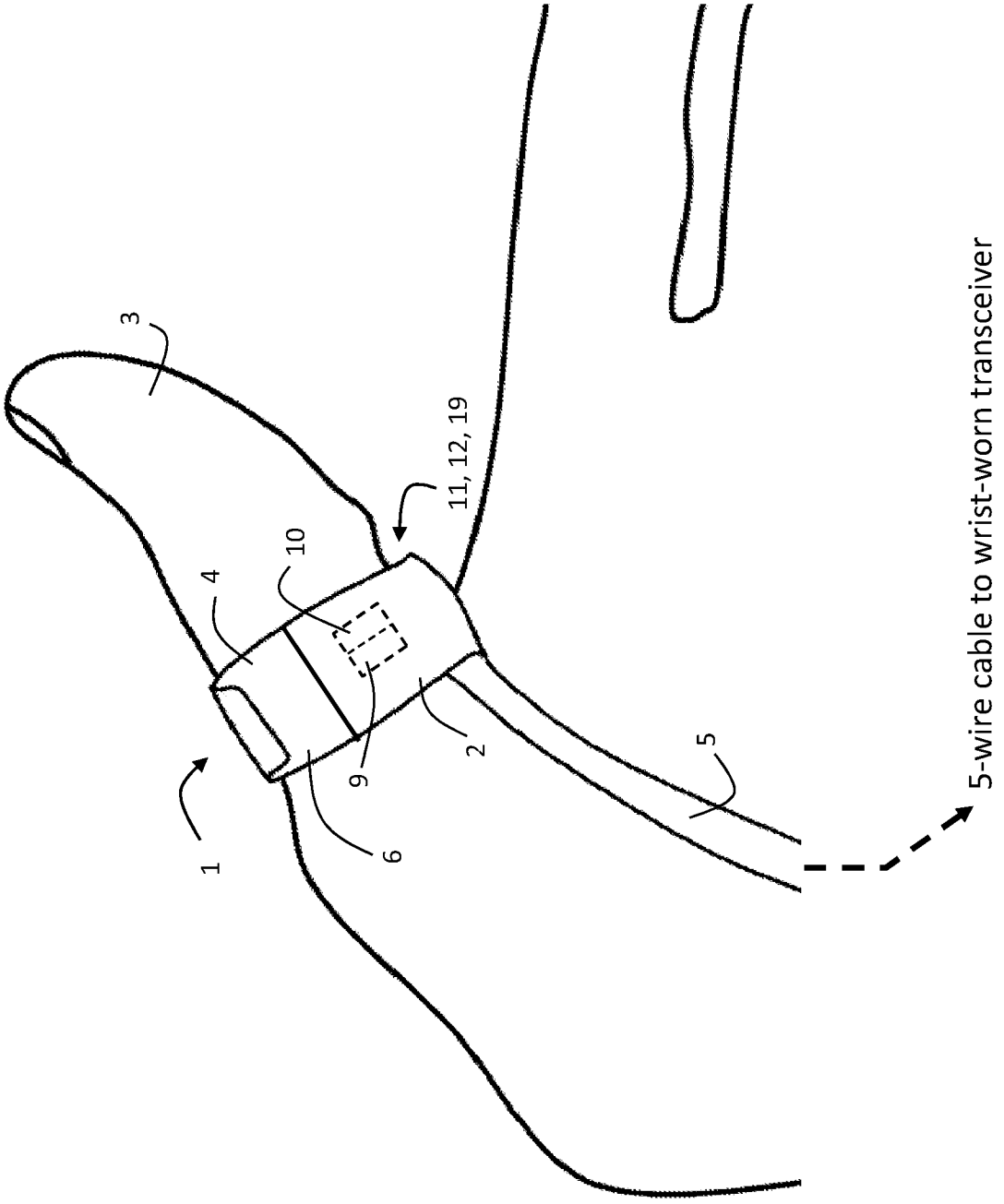


Fig. 1

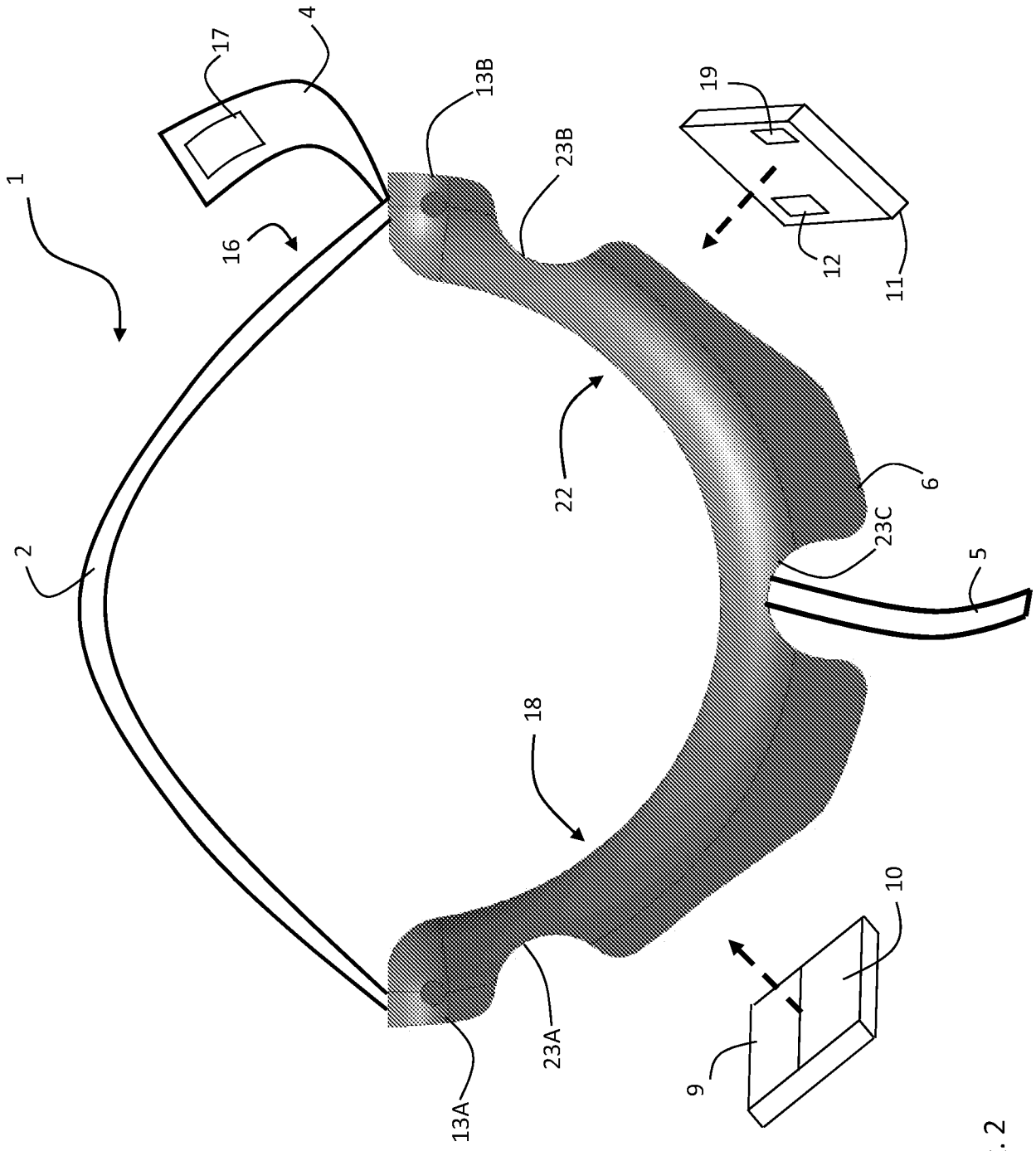


Fig. 2

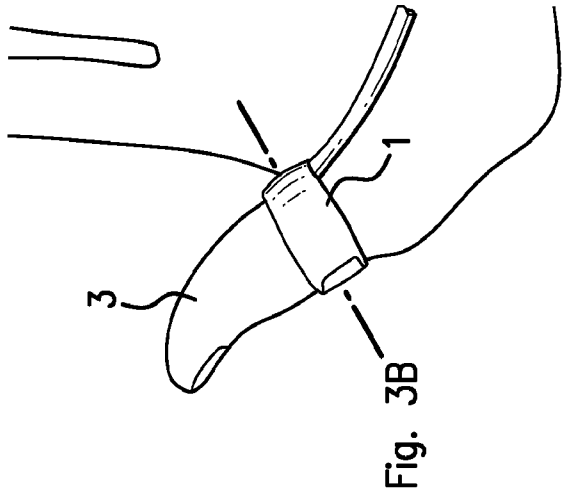


Fig. 3B

Fig. 3A

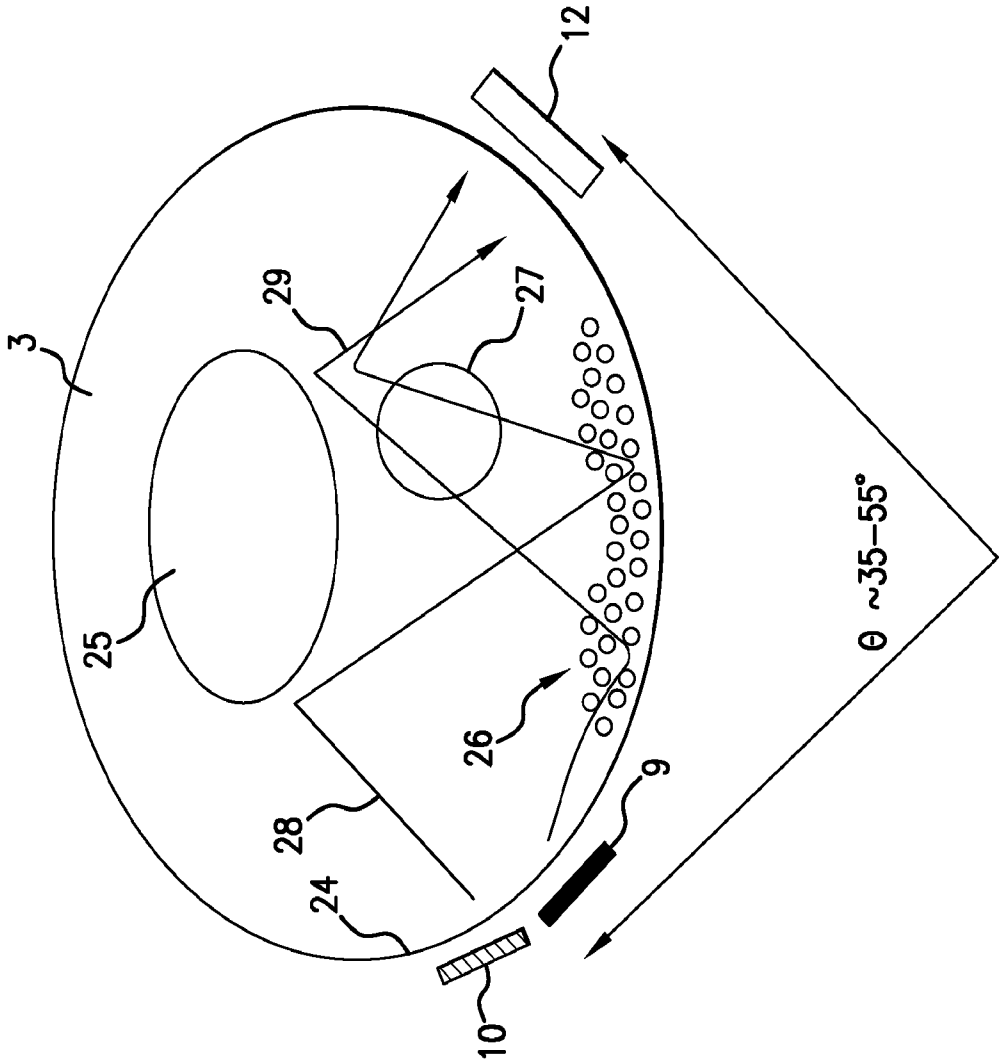


Fig. 3B

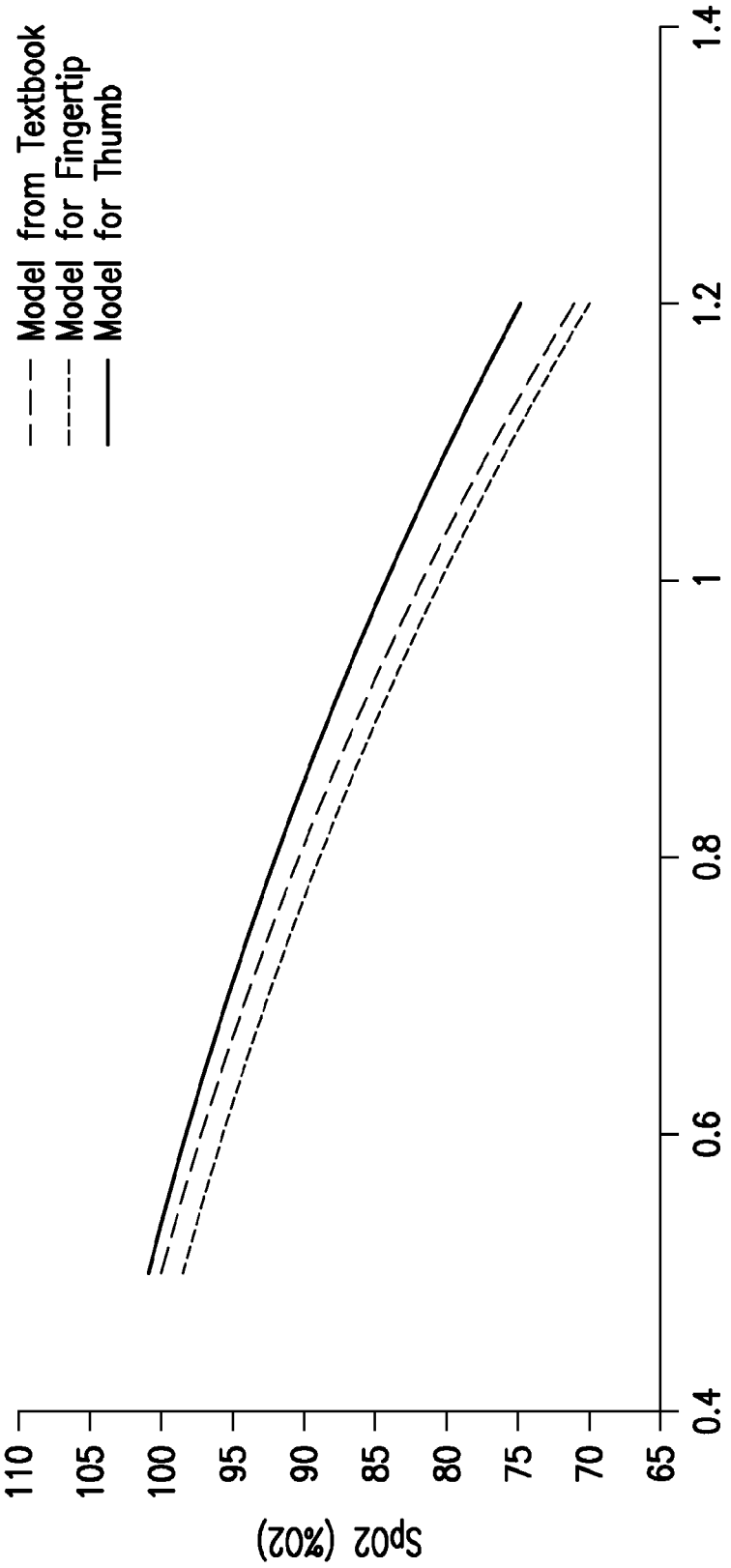

Model from Textbook
Model for Fingertip
Model for Thumb
SpO2 (%O2)
110
105
100
95
90
85
80
75
70
65
0.4
0.6
0.8
1
1.2
1.4
RoR

Fig. 4

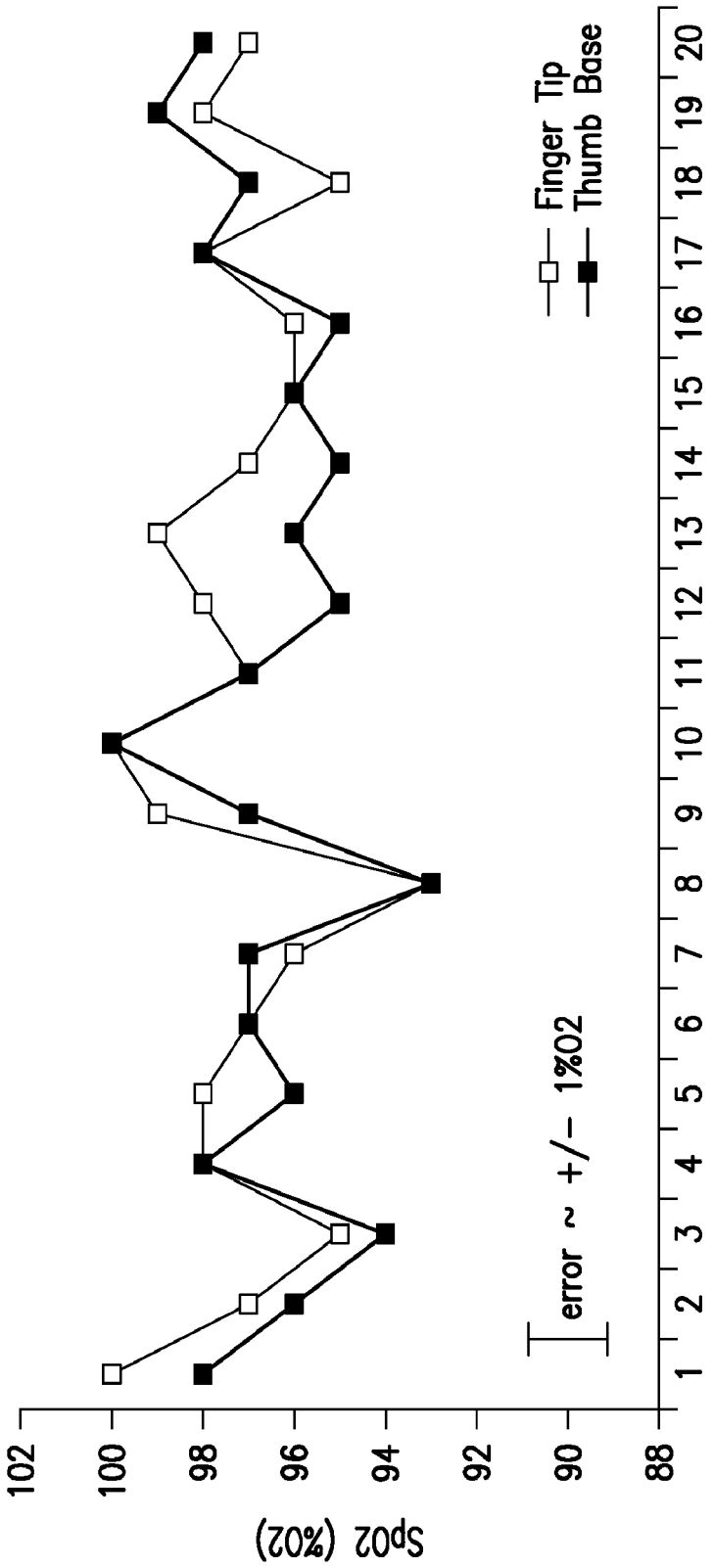

SpO2 (%O2)
102
100
98
96
94
92
90
88
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Subject
Finger Tip
Thumb Base
error ~ +/- 1%O2

Fig. 5

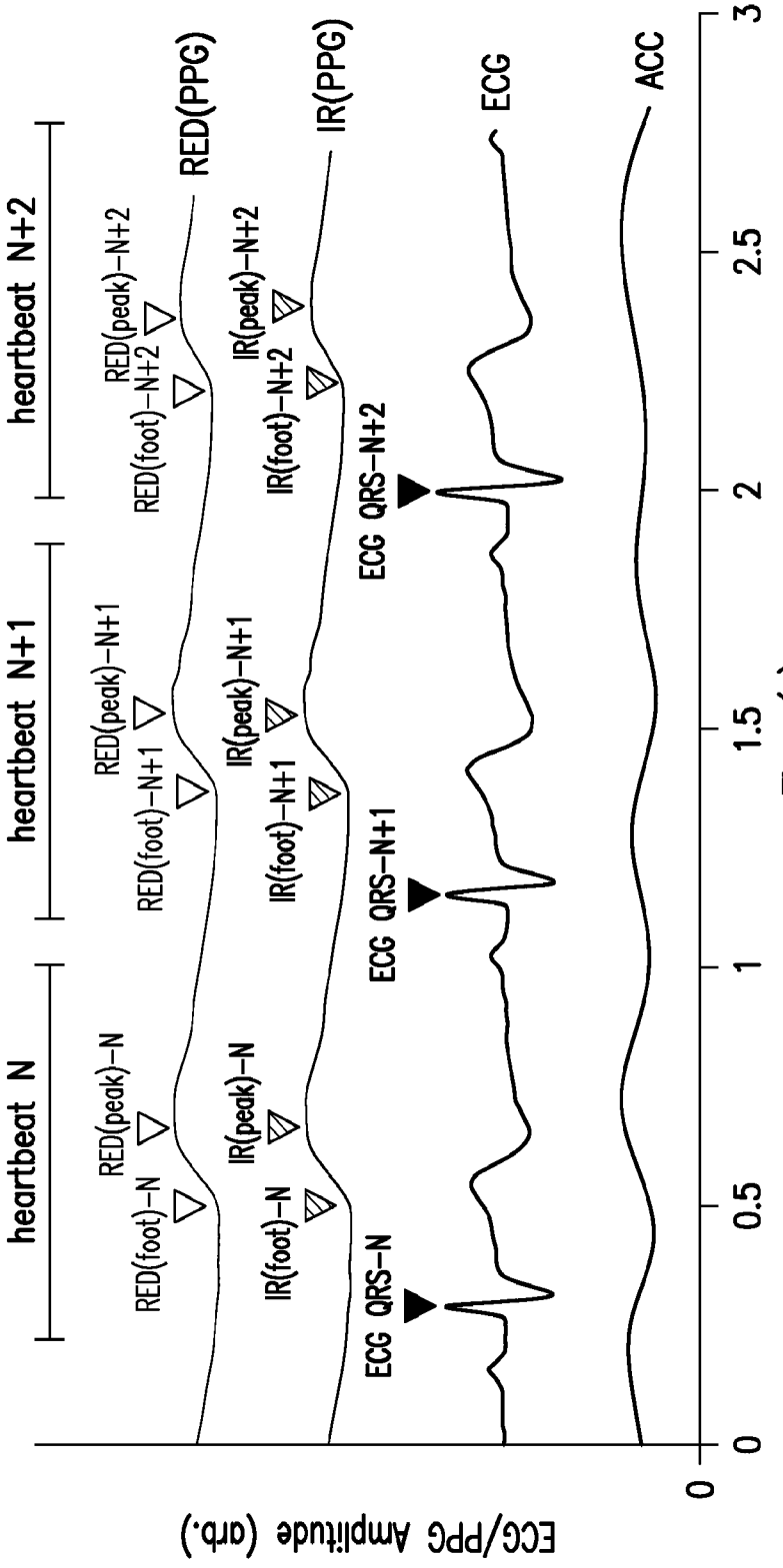
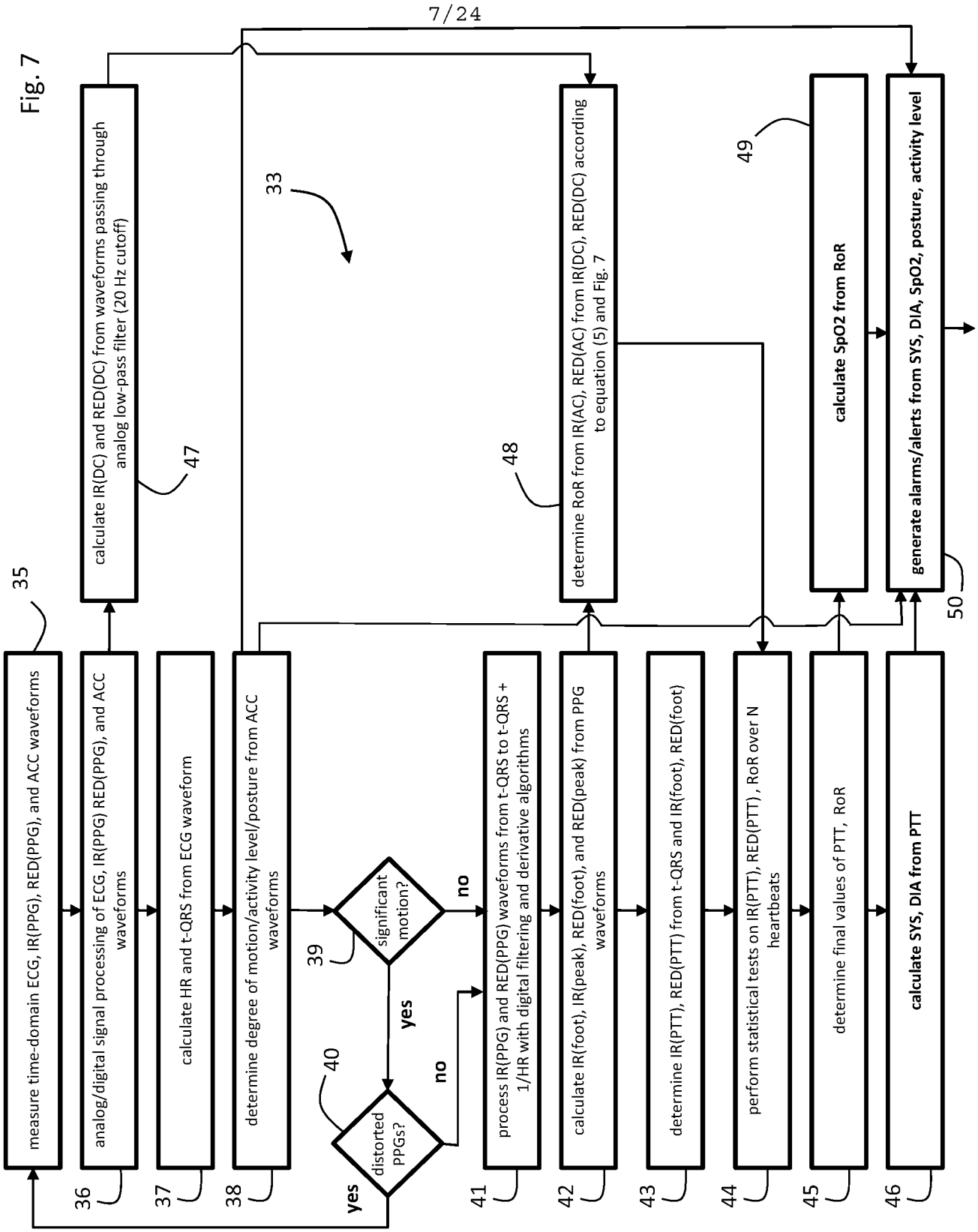

heartbeat N
heartbeat N+1
heartbeat N+2
RED(peak)–N
RED(foot)–N
IR(peak)–N
IR(foot)–N
ECG QRS–N
RED(peak)–N+1
RED(foot)–N+1
IR(peak)–N+1
IR(foot)–N+1
ECG QRS–N+1
RED(peak)–N+2
RED(foot)–N+2
IR(peak)–N+2
IR(foot)–N+2
ECG QRS–N+2
RED(PPG)
IR(PPG)
ECG
ACC
0
0.5
1
1.5
2
2.5
3
Time (s)
ECG/PPG Amplitude (arb.)

Fig. 6

Fig. 7


35
measure time-domain ECG, IR(PPG), RED(PPG), and ACC waveforms
36
analog/digital signal processing of ECG, IR(PPG) RED(PPG), and ACC waveforms
37
calculate HR and t-QRS from ECG waveform
38
determine degree of motion/activity level/posture from ACC waveforms
39
significant motion?
yes
no
40
distorted PPGs?
yes
no
41
process IR(PPG) and RED(PPG) waveforms from t-QRS to t-QRS + 1/HR with digital filtering and derivative algorithms
42
calculate IR(foot), IR(peak), RED(foot), and RED(peak) from PPG waveforms
43
determine IR(PTT), RED(PTT) from t-QRS and IR(foot), RED(foot)
44
perform statistical tests on IR(PTT), RED(PTT) , RoR over N heartbeats
45
determine final values of PTT, RoR
46
calculate SYS, DIA from PTT
47
calculate IR(DC) and RED(DC) from waveforms passing through analog low-pass filter (20 Hz cutoff)
48
determine RoR from IR(AC), RED(AC) from IR(DC), RED(DC) according to equation (5) and Fig. 7
49
calculate SpO2 from RoR
50
generate alarms/alerts from SYS, DIA, SpO2, posture, activity level
33

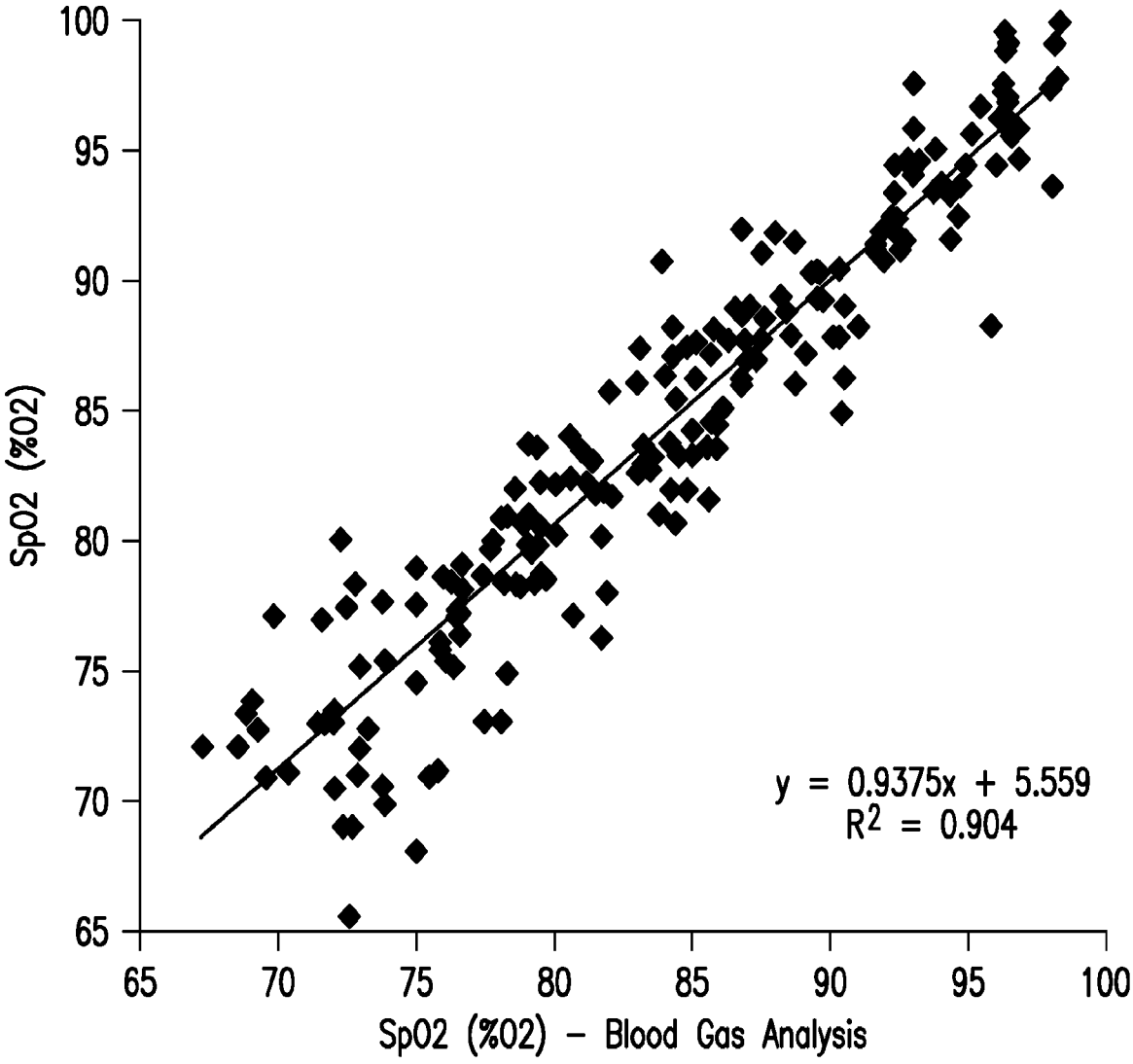

100
95
90
85
80
75
70
65
SpO2 (%O2)
65
70
75
80
85
90
95
100
SpO2 (%O2) – Blood Gas Analysis
y = 0.9375x + 5.559
R2 = 0.904

Fig. 8

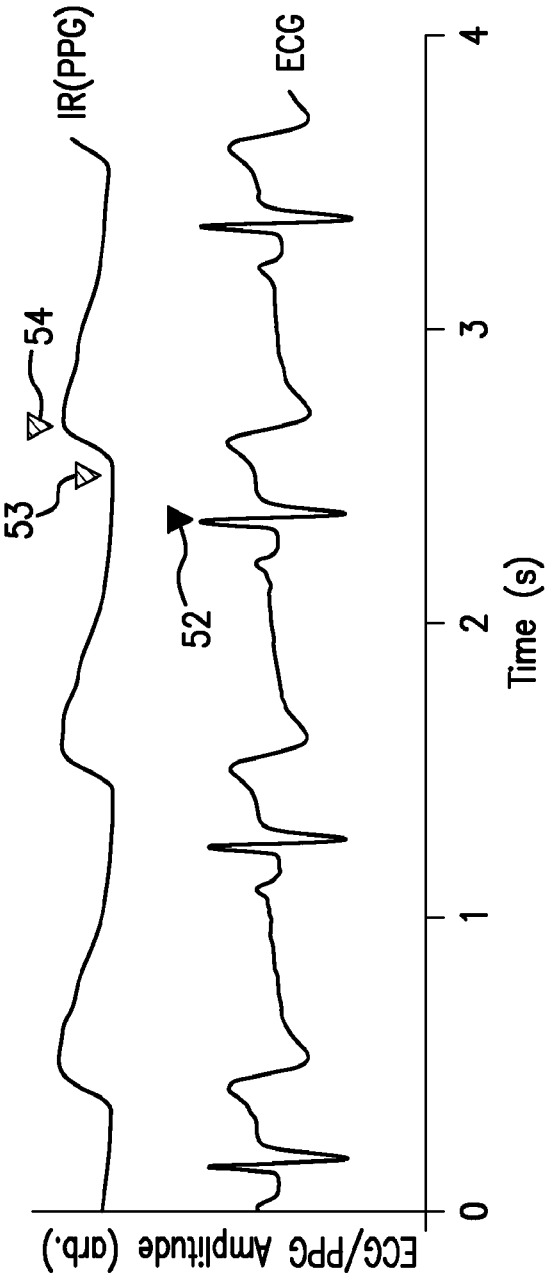

IR(PPG)
ECG
54
53
52
ECG/PPG Amplitude (arb.)
0
1
2
3
4
Time (s)

Fig. 9A

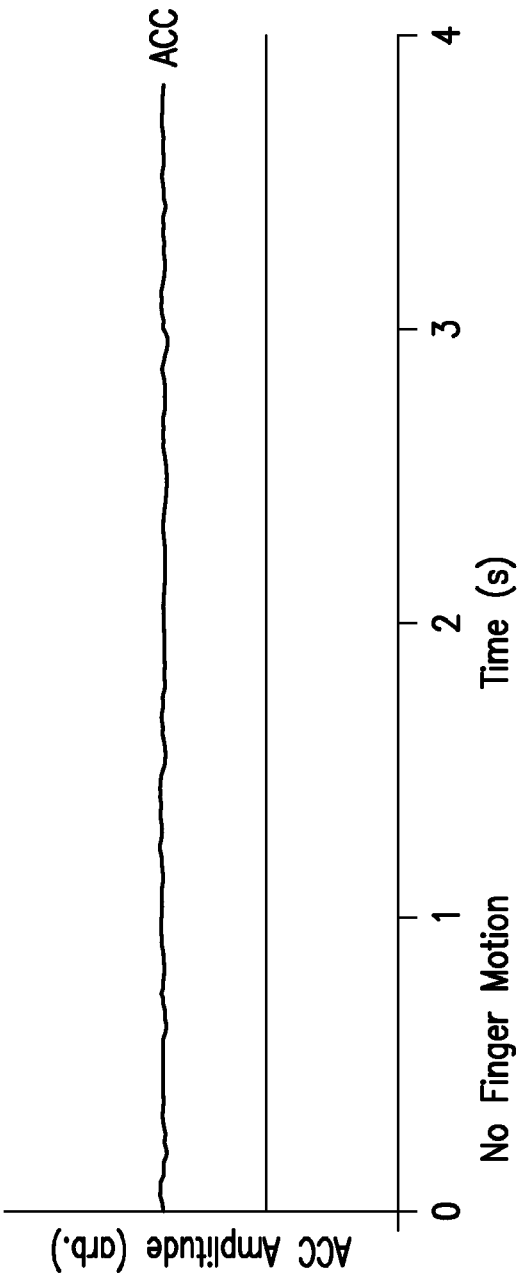

ACC
ACC Amplitude (arb.)
0
1
2
3
4
Time (s)
No Finger Motion

Fig. 9B

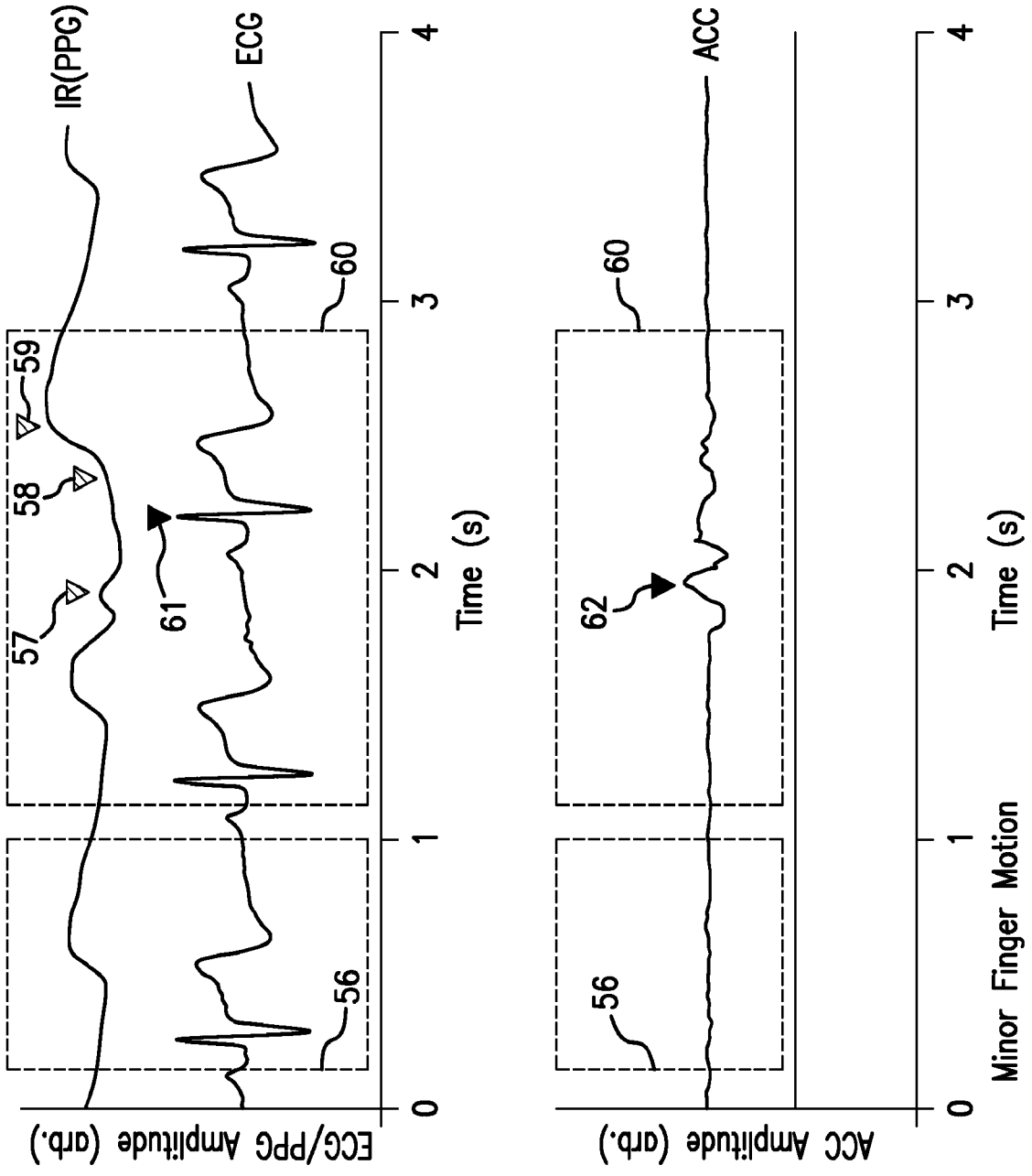


Fig. 10A

Fig. 10B

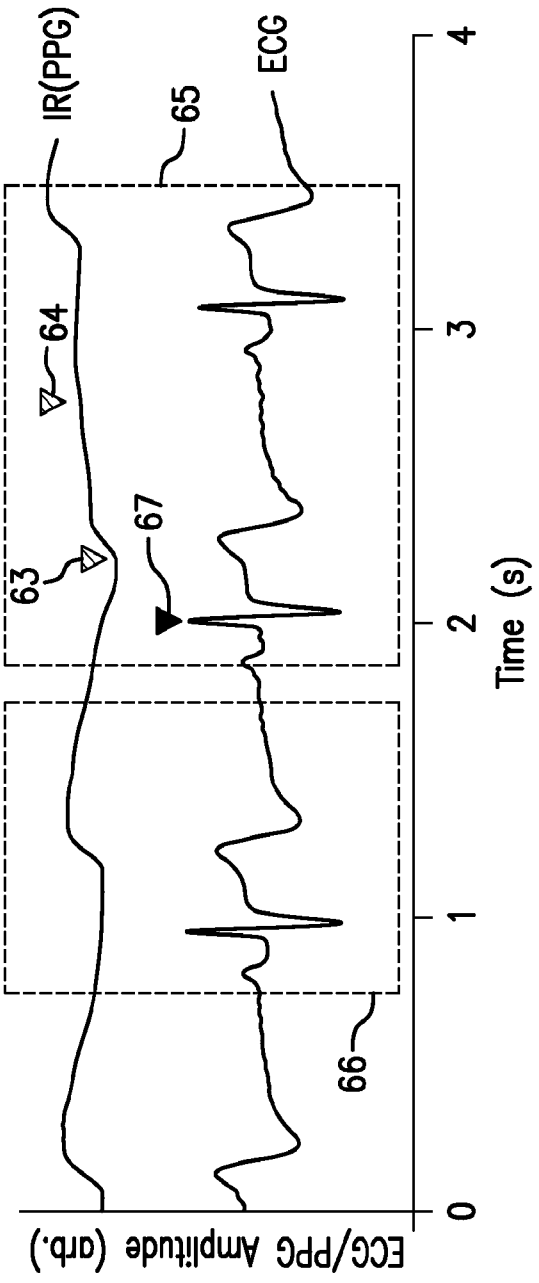


Fig. 11A

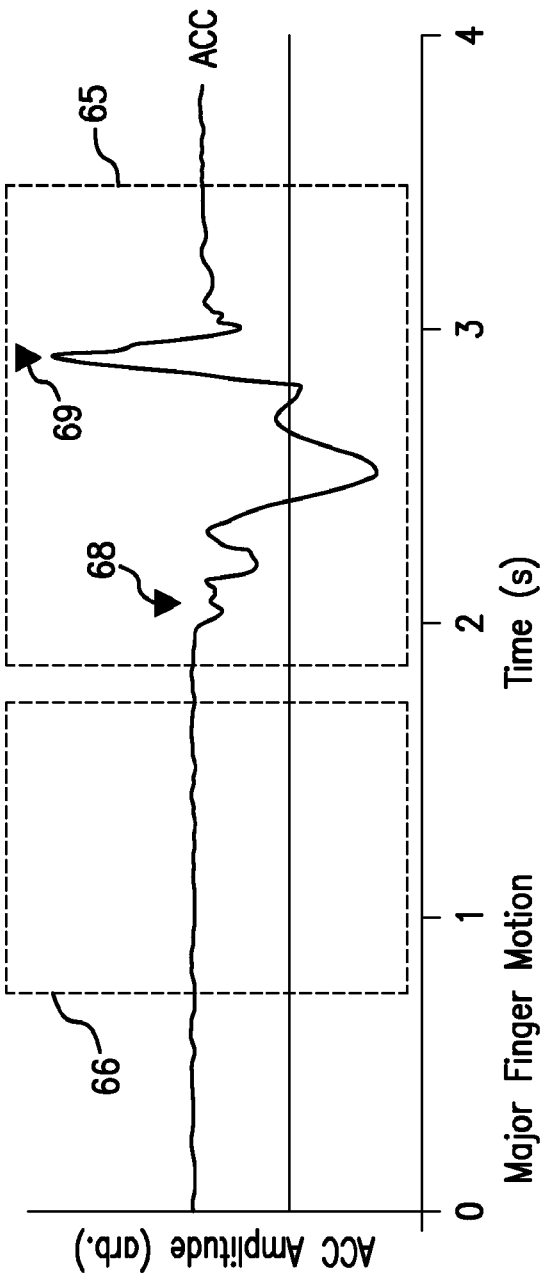


Fig. 11B

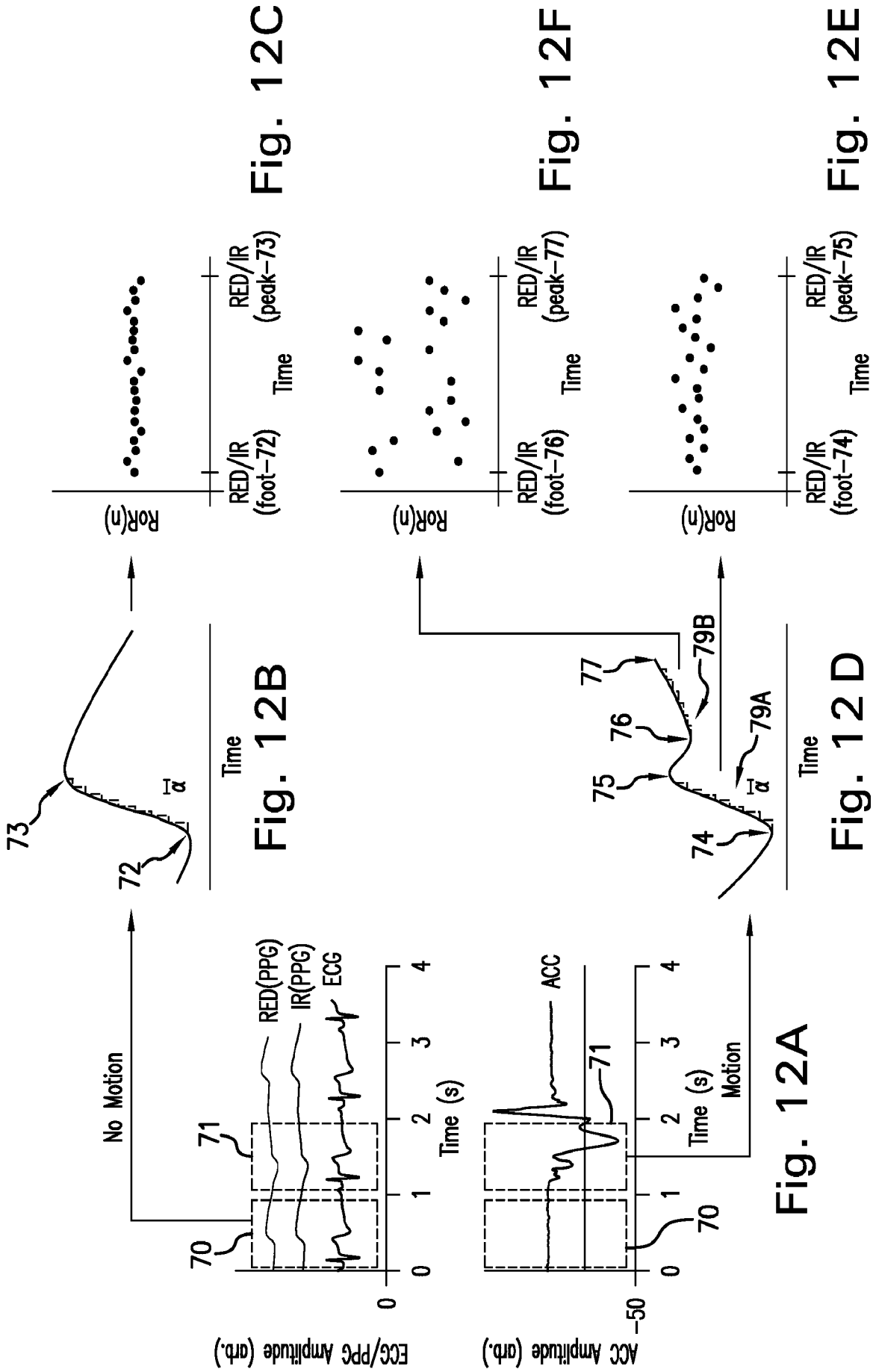


Fig. 12A

Fig. 12B

Fig. 12C

Fig. 12D

Fig. 12E

Fig. 12F

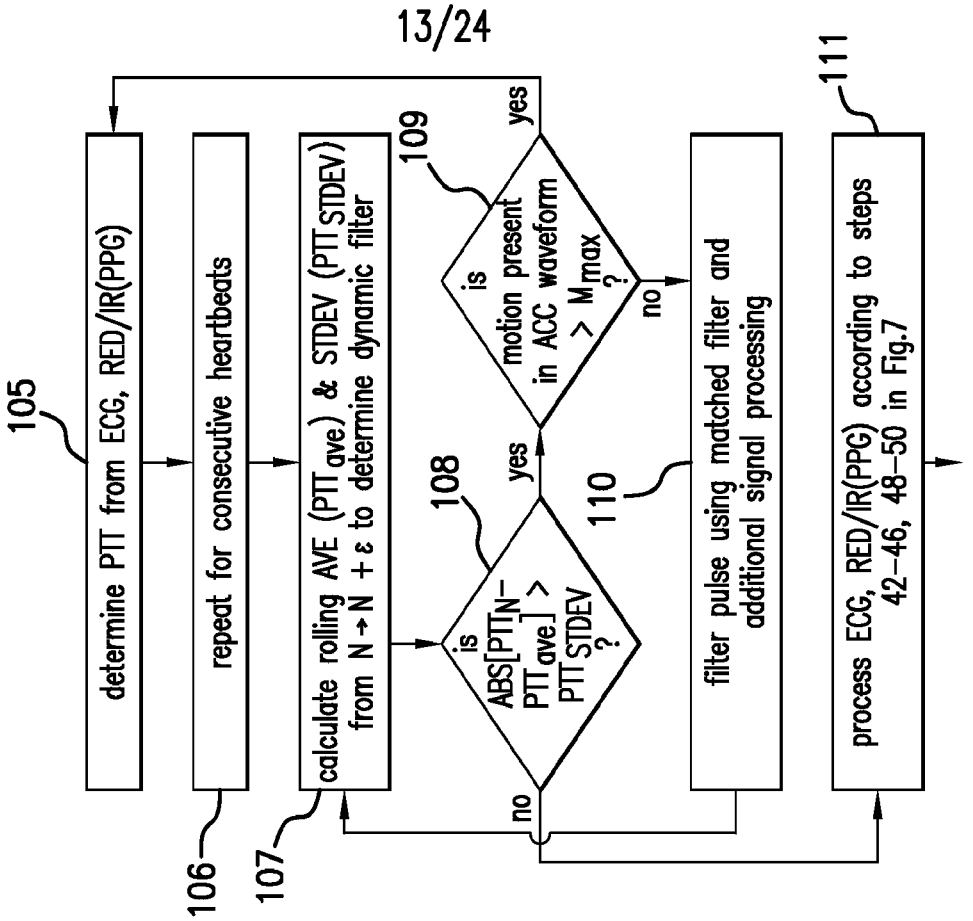


Fig. 13D

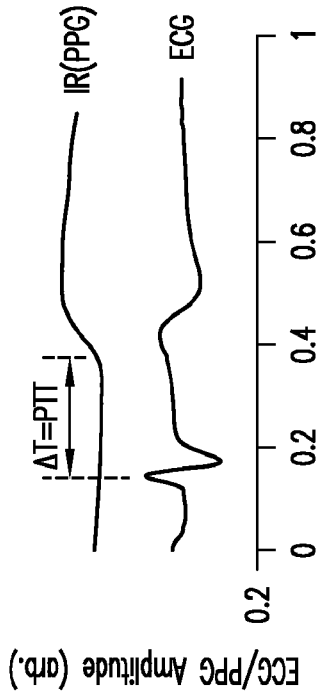


Fig. 13A

Fig. 13B

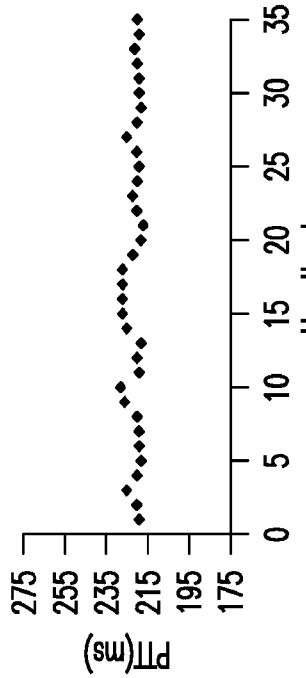


Fig. 13C

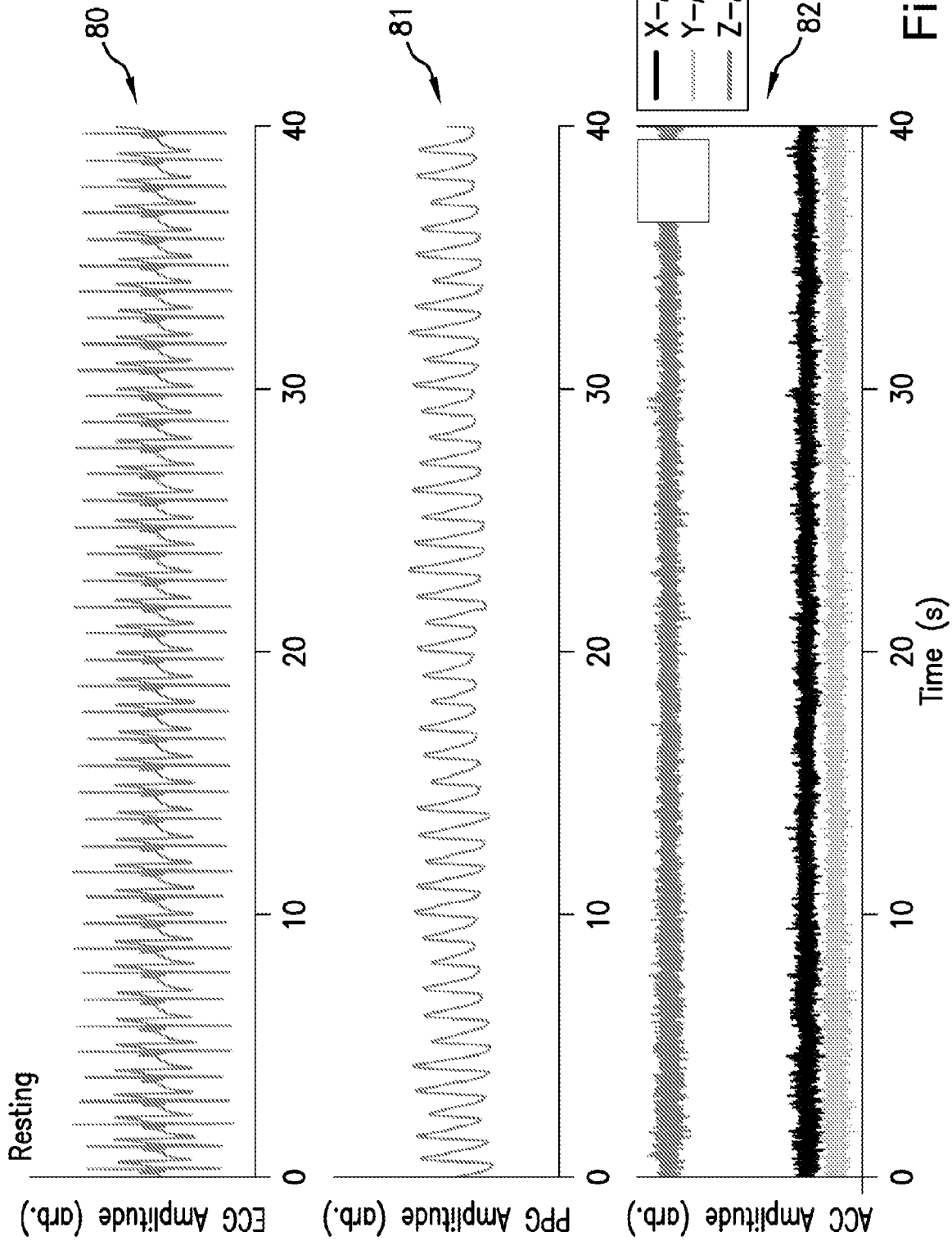

Resting
80
81
82
X-Axis
Y-Axis
Z-Axis
ECG Amplitude (arb.)
PPG Amplitude (arb.)
ACC Amplitude (arb.)
0
10
20
30
40
Time (s)

Fig. 14

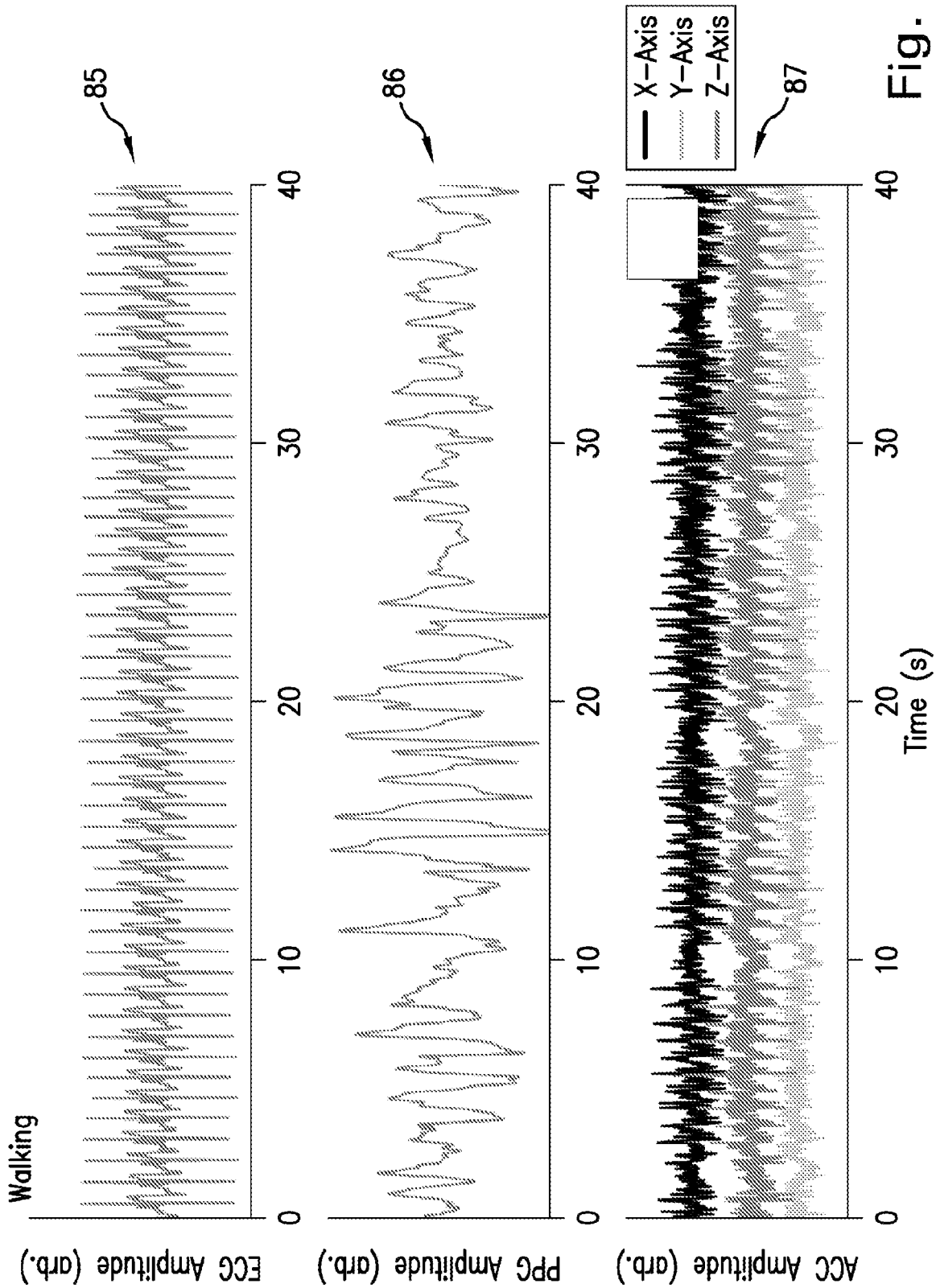

Walking
85
86
87
X-Axis
Y-Axis
Z-Axis
ECG Amplitude (arb.)
PPG Amplitude (arb.)
ACC Amplitude (arb.)
0
10
20
30
40
Time (s)

Fig. 15

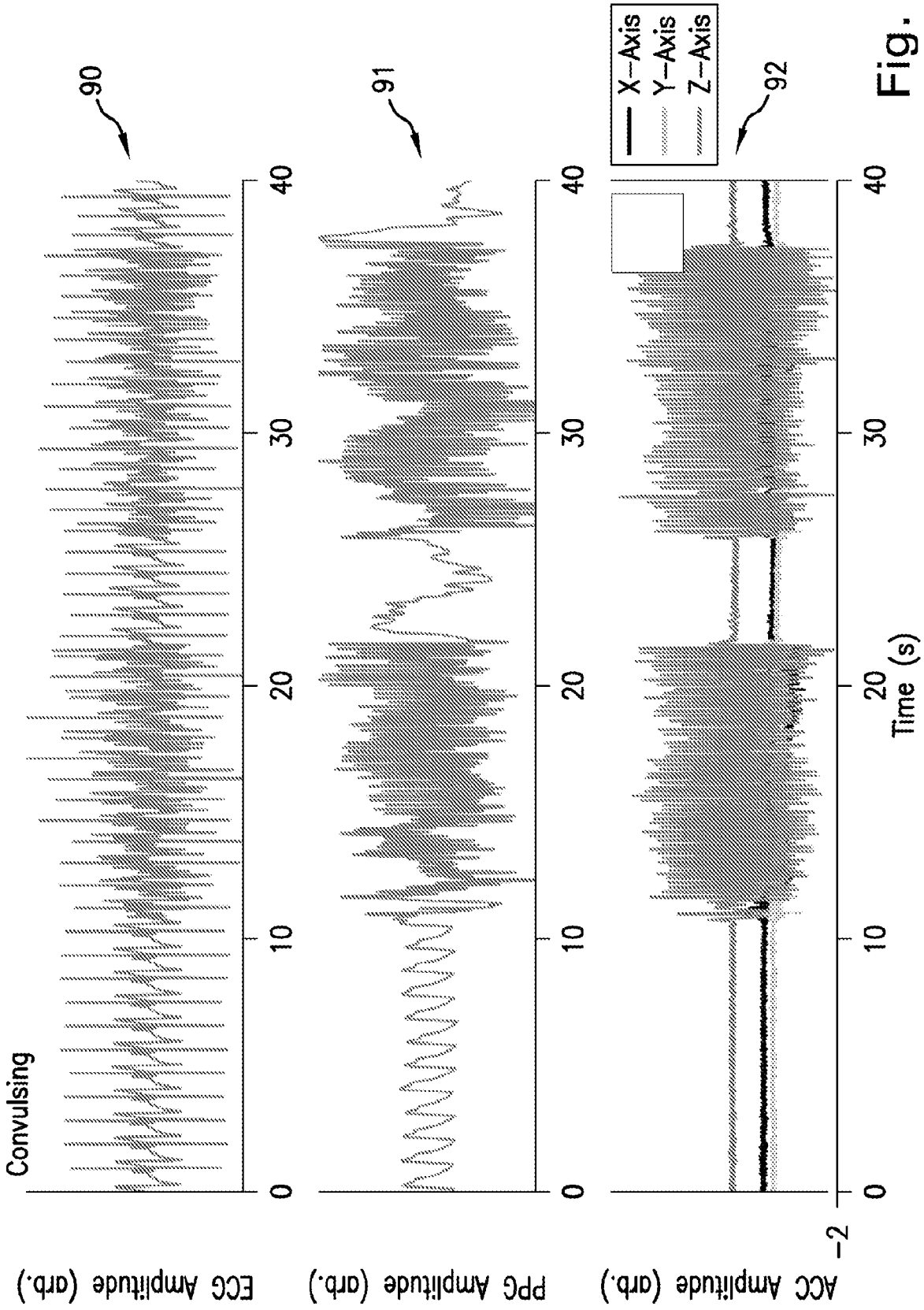

90
91
92
X–Axis
Y–Axis
Z–Axis
Convulsing
ECG Amplitude (arb.)
PPG Amplitude (arb.)
ACC Amplitude (arb.)
Time (s)
0
10
20
30
40
−2

Fig. 16

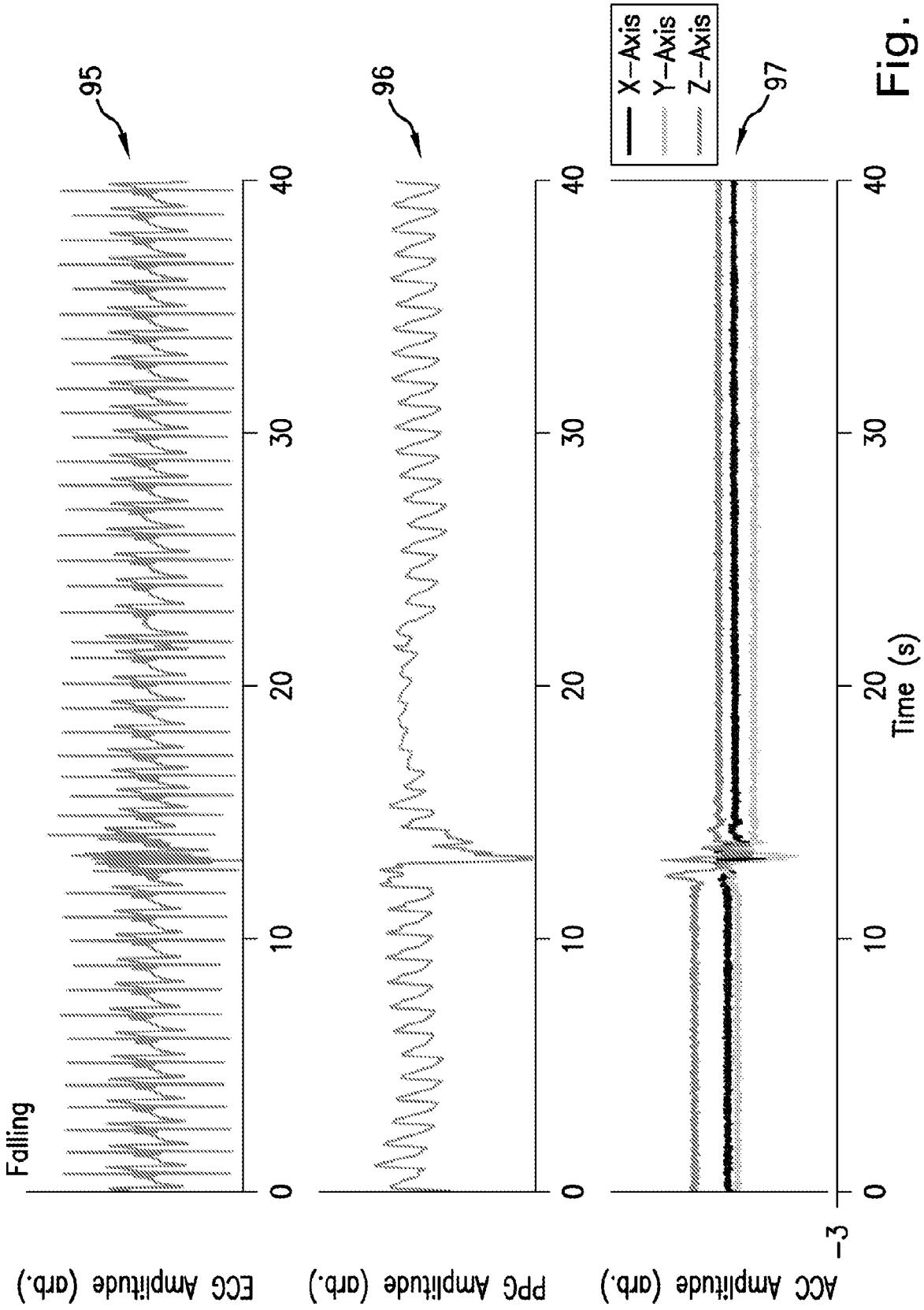

95
96
97
X–Axis
Y–Axis
Z–Axis
Falling
ECG Amplitude (arb.)
PPG Amplitude (arb.)
ACC Amplitude (arb.)
Time (s)
0
10
20
30
40
−3

Fig. 17

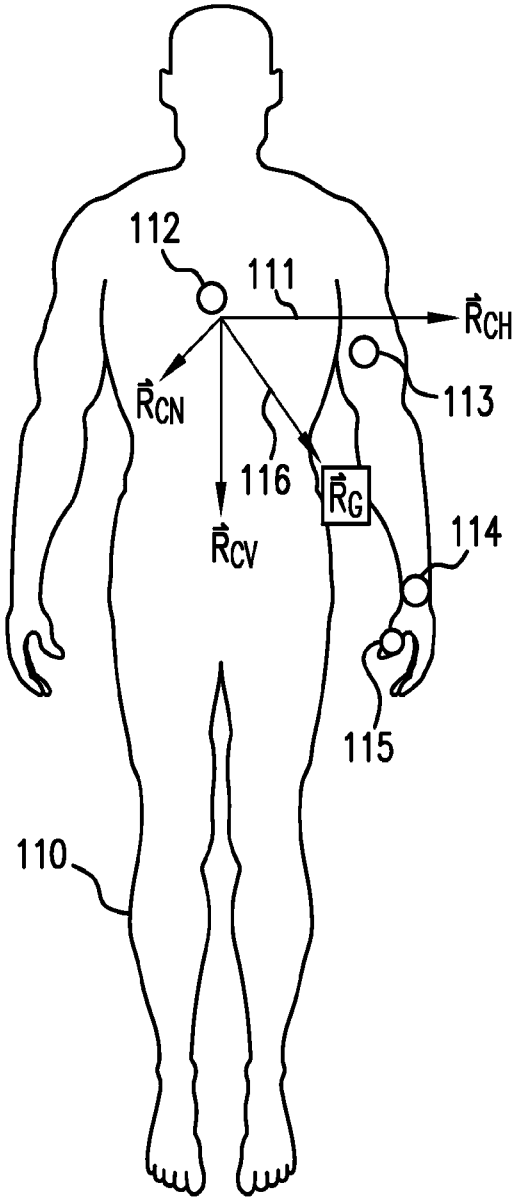


Fig. 18

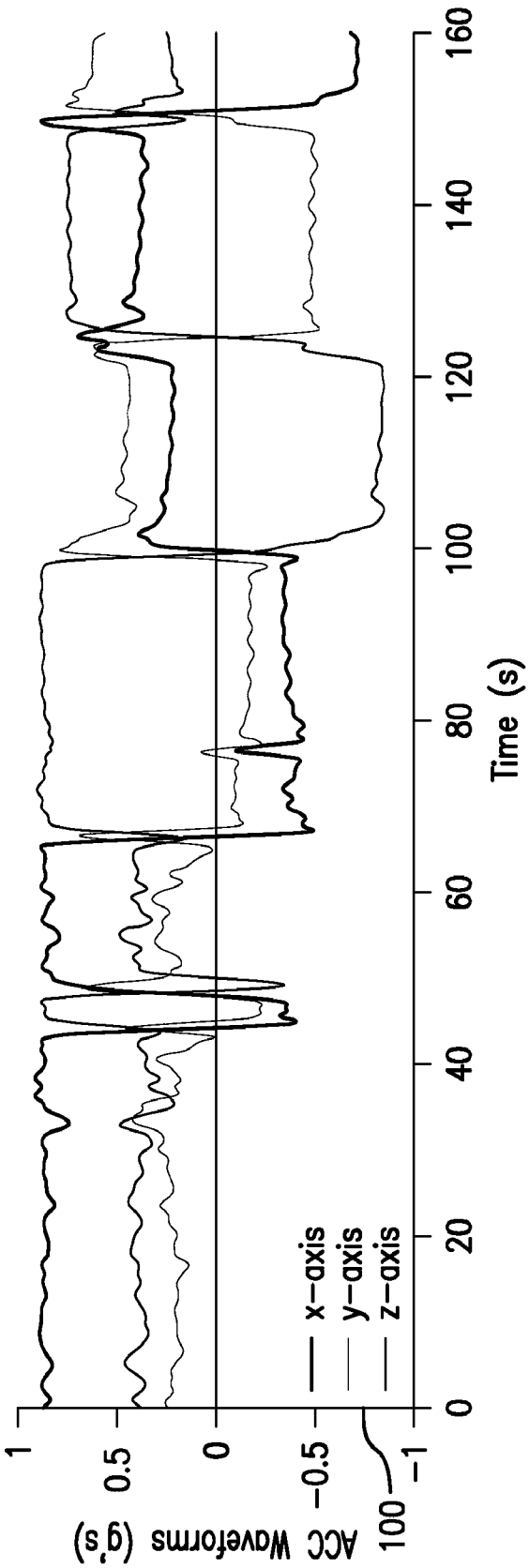


Fig. 19A

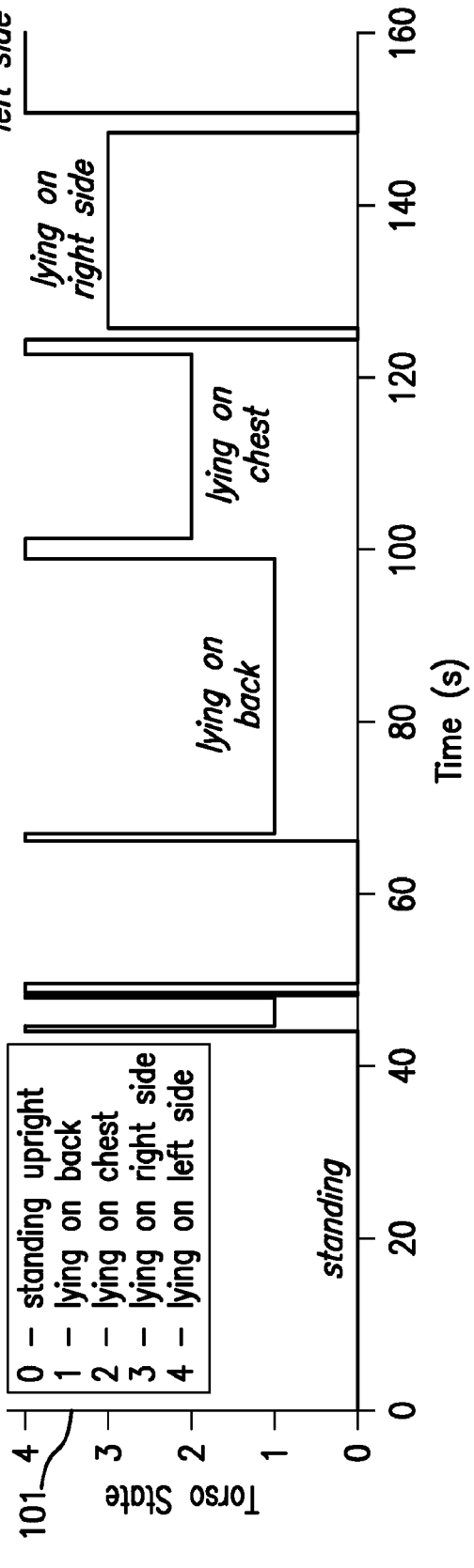


Fig. 19B

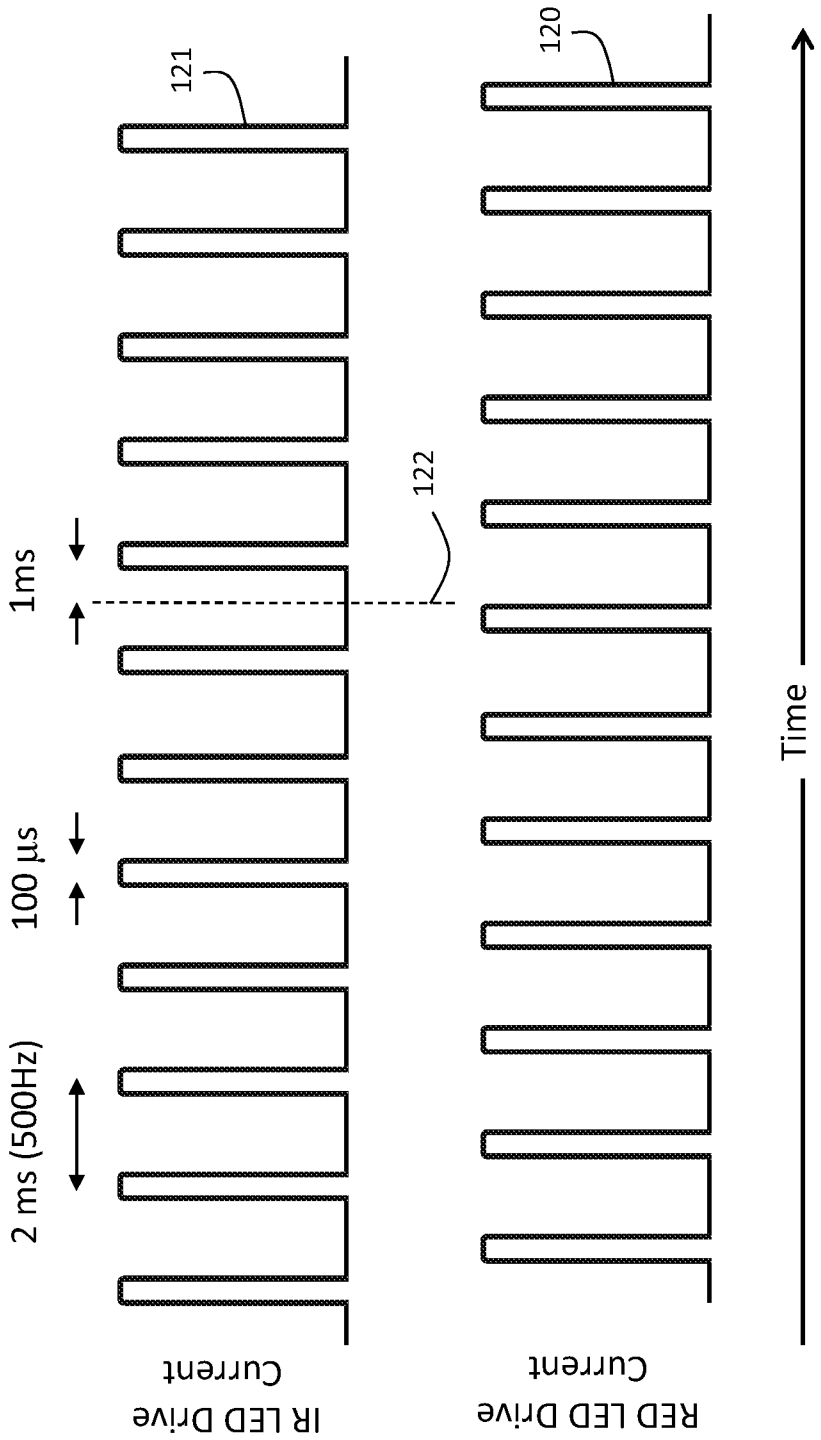

121
120
122
1ms
100 µs
2 ms (500Hz)
IR LED Drive Current
RED LED Drive Current
Time

Fig. 20

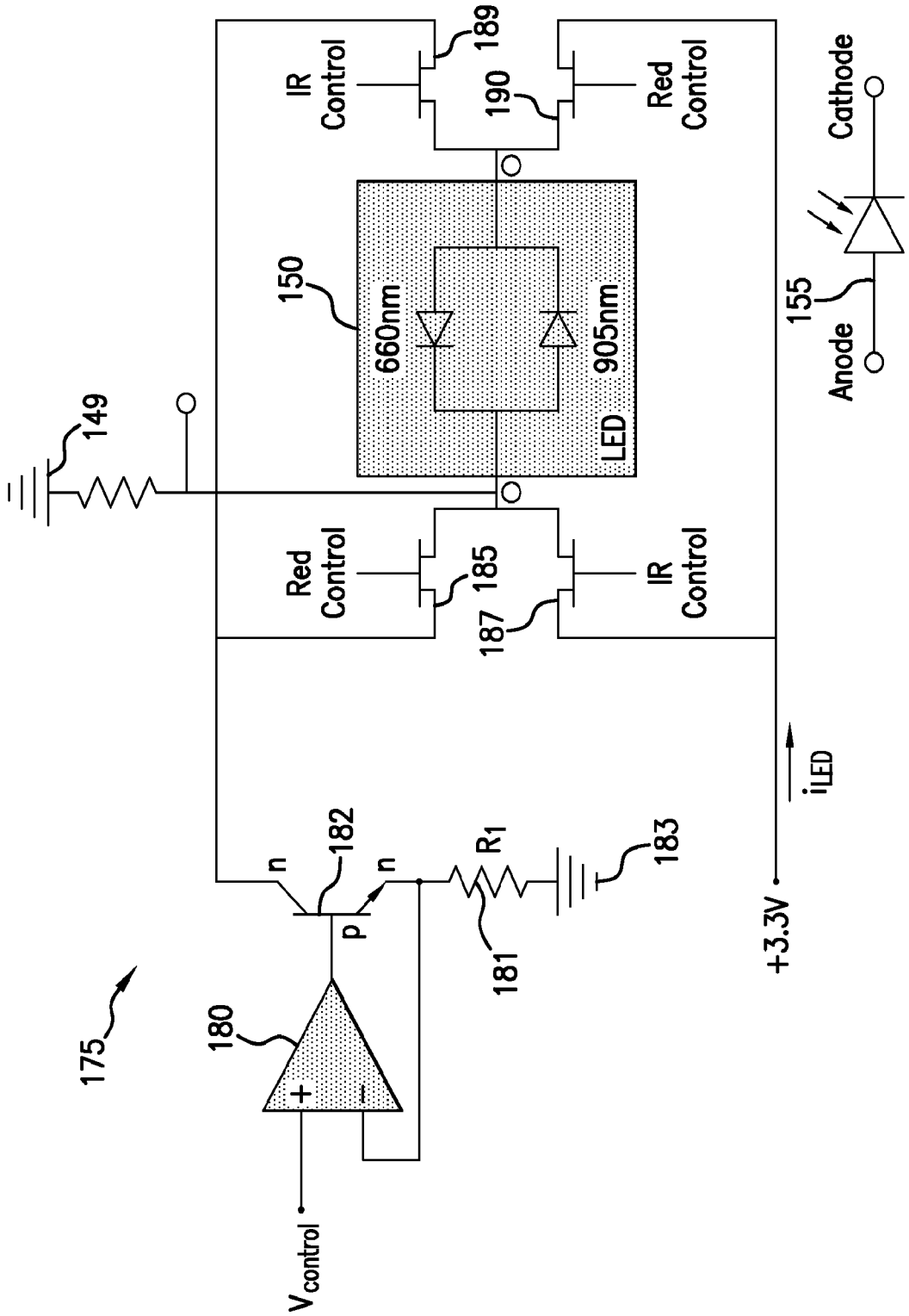

IR Control
189
190
Red Control
Cathode
150
660nm
905nm
LED
155
Anode
149
Red Control
185
187
IR Control
i_{LED}
182
n
n
p
R_1
183
181
+3.3V
175
180
+
-
$V_{control}$

Fig. 21

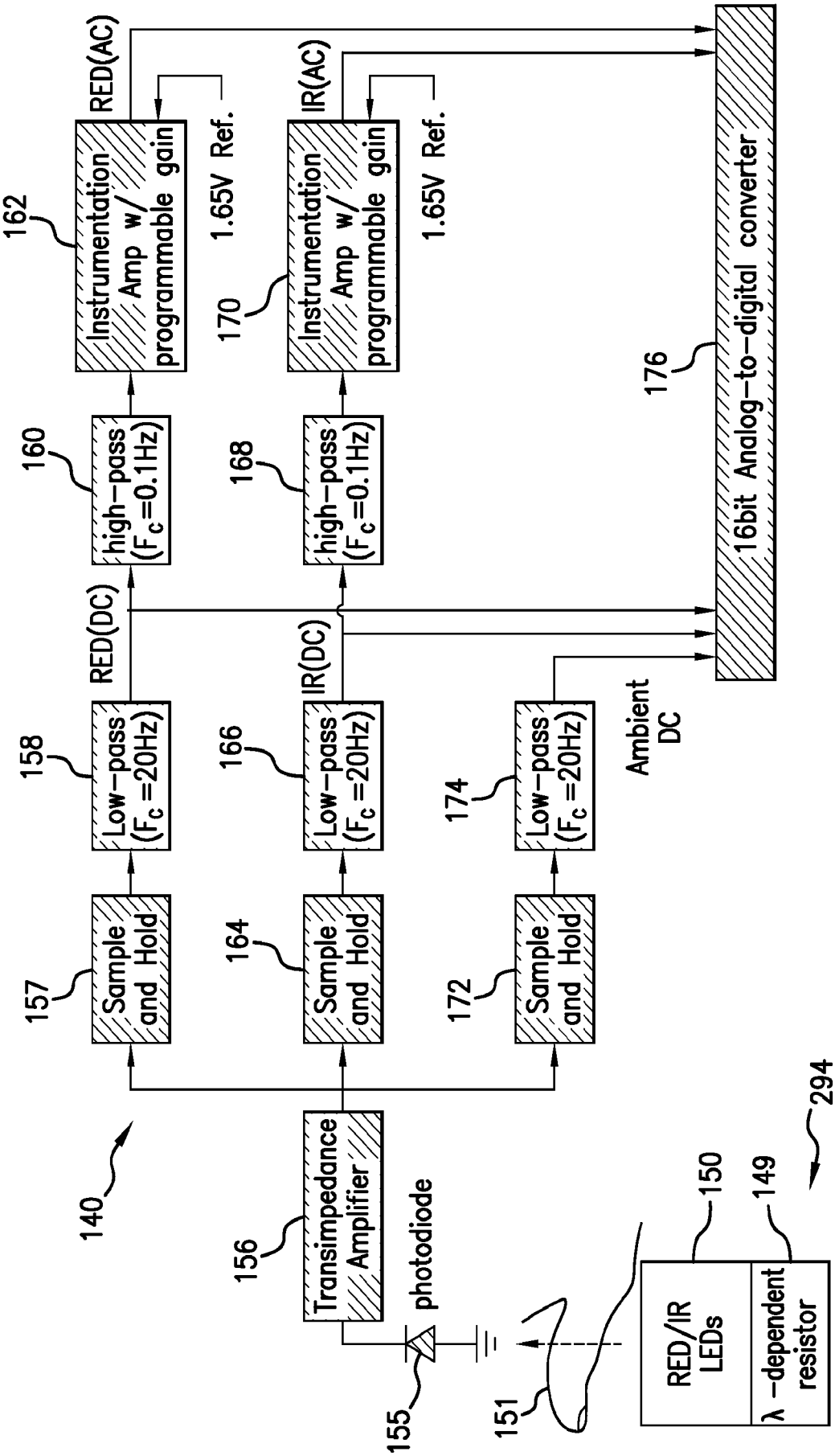

RED(AC)
IR(AC)
162
Instrumentation Amp w/ programmable gain
1.65V Ref.
170
Instrumentation Amp w/ programmable gain
1.65V Ref.
176
16bit Analog-to-digital converter
160
high-pass (F_c=0.1Hz)
168
high-pass (F_c=0.1Hz)
RED(DC)
IR(DC)
Ambient DC
158
Low-pass (F_c=20Hz)
166
Low-pass (F_c=20Hz)
174
Low-pass (F_c=20Hz)
157
Sample and Hold
164
Sample and Hold
172
Sample and Hold
140
156
Transimpedance Amplifier
photodiode
155
151
150
RED/IR LEDs
149
λ -dependent resistor
294

Fig. 22

Configuration for Indexing cNIBP Measurement
(first ~60 seconds)

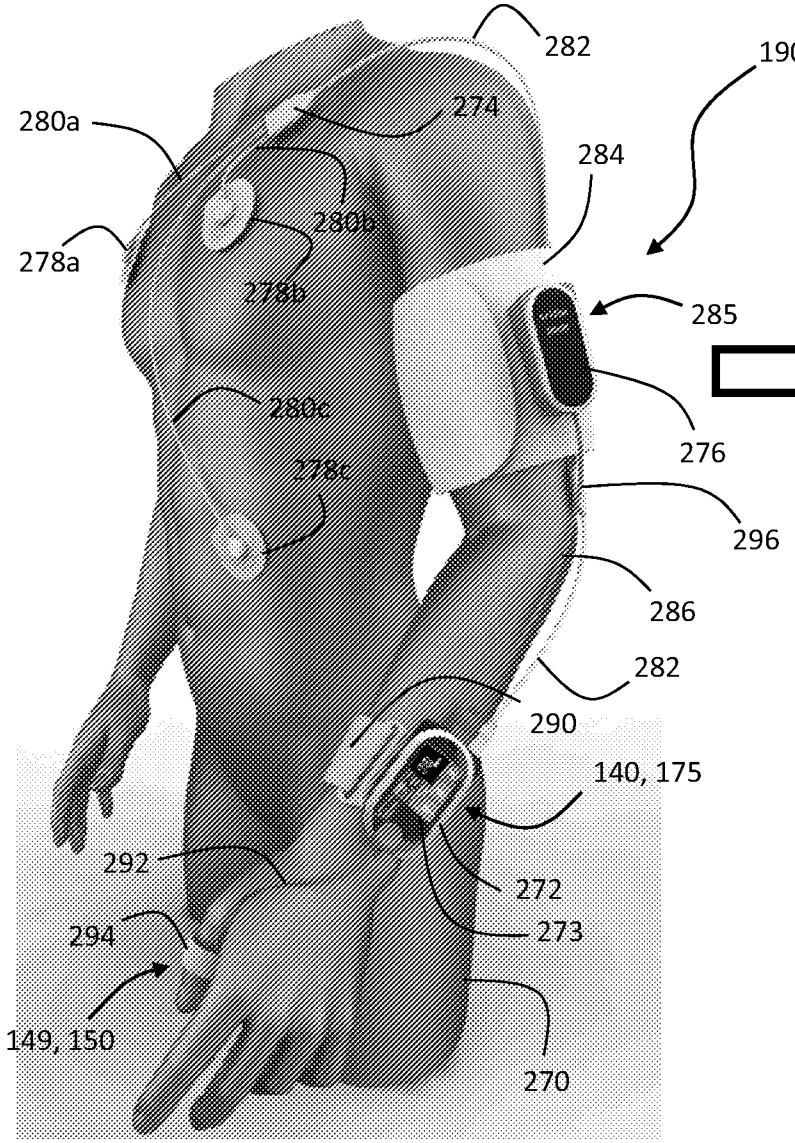


Fig. 23A

Configuration for cNIBP /SpO2 Measurements
(remaining 3 hours, 59 minutes)

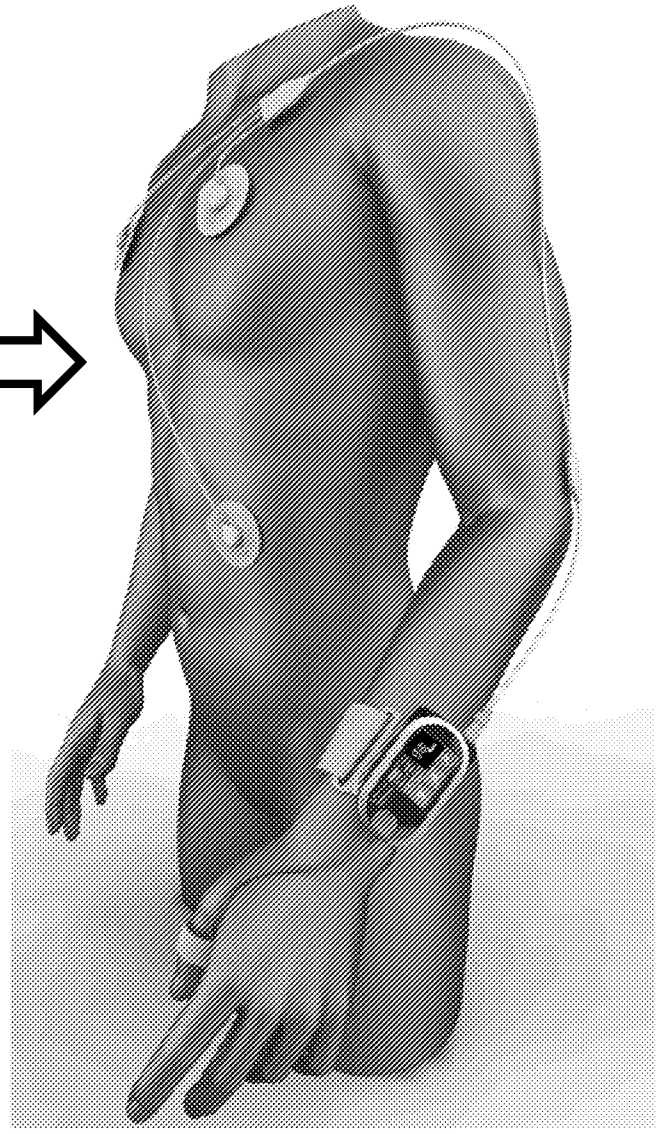


Fig. 23B

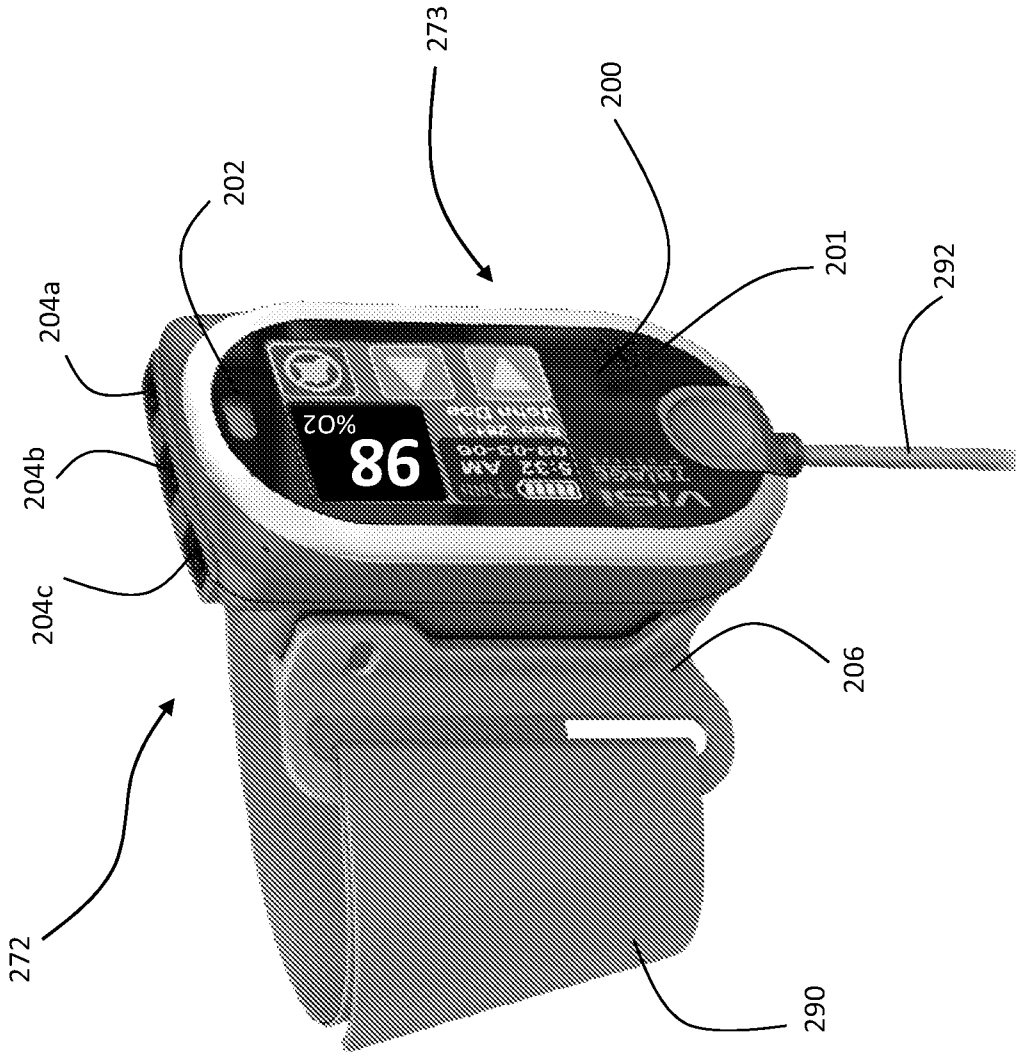


Fig. 24