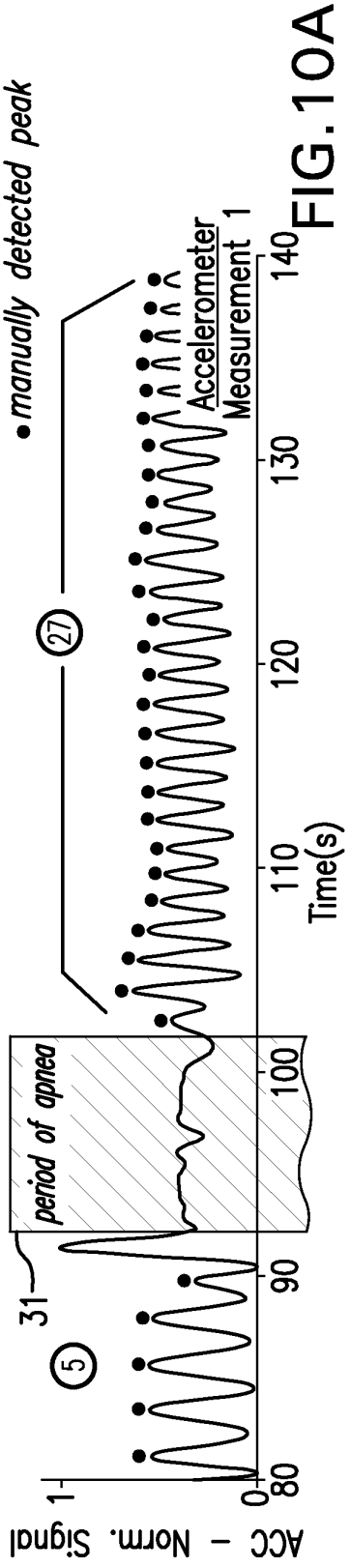


FIG.10A

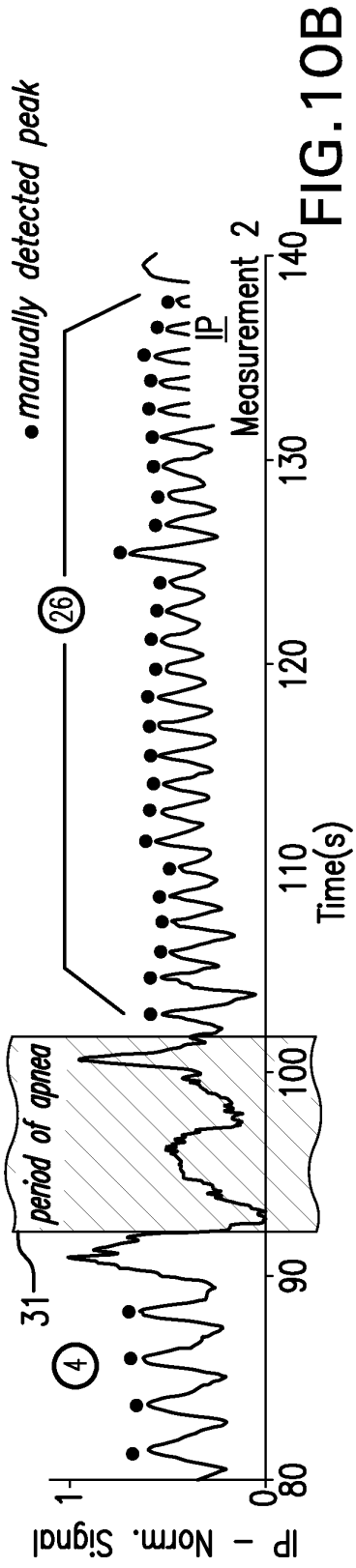


FIG.10B

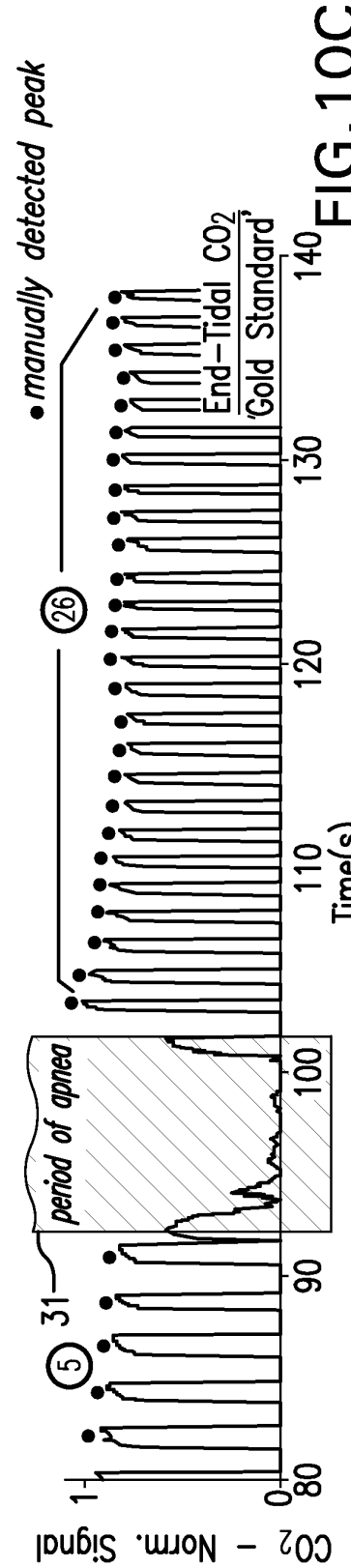


FIG.10C

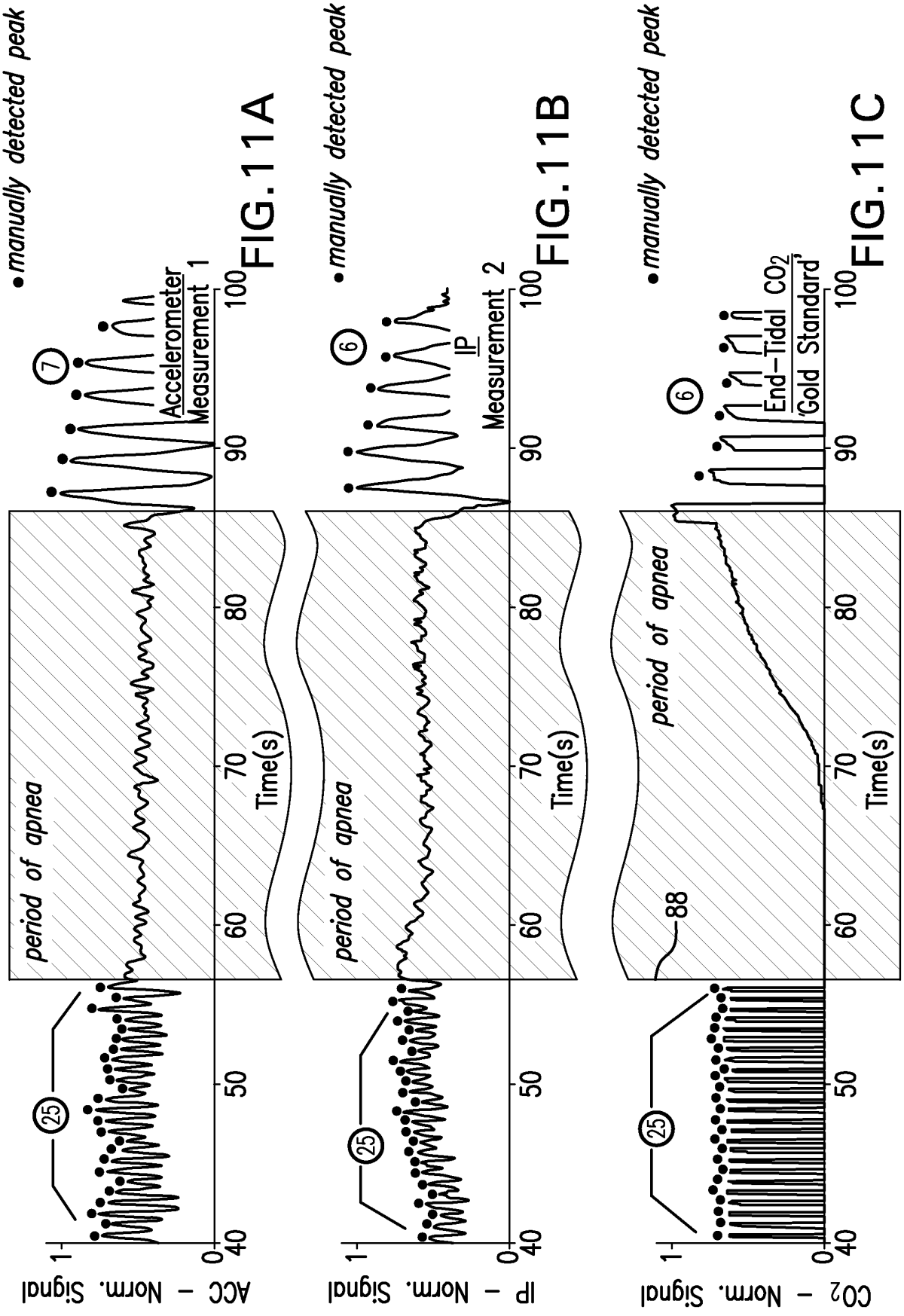


FIG.11A

FIG.11B

FIG.11C

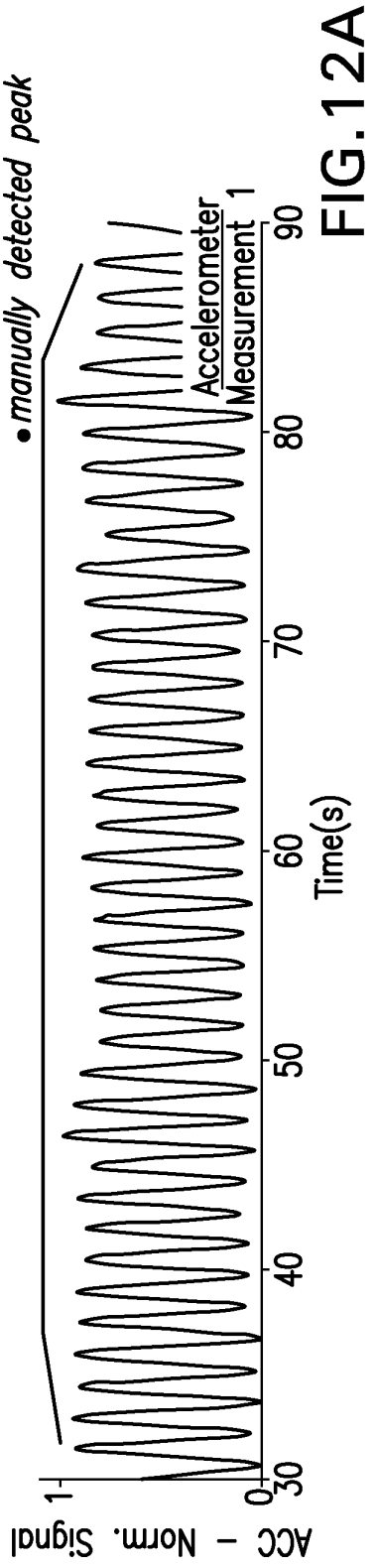


FIG. 12A

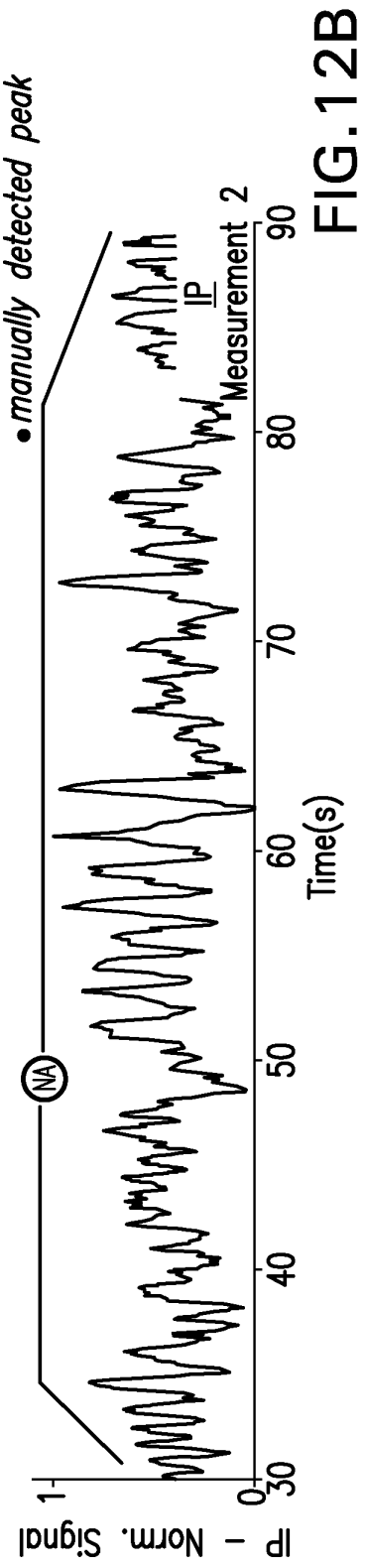


FIG. 12B

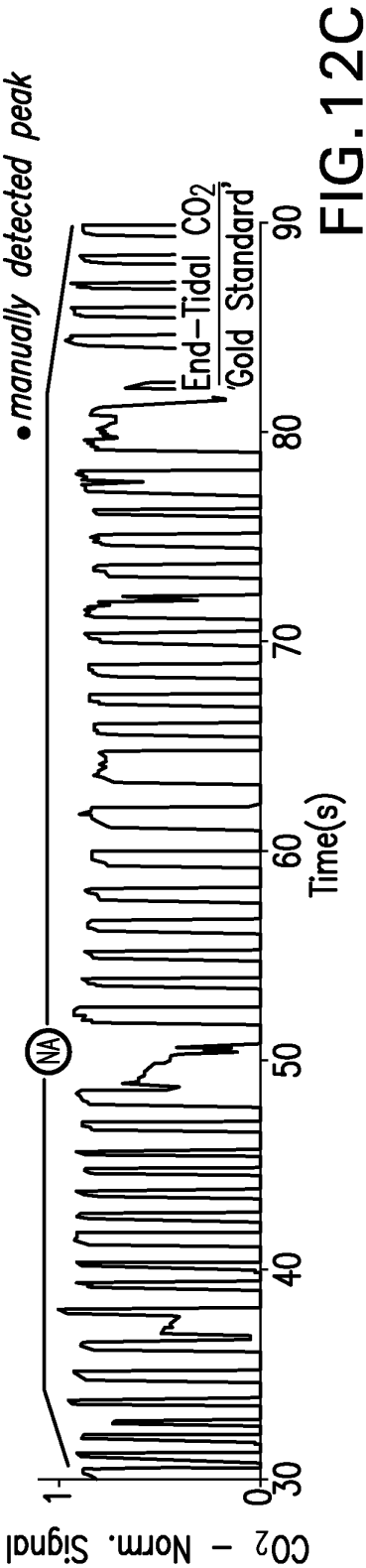


FIG. 12C

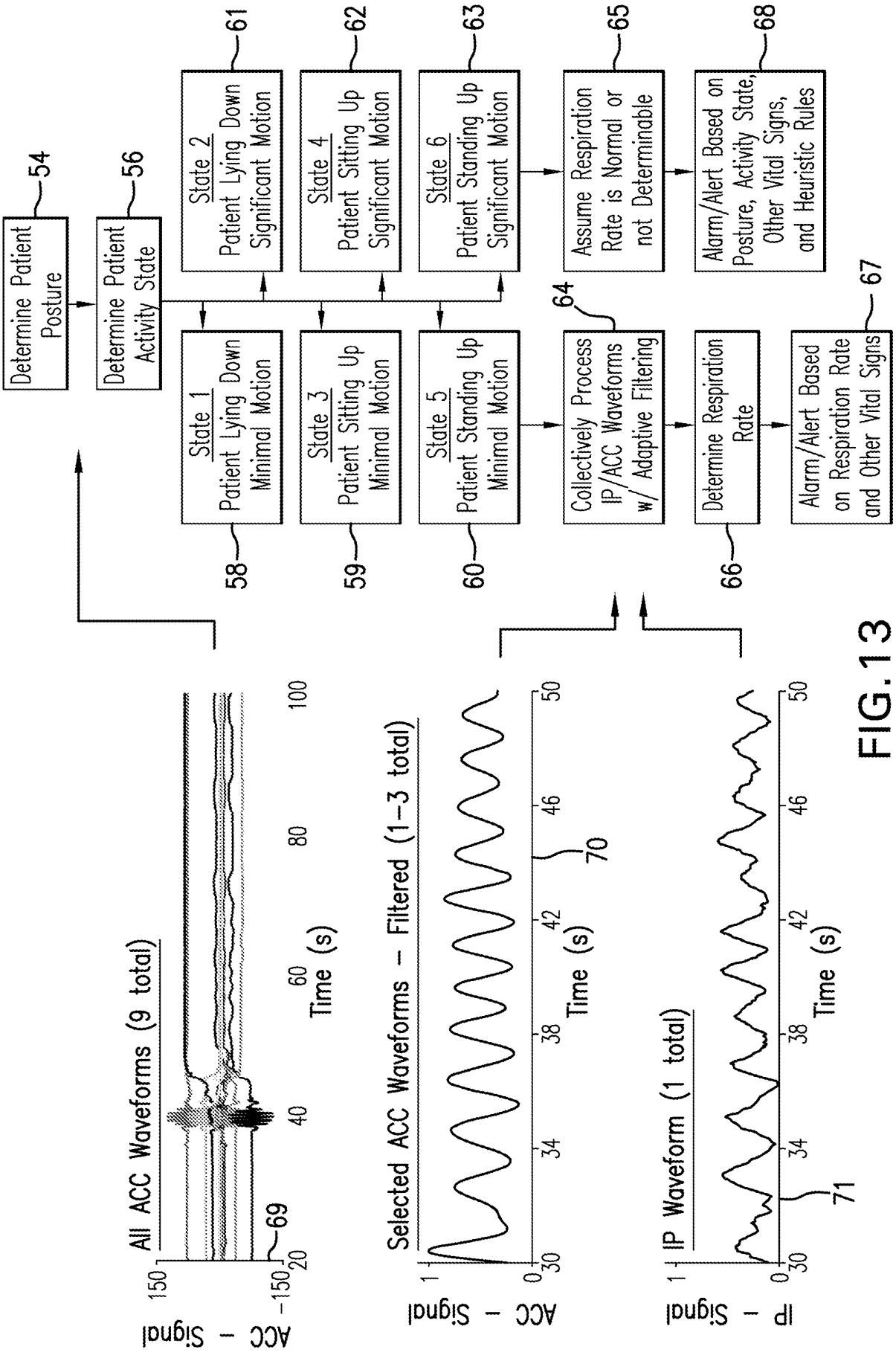

Determine Patient Posture
54
Determine Patient Activity State
56
State 1
Patient Lying Down
Minimal Motion
58
State 2
Patient Lying Down
Significant Motion
61
State 3
Patient Sitting Up
Minimal Motion
59
State 4
Patient Sitting Up
Significant Motion
62
State 5
Patient Standing Up
Minimal Motion
60
State 6
Patient Standing Up
Significant Motion
63
Collectively Process IP/ACC Waveforms w/ Adaptive Filtering
64
Assume Respiration Rate is Normal or not Determinable
65
Determine Respiration Rate
66
Alarm/Alert Based on Respiration Rate and Other Vital Signs
67
Alarm/Alert Based on Posture, Activity State, Other Vital Signs, and Heuristic Rules
68
All ACC Waveforms (9 total)
ACC - Signal
Time (s)
69
Selected ACC Waveforms - Filtered (1-3 total)
70
IP Waveform (1 total)
IP - Signal
71

FIG. 13

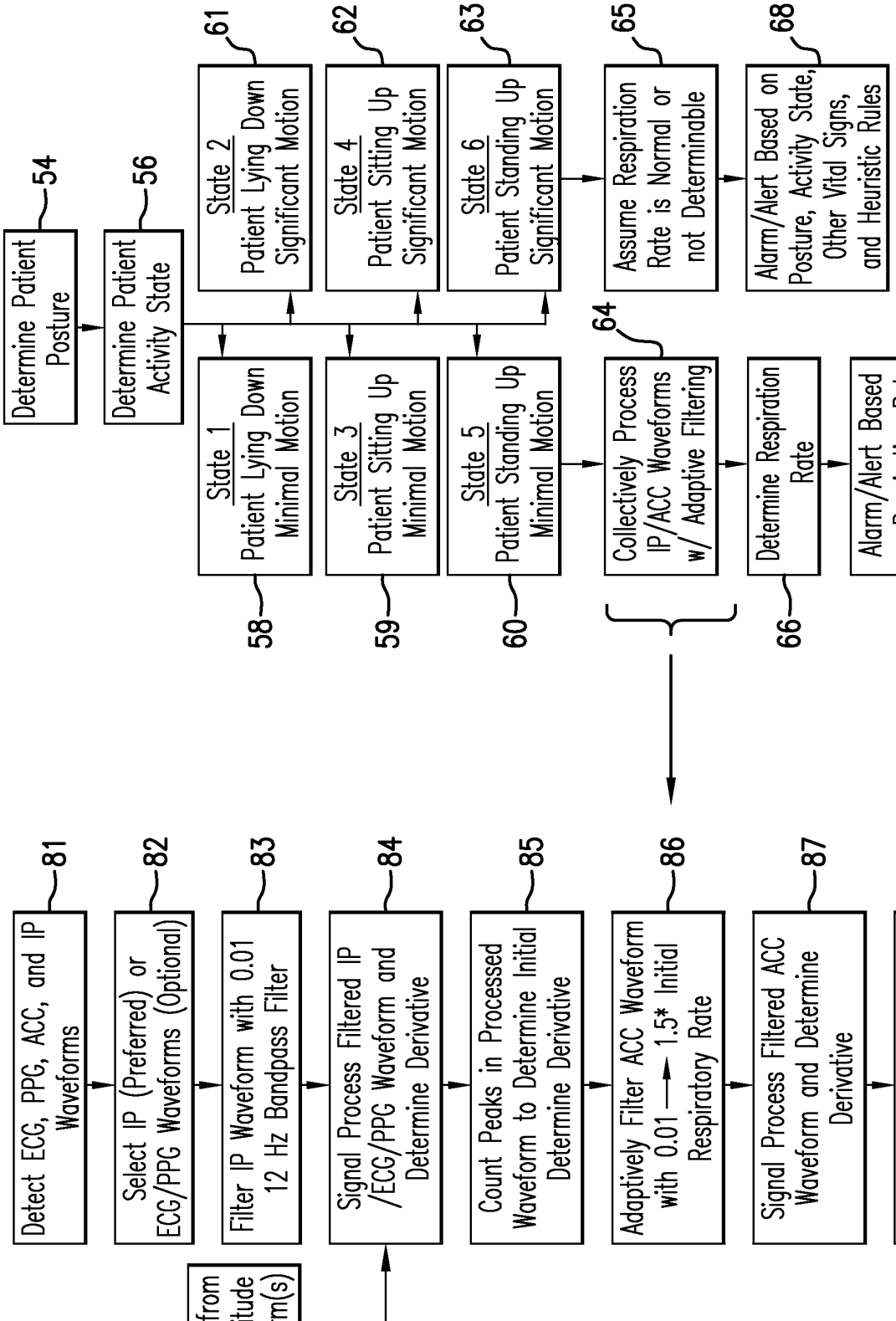

Determine Patient Posture
54
Determine Patient Activity State
56
State 1 Patient Lying Down Minimal Motion
58
State 2 Patient Lying Down Significant Motion
61
State 3 Patient Sitting Up Minimal Motion
59
State 4 Patient Sitting Up Significant Motion
62
State 5 Patient Standing Up Minimal Motion
60
State 6 Patient Standing Up Significant Motion
63
Collectively Process IP/ACC Waveforms w/ Adaptive Filtering
64
Assume Respiration Rate is Normal or not Determinable
65
Determine Respiration Rate
66
Alarm/Alert Based on Posture, Activity State, Other Vital Signs, and Heuristic Rules
68
Alarm/Alert Based on Respiration Rate and Other Vital Signs
67
From Figure 13
Detect ECG, PPG, ACC, and IP Waveforms
81
Select IP (Preferred) or ECG/PPG Waveforms (Optional)
82
Filter IP Waveform with 0.01 12 Hz Bandpass Filter
83
Signal Process Filtered IP /ECG/PPG Waveform and Determine Derivative
84
Count Peaks in Processed Waveform to Determine Initial Determine Derivative
85
Adaptively Filter ACC Waveform with 0.01 → 1.5* Initial Respiratory Rate
86
Signal Process Filtered ACC Waveform and Determine Derivative
87
Count Peaks in Processed ACC Waveform to Determine Final Respiratory Rate
88
Respiratory Rate
Determine Envelope from Peak-to-Peak Amplitude of PPG/ECG Waveform(s)
89

FIG. 14

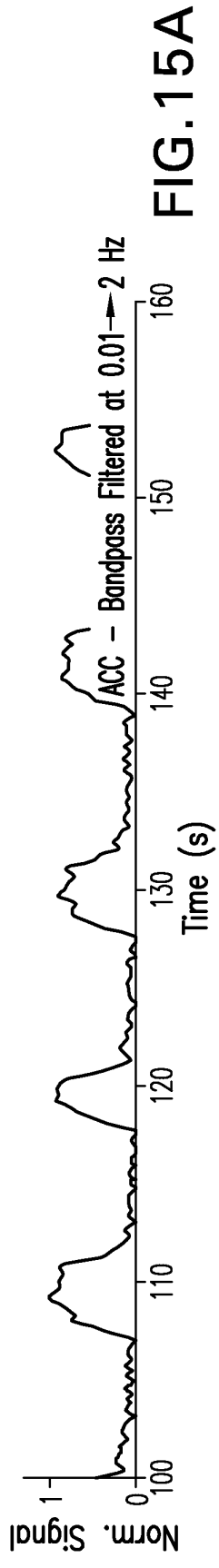


FIG. 15A

FIG. 15B

FIG. 15C

FIG. 15D

FIG. 15E

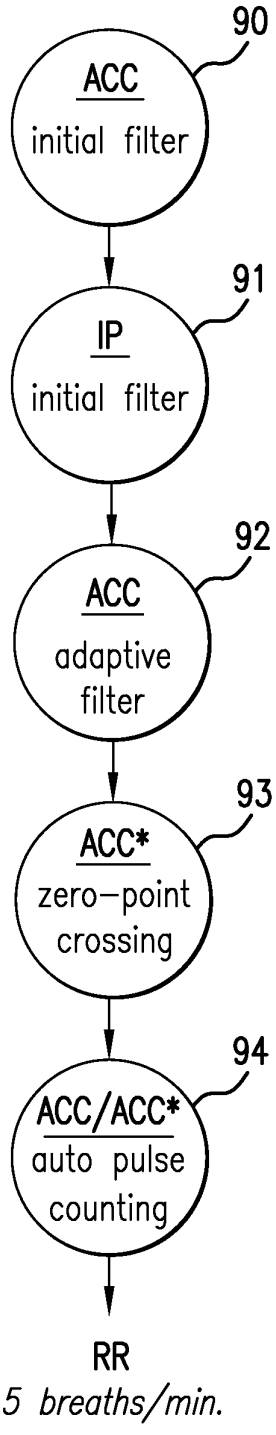

90
ACC
initial filter
91
IP
initial filter
92
ACC
adaptive filter
93
ACC*
zero-point crossing
94
ACC/ACC*
auto pulse counting
RR
5 breaths/min.

FIG.15F

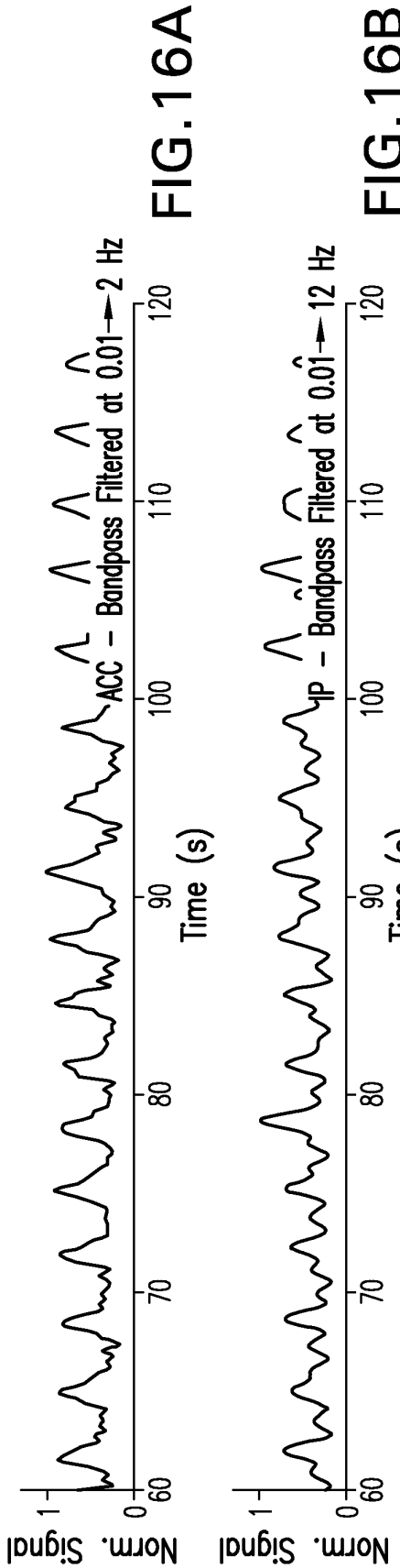


FIG. 16A

FIG. 16B

FIG. 16C

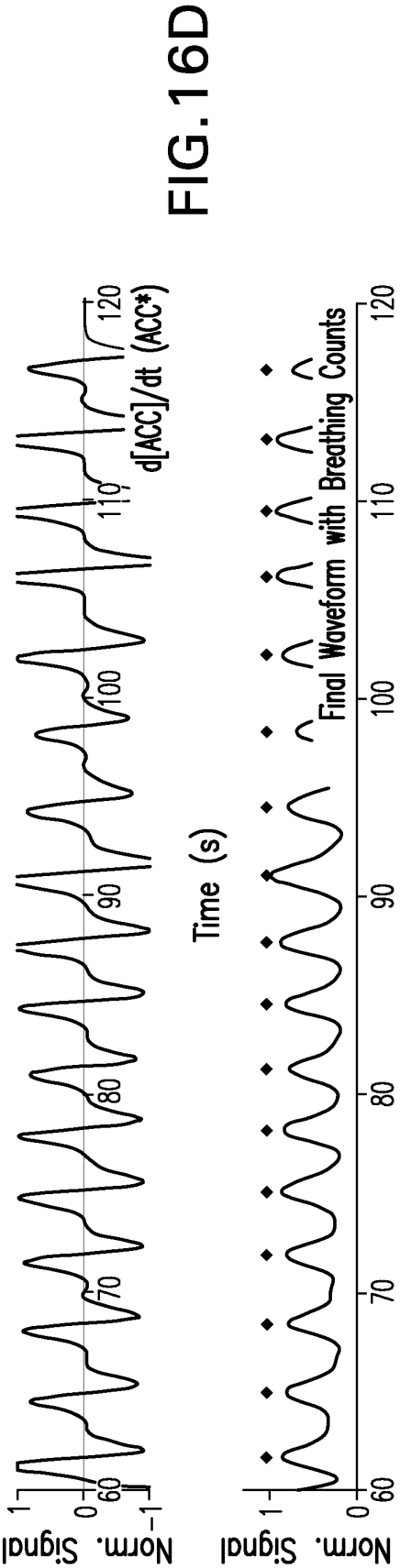


FIG. 16D

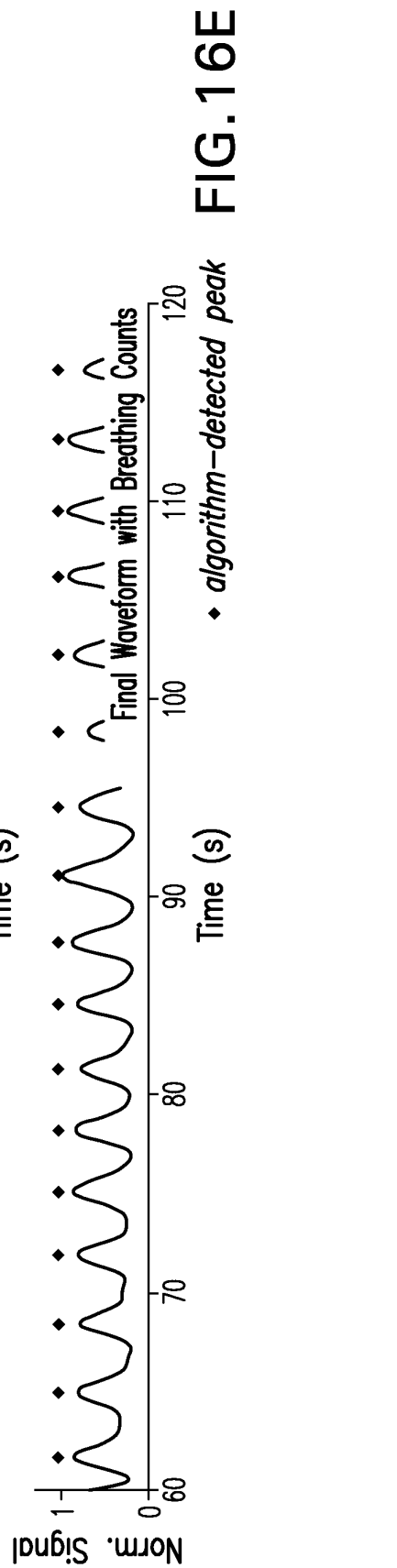


FIG. 16E

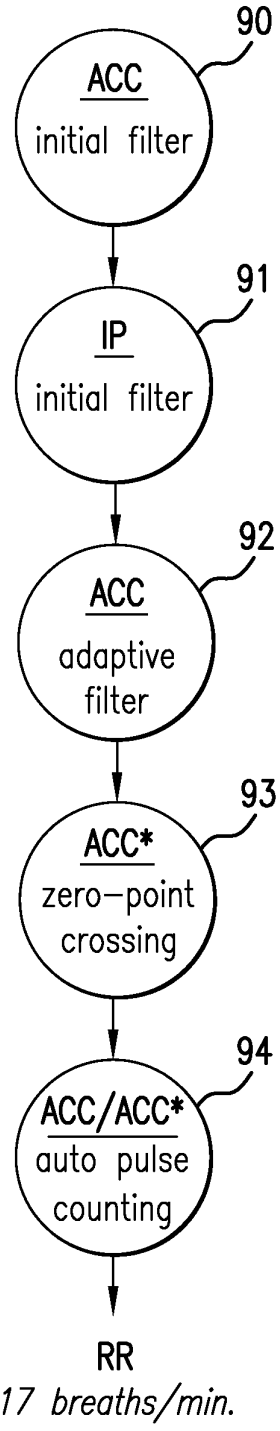

90
ACC
initial filter
91
IP
initial filter
92
ACC
adaptive filter
93
ACC*
zero-point crossing
94
ACC/ACC*
auto pulse counting
RR
17 breaths/min.

FIG.16F

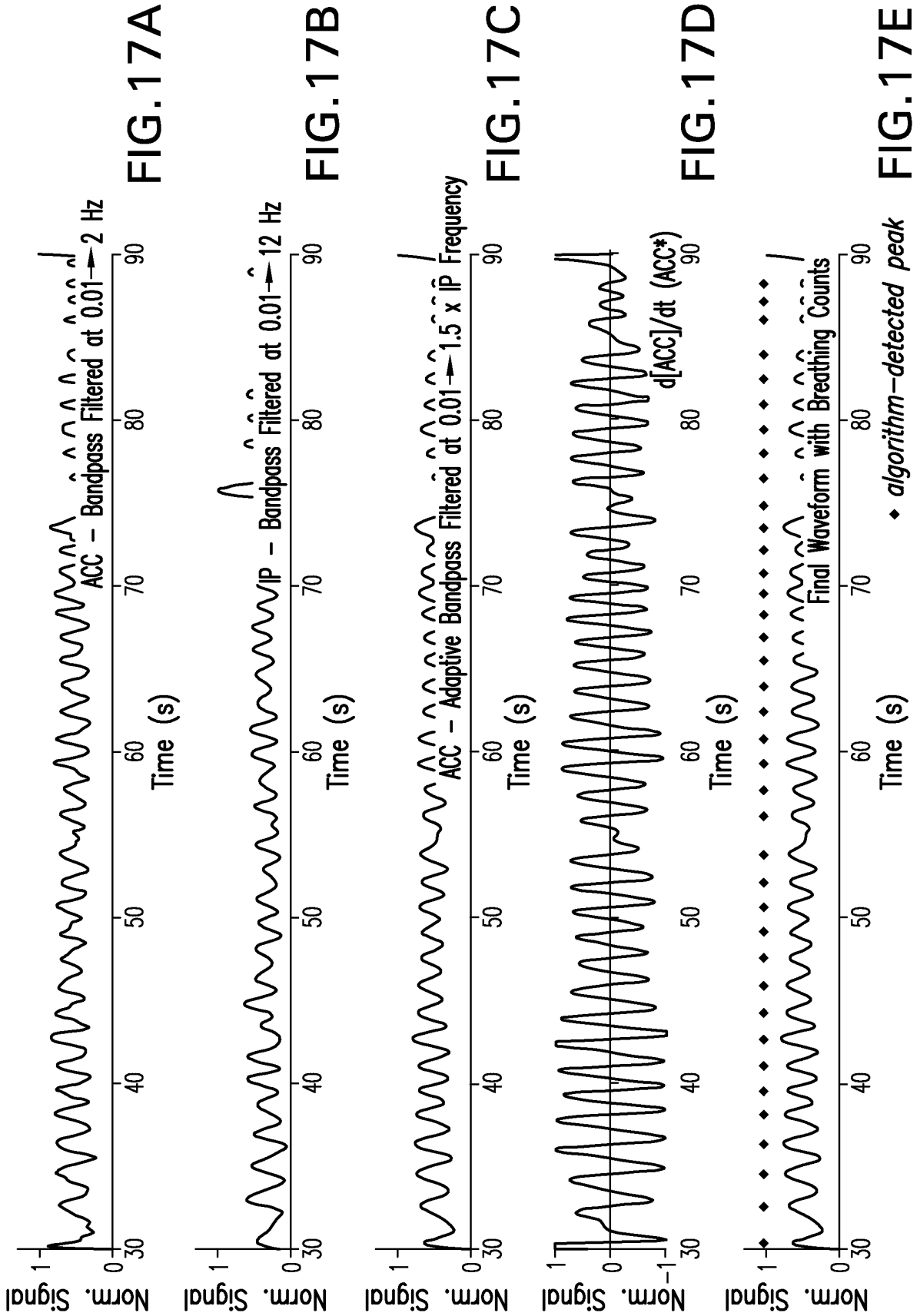


FIG. 17A

FIG. 17B

FIG. 17C

FIG. 17D

FIG. 17E

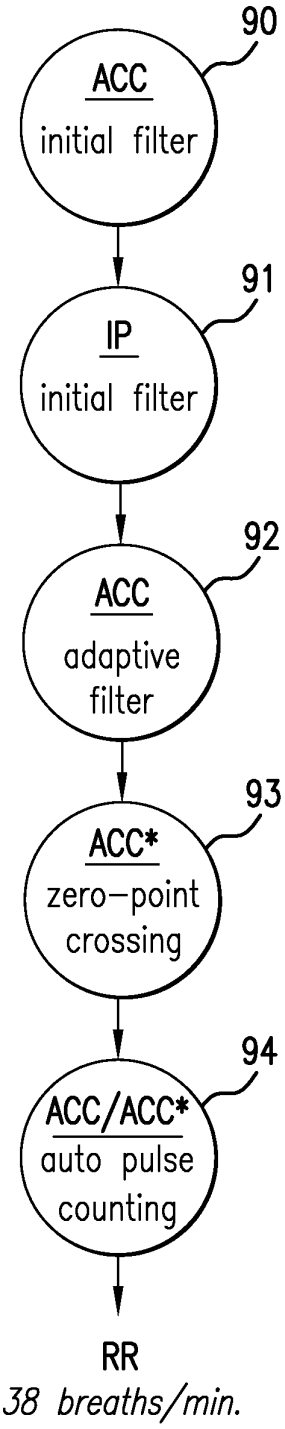

90
ACC
initial filter
91
IP
initial filter
92
ACC
adaptive filter
93
ACC*
zero-point crossing
94
ACC/ACC*
auto pulse counting
RR
38 breaths/min.

FIG.17F

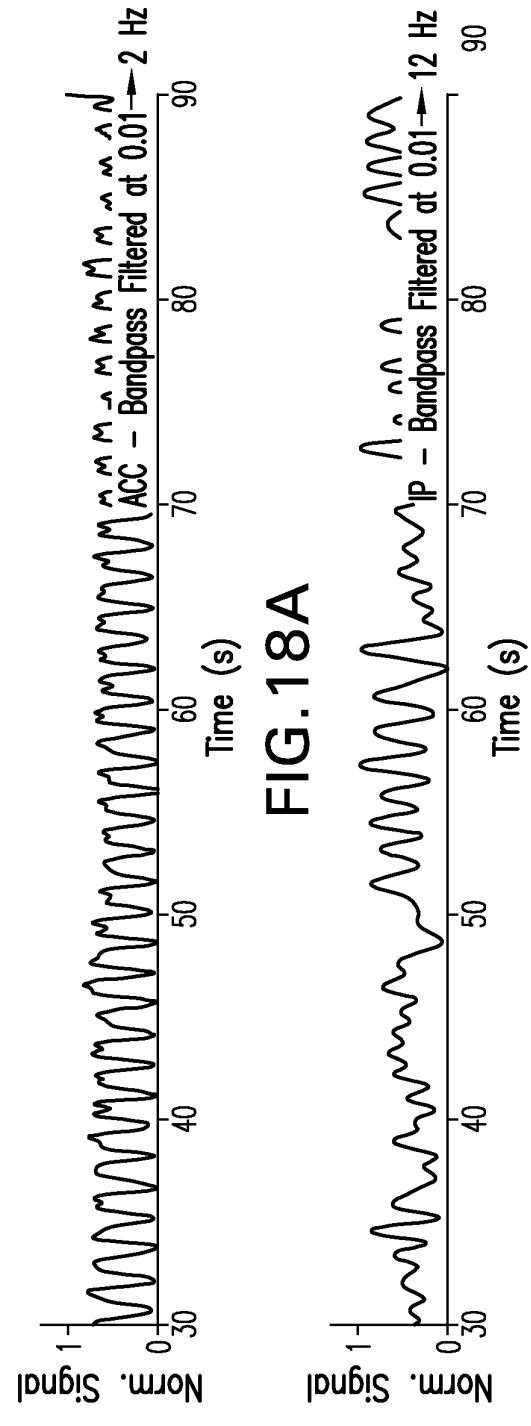


FIG.18A

FIG.18B

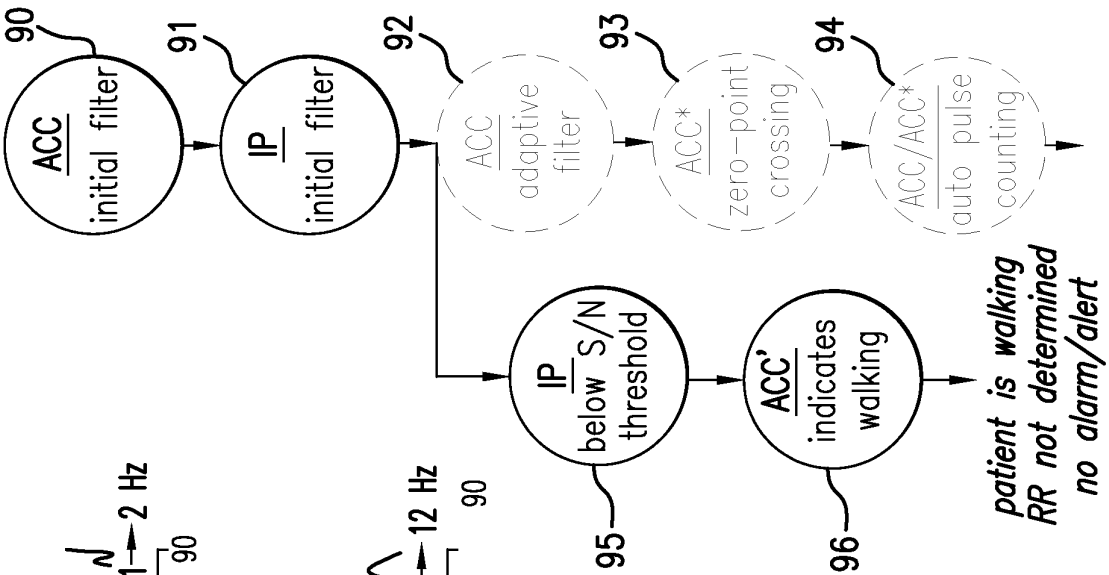


FIG.18C

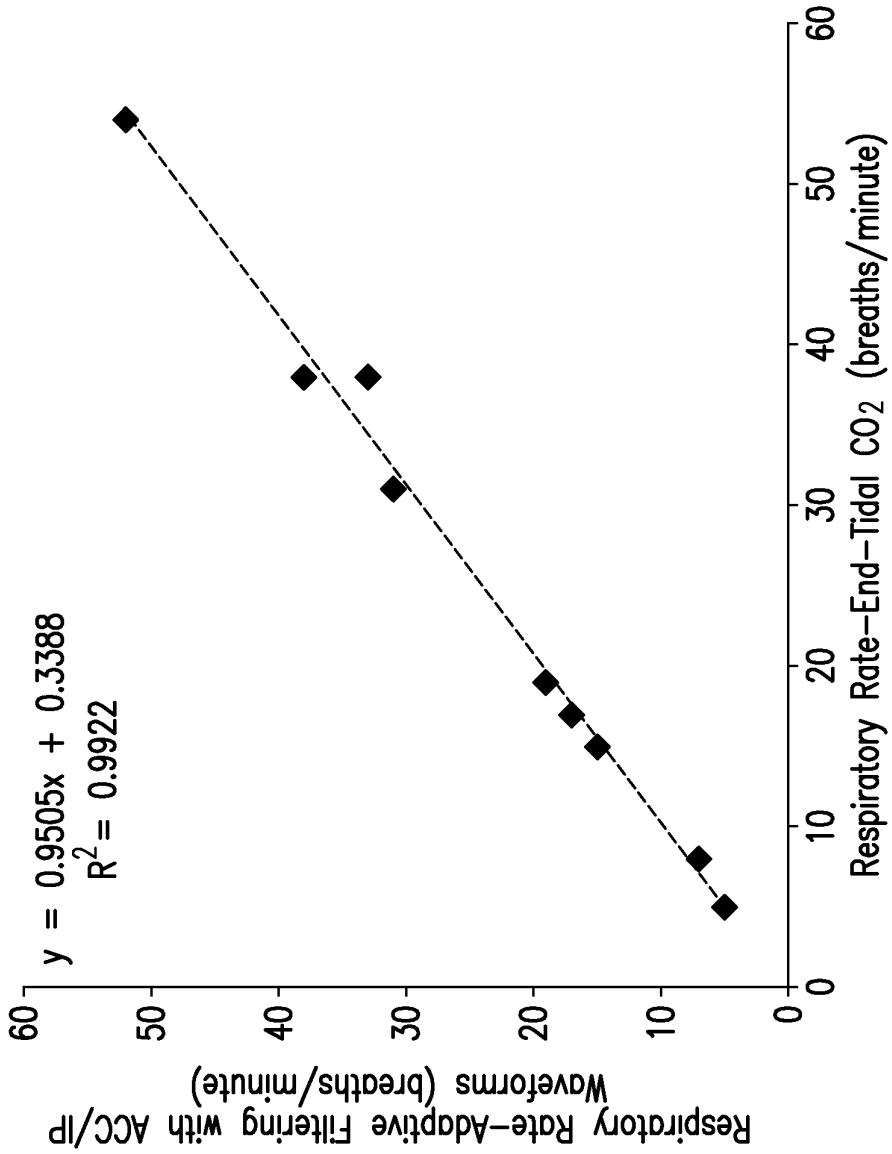

Respiratory Rate–Adaptive Filtering with ACC/IP
Waveforms (breaths/minute)
Respiratory Rate–End–Tidal CO_2 (breaths/minute)
y = 0.9505x + 0.3388
R^2 = 0.9922
0
10
20
30
40
50
60

FIG. 19

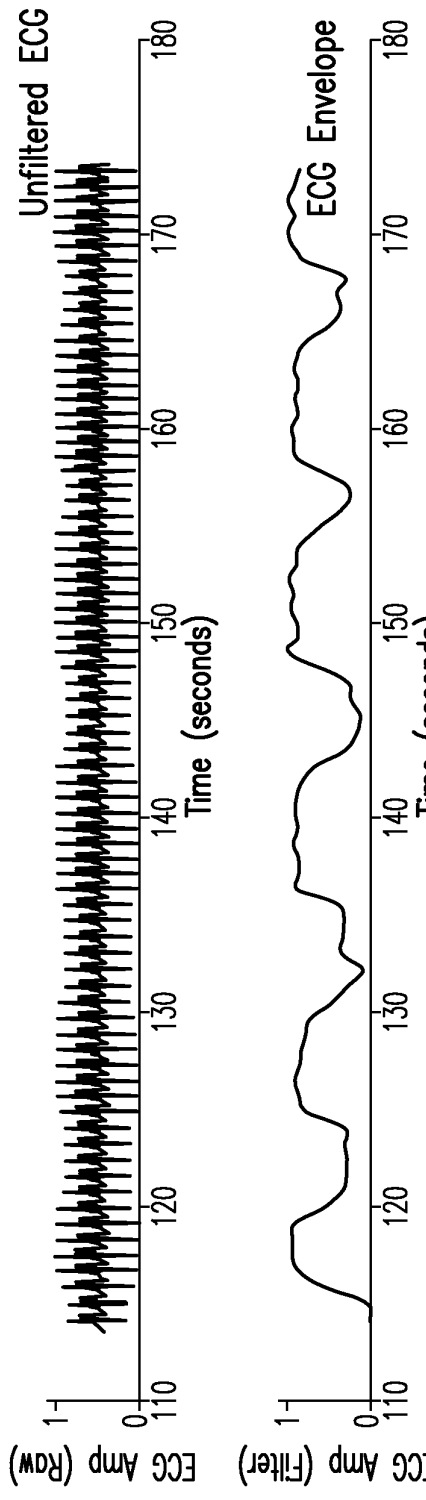


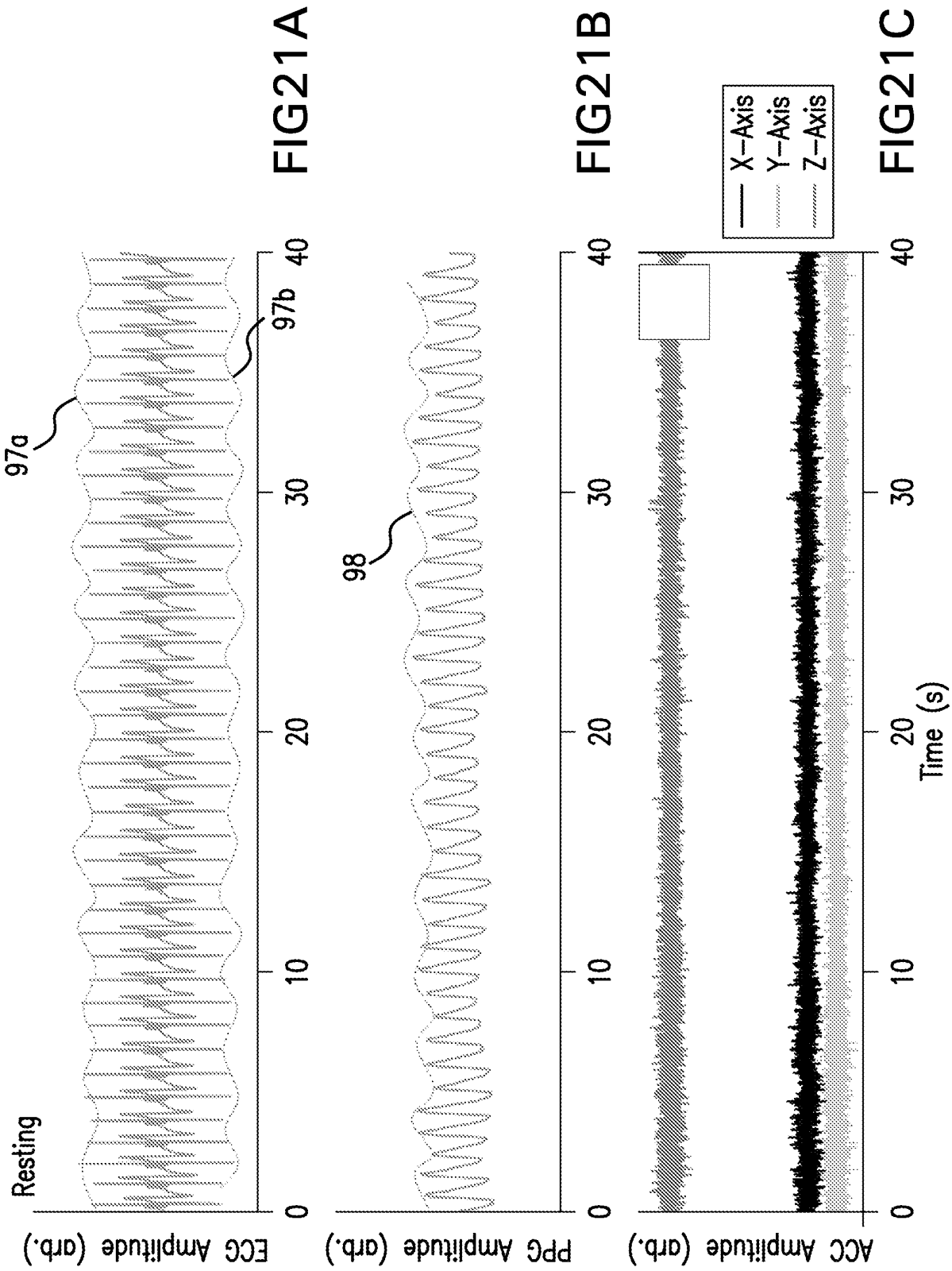
FIG.20A

FIG.20B

FIG.20C

FIG.20D

FIG.20E


Resting
97a
97b
ECG Amplitude (arb.)
0
10
20
30
40
FIG21A
98
PPG Amplitude (arb.)
FIG21B
X–Axis
Y–Axis
Z–Axis
ACC Amplitude (arb.)
Time (s)
FIG21C

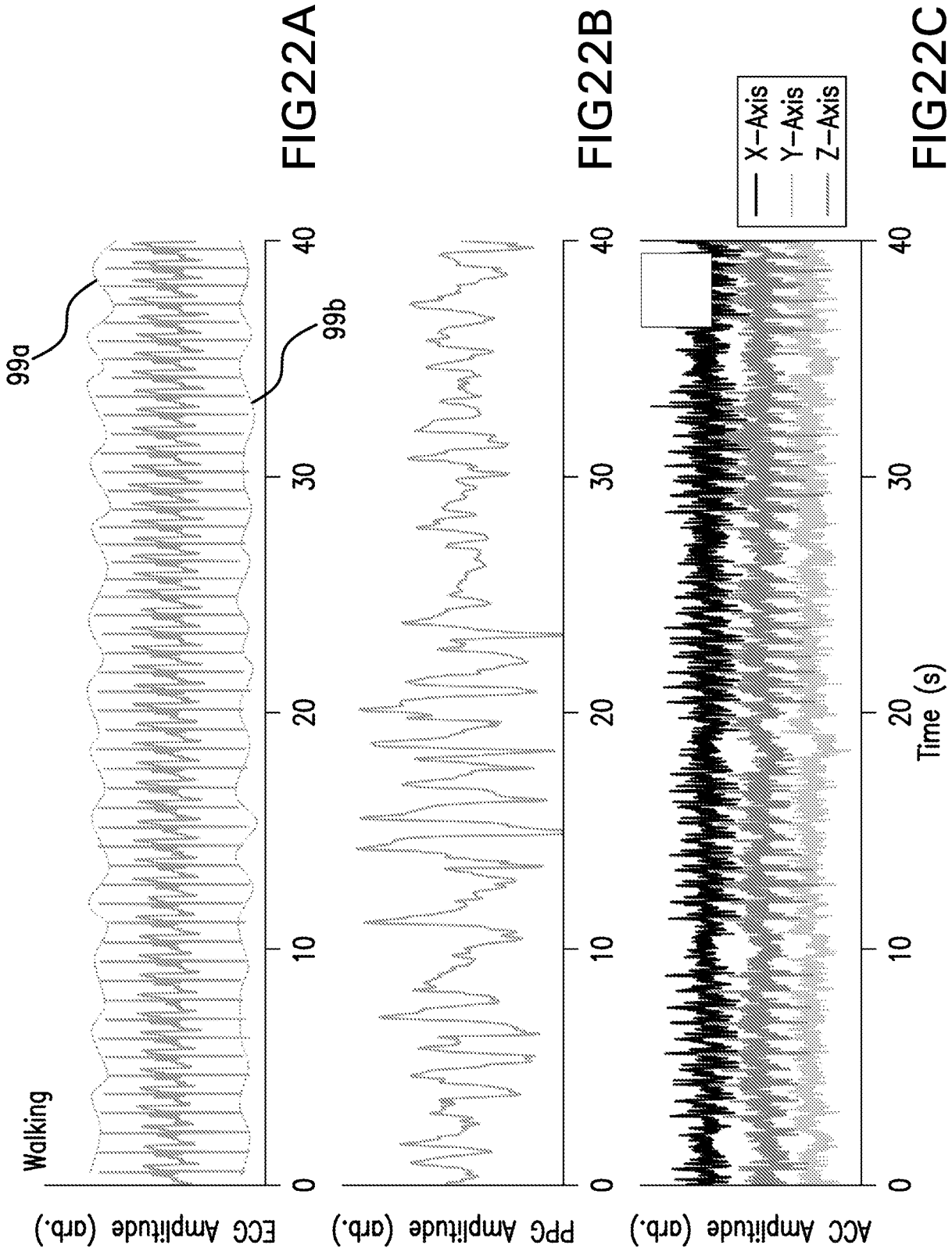


FIG22A

FIG22B

FIG22C

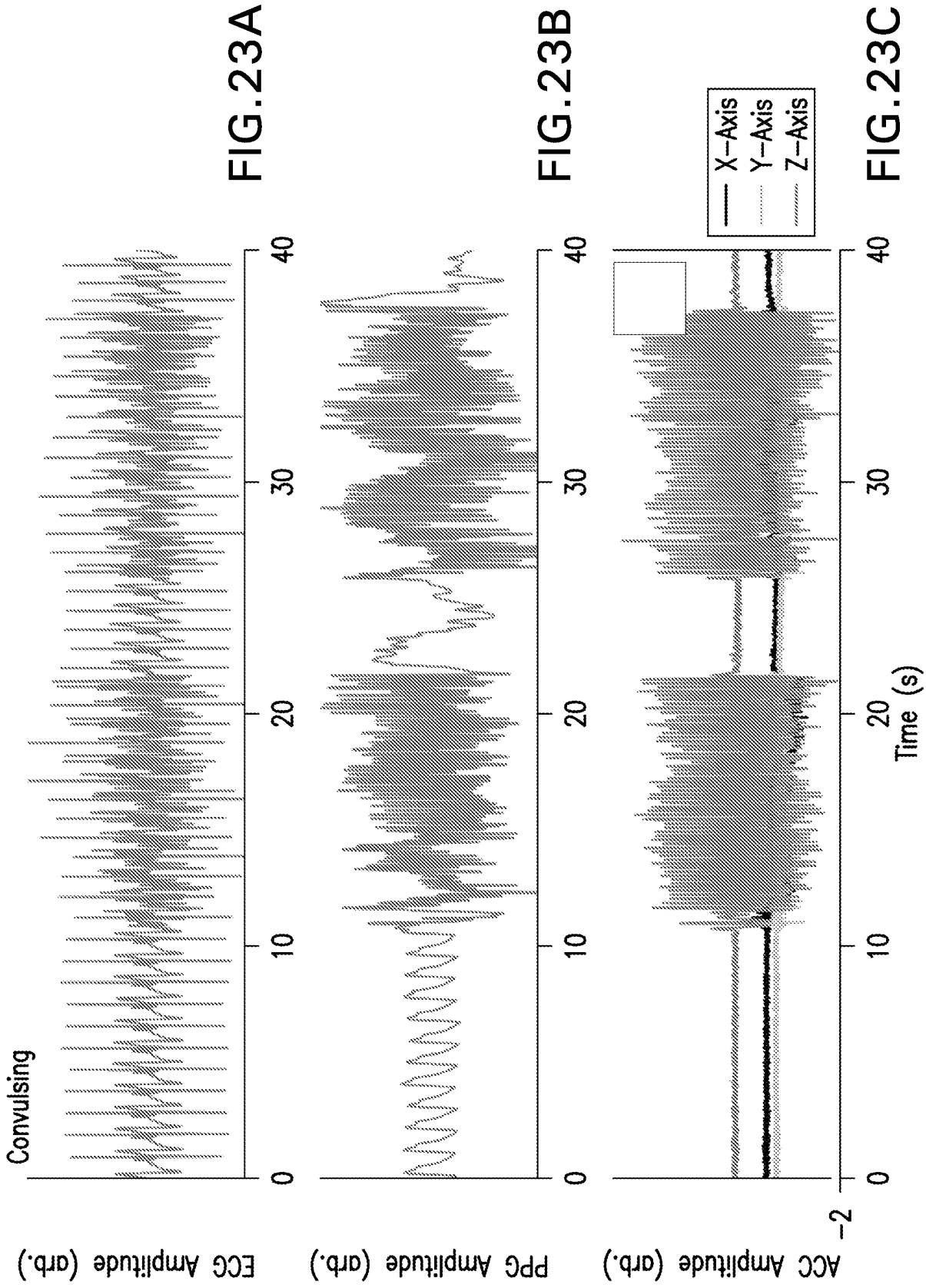


FIG.23A

FIG.23B

FIG.23C

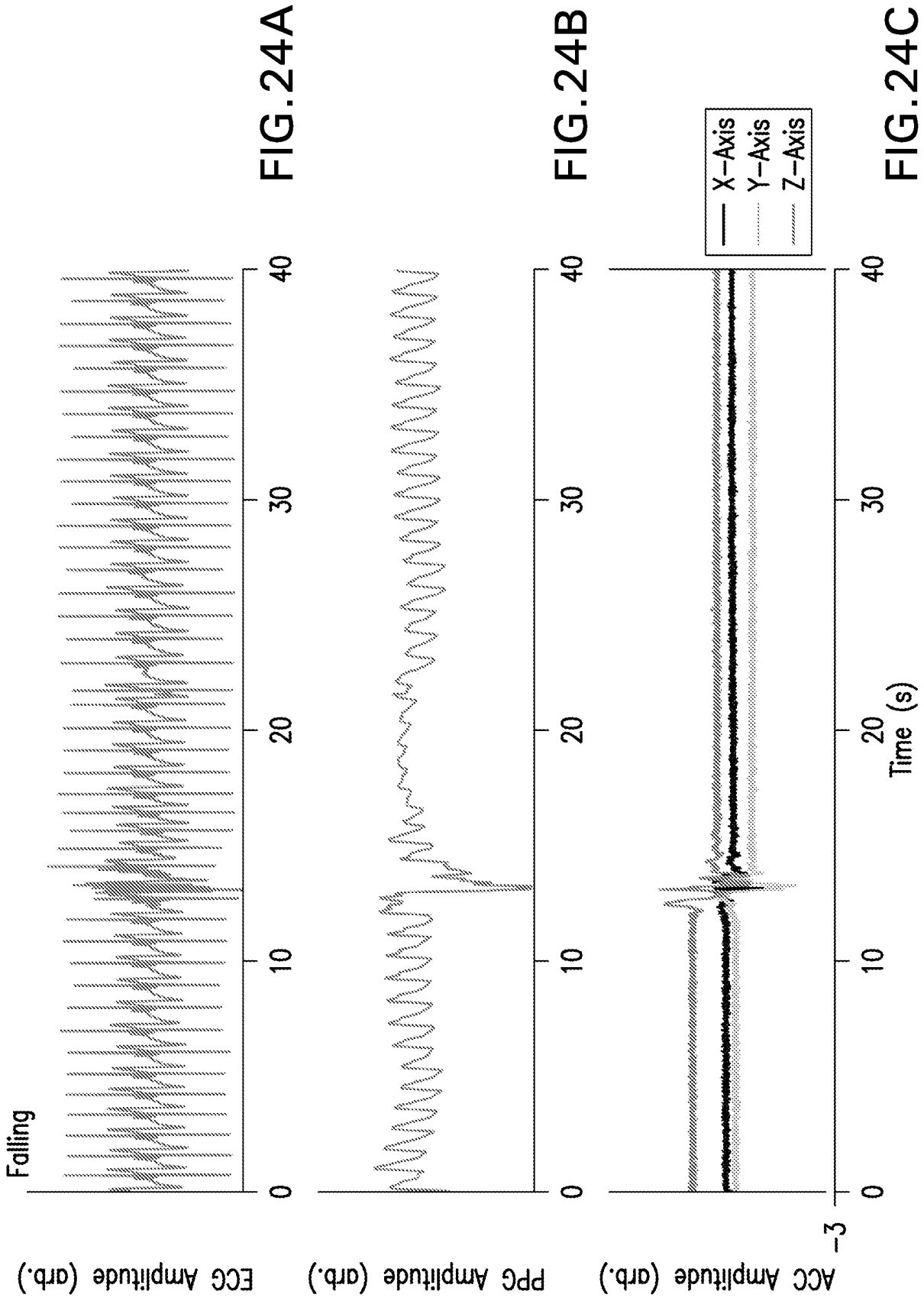


FIG.24A

FIG.24B

FIG.24C

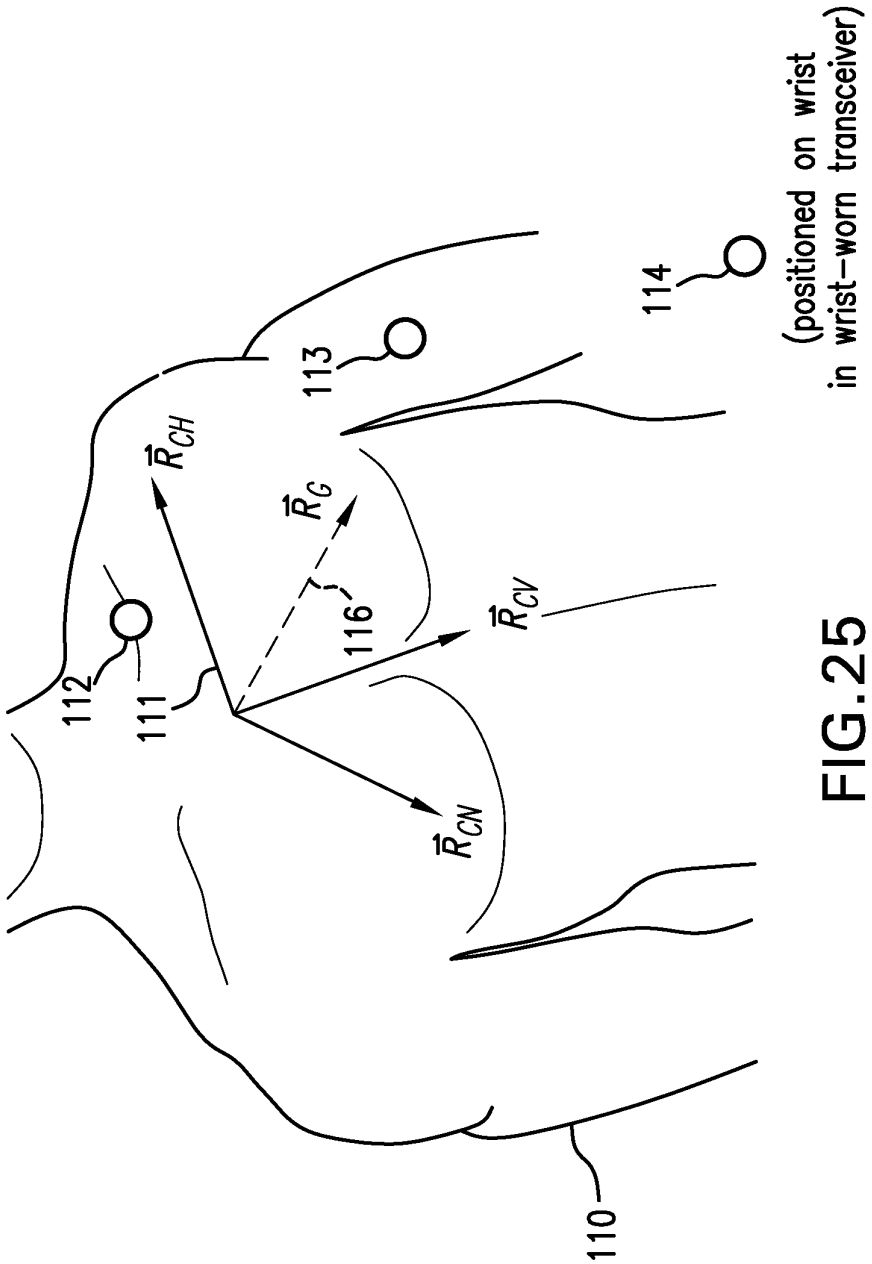

112
111
113
114
116
110
$\vec{R}_{CH}$
$\vec{R}_G$
$\vec{R}_{CV}$
$\vec{R}_{CN}$
(positioned on wrist
in wrist-worn transceiver)

FIG.25

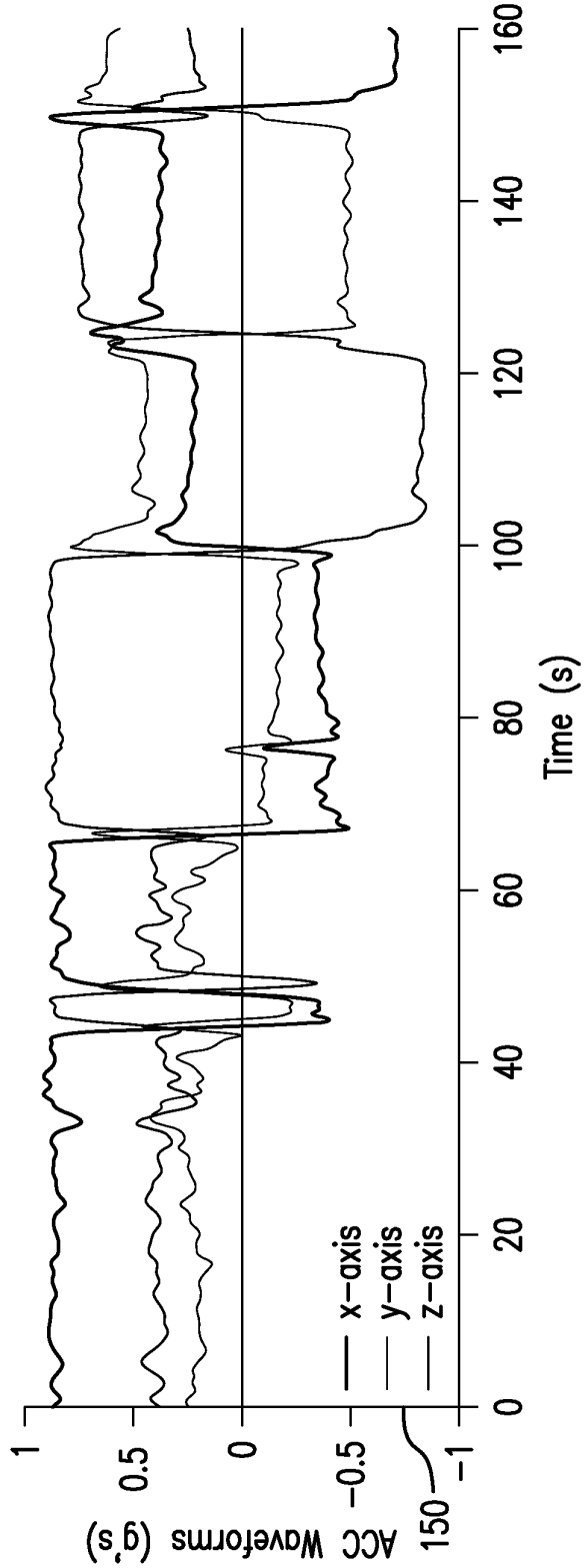


FIG.26A

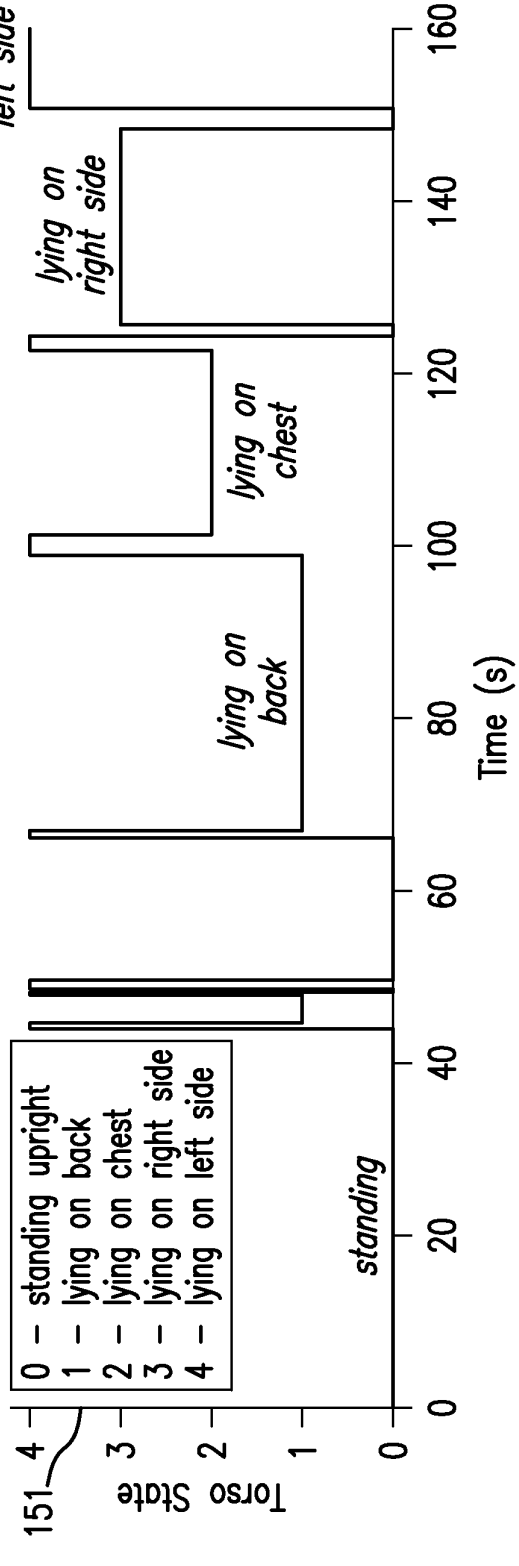


FIG.26B

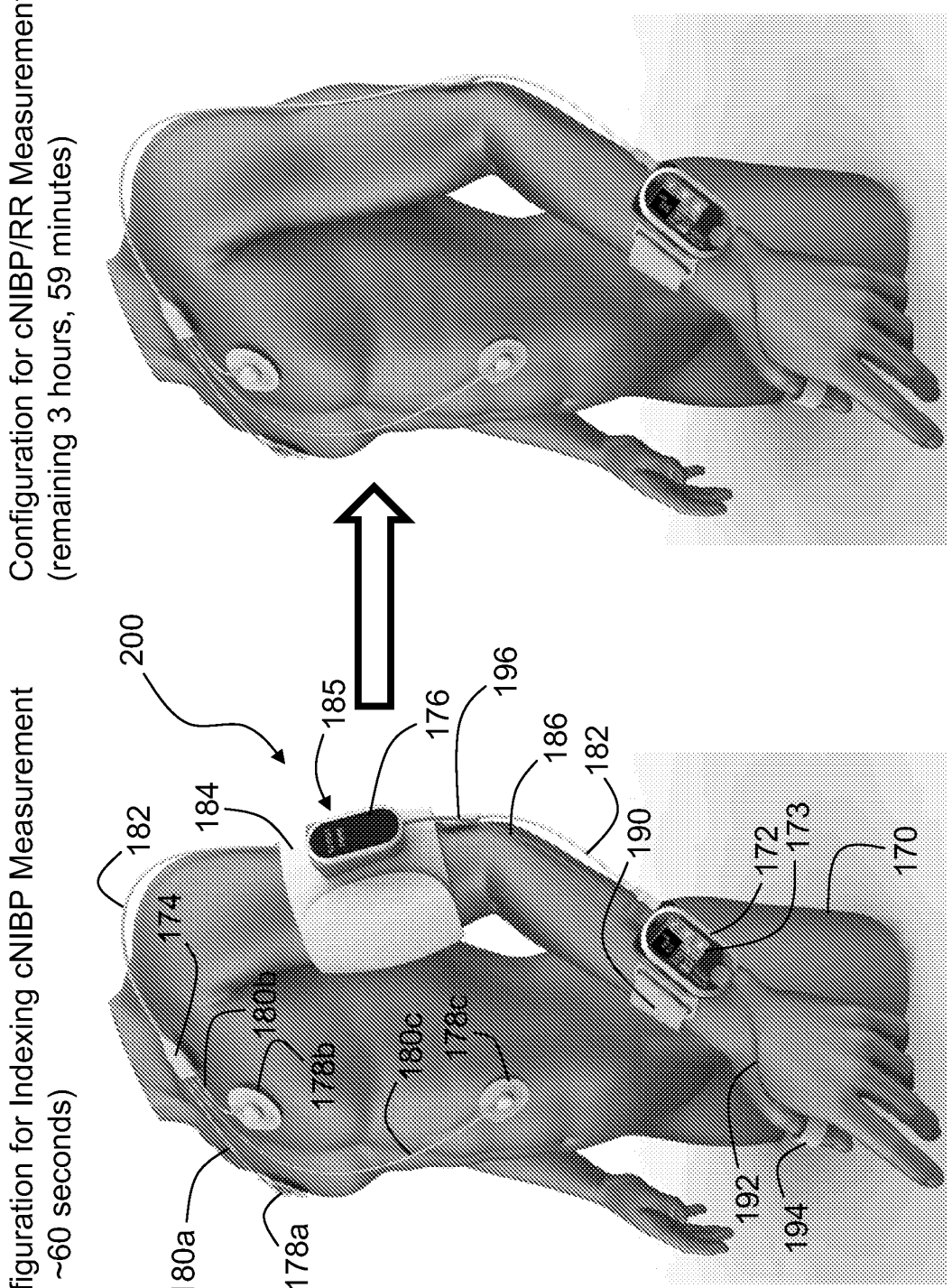


FIG.27A

FIG.27B

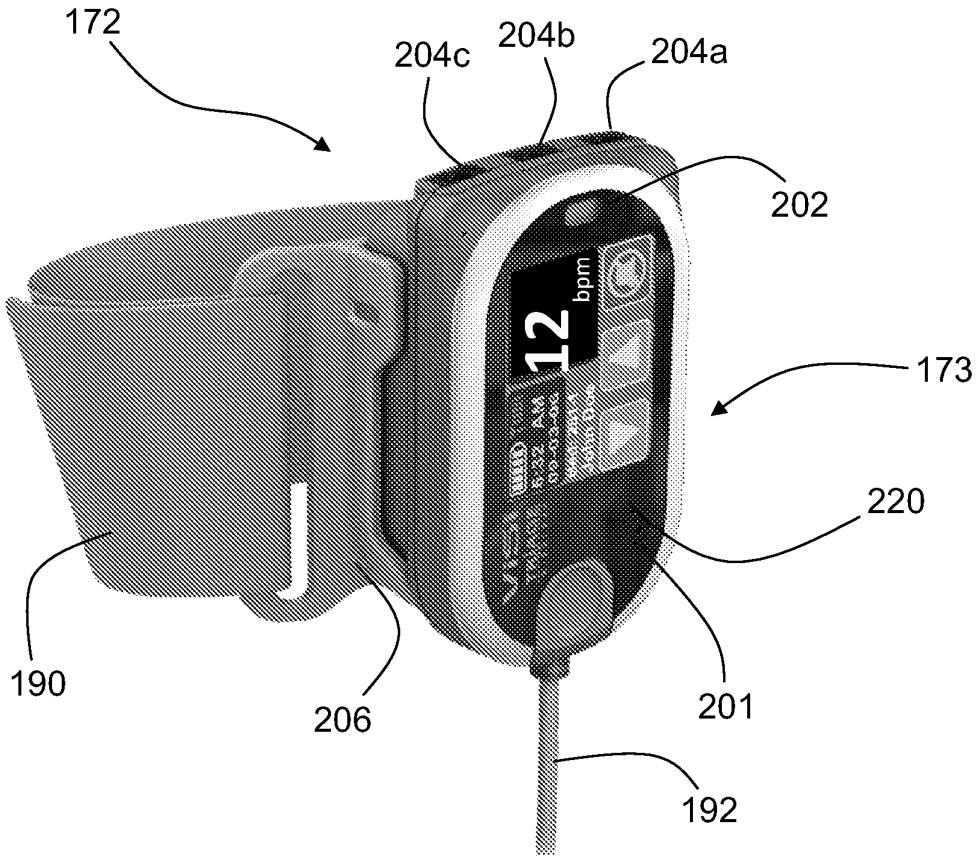


FIG.28

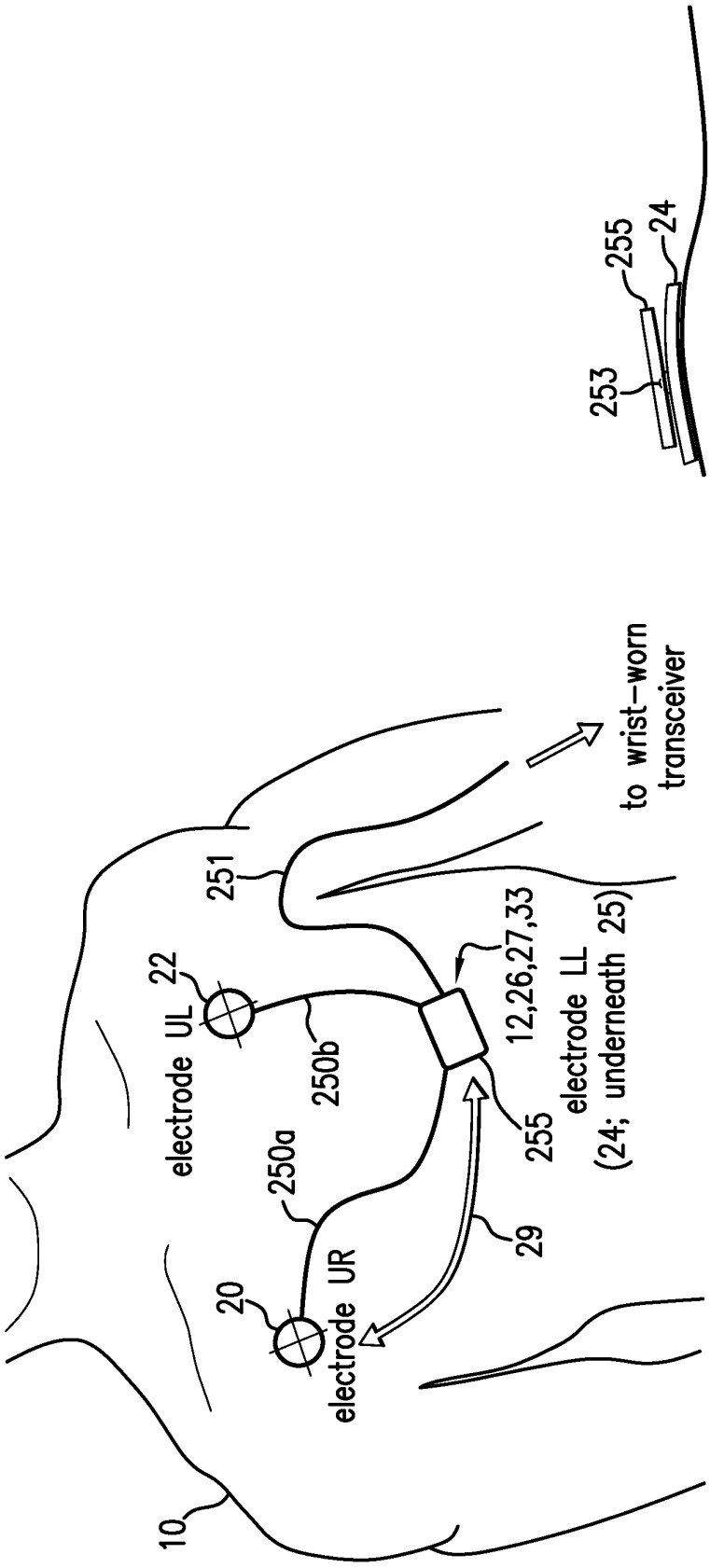


FIG.29A

FIG.29B