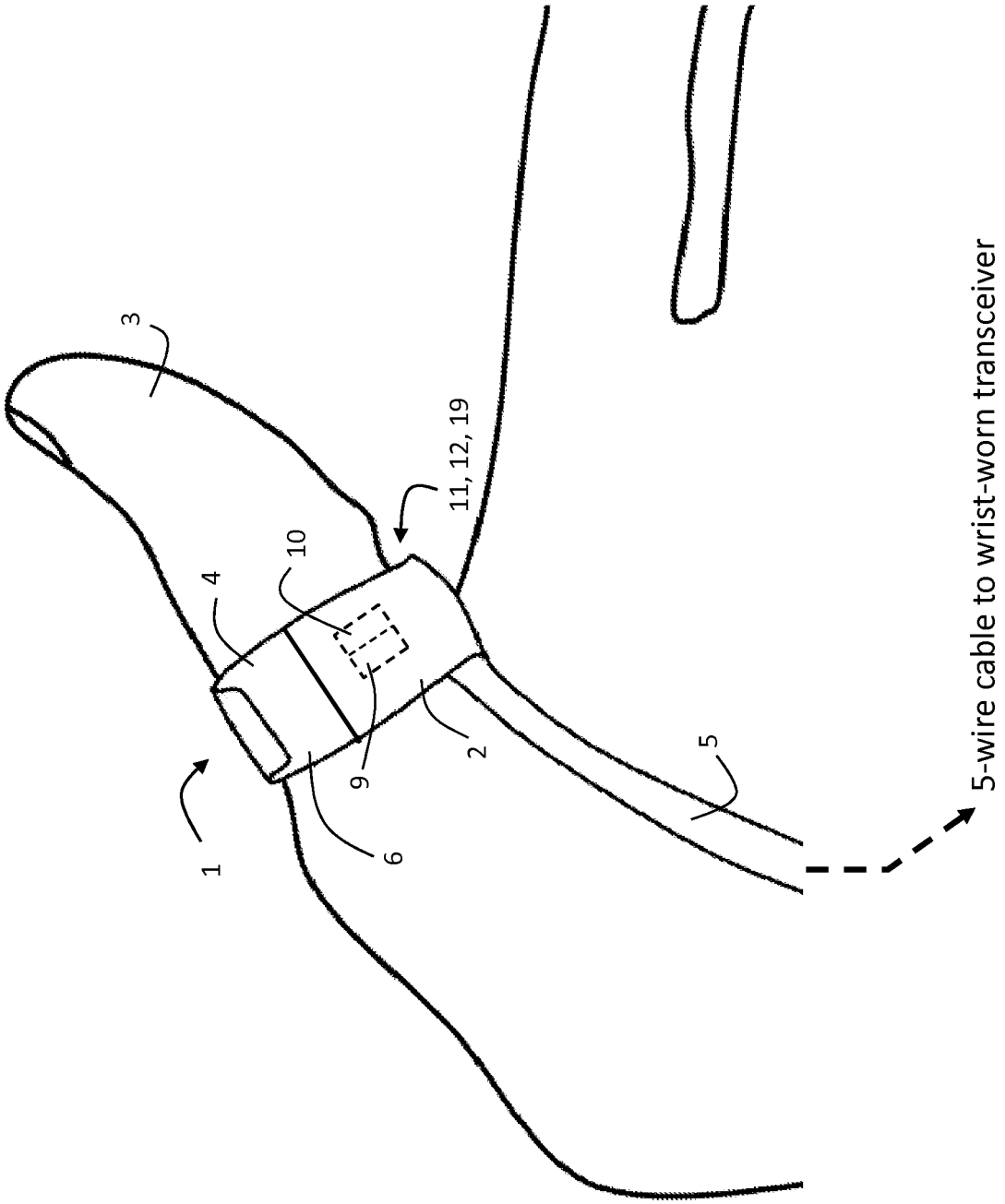


Fig. 1

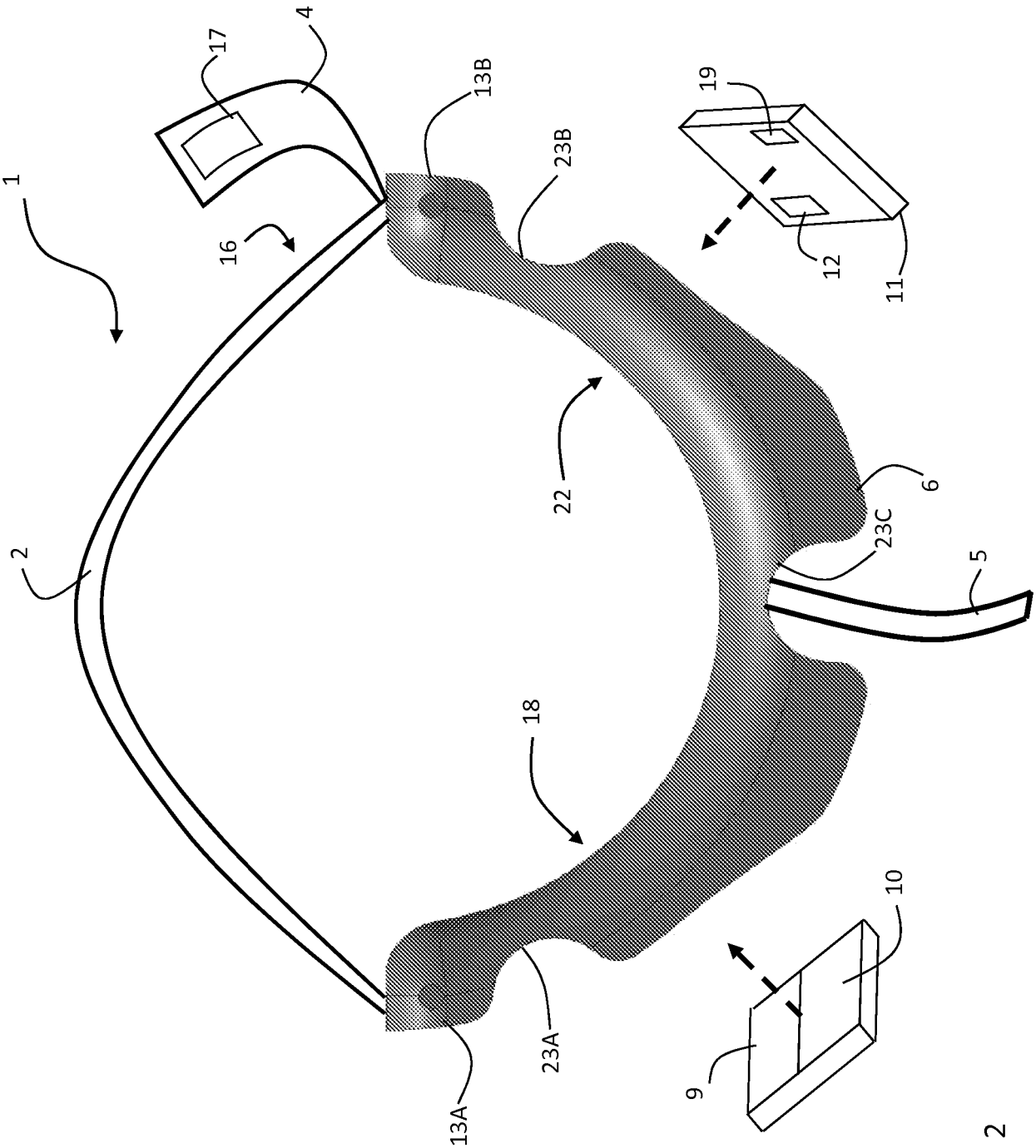


Fig. 2

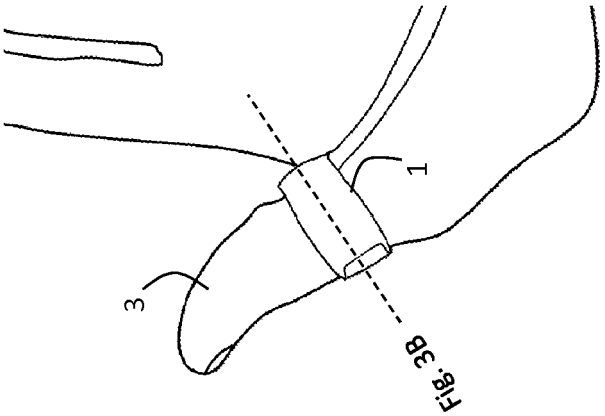


Fig. 3A

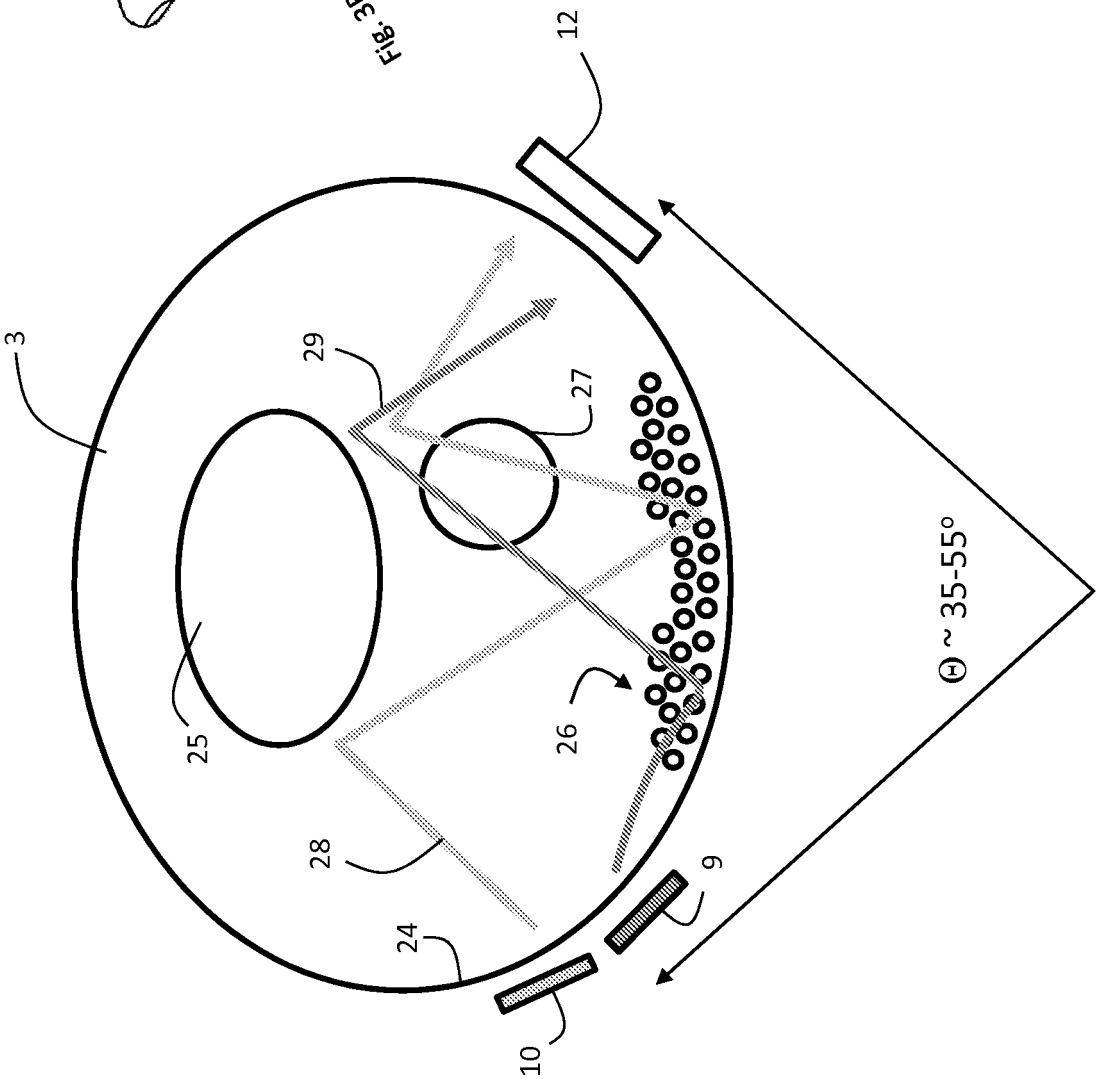


Fig. 3B

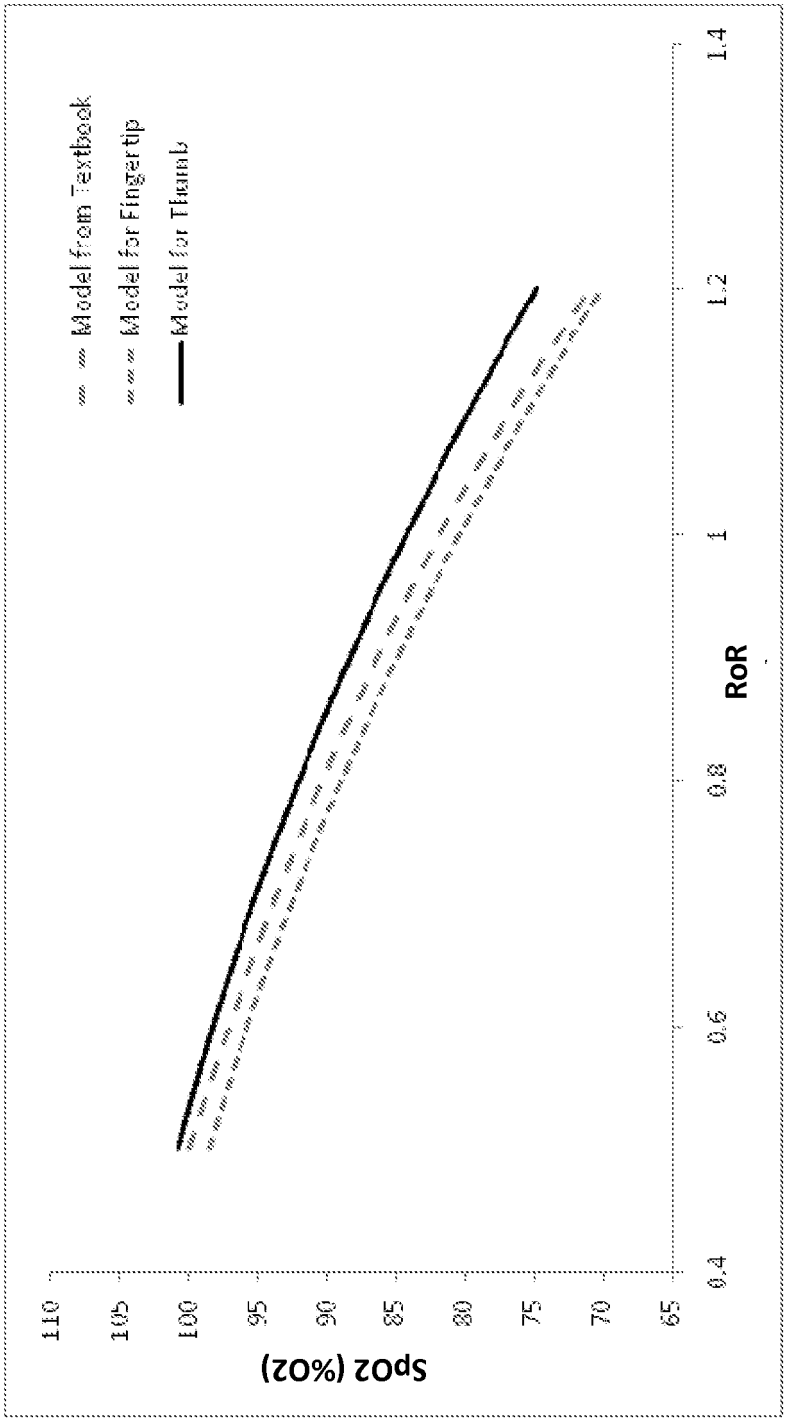

Model from Textbook
Model for Fingertip
Model for Thumb
SpO2 (%O2)
110
105
100
95
90
85
80
75
70
65
0.4
0.6
0.8
1
1.2
1.4
RoR

Fig. 4

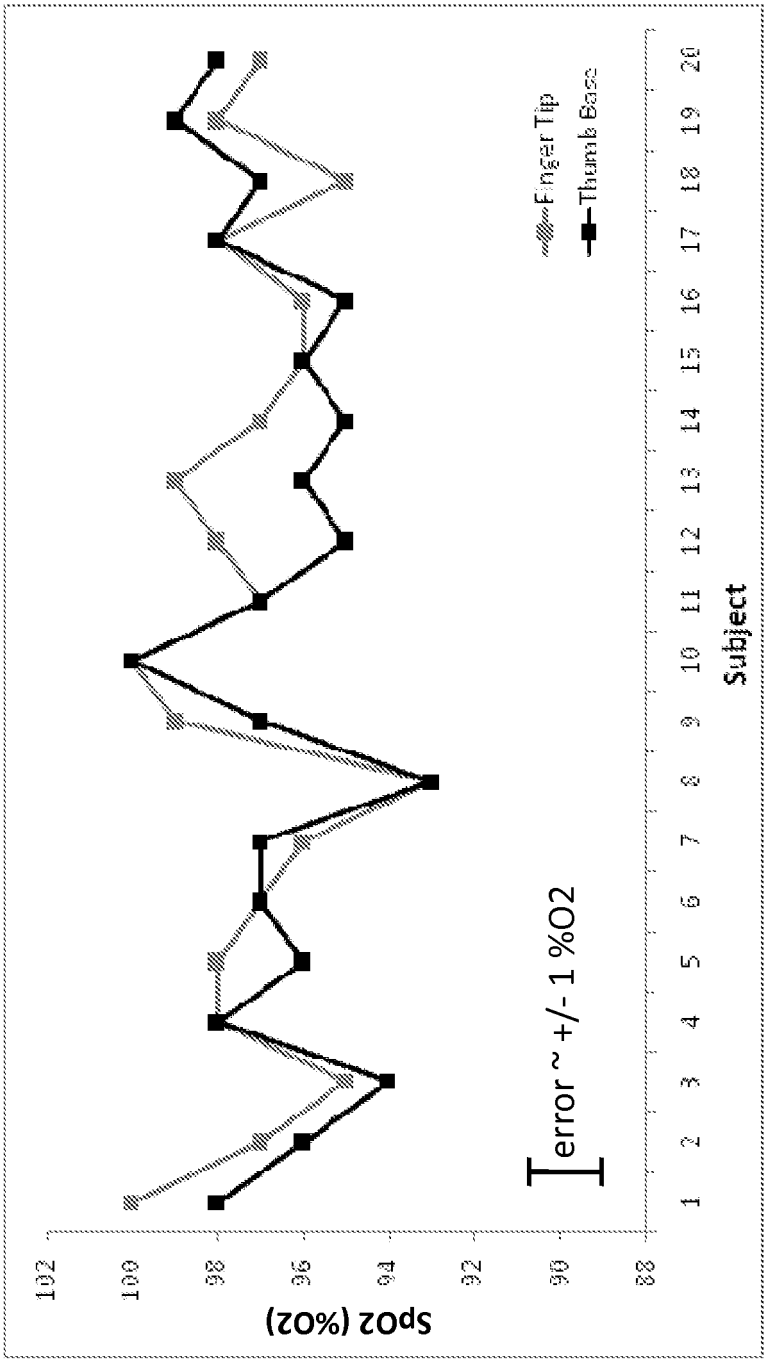

SpO2 (%O2)
102
100
98
96
94
92
90
88
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Subject
Finger Tip
Thumb Base
error ~ +/- 1 %O2

Fig. 5

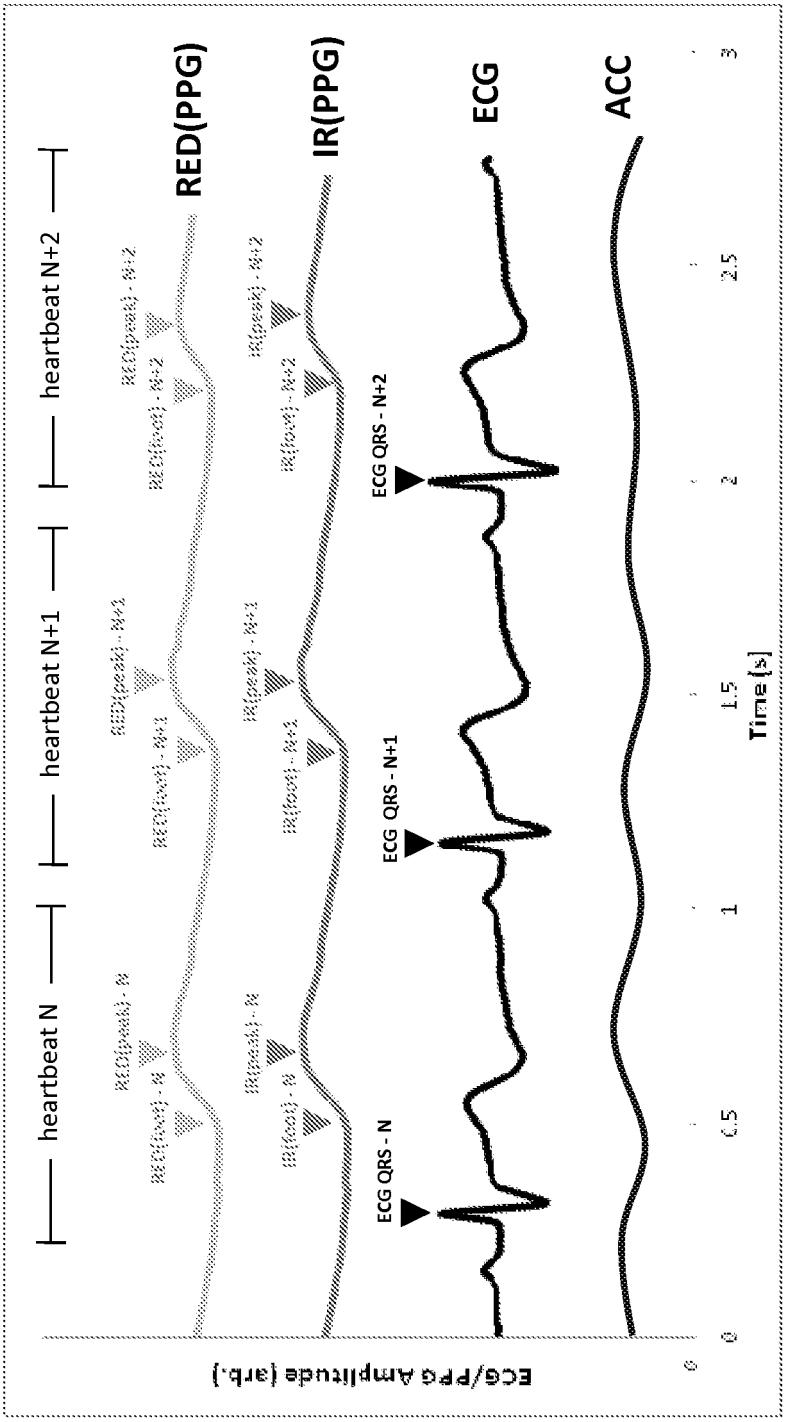
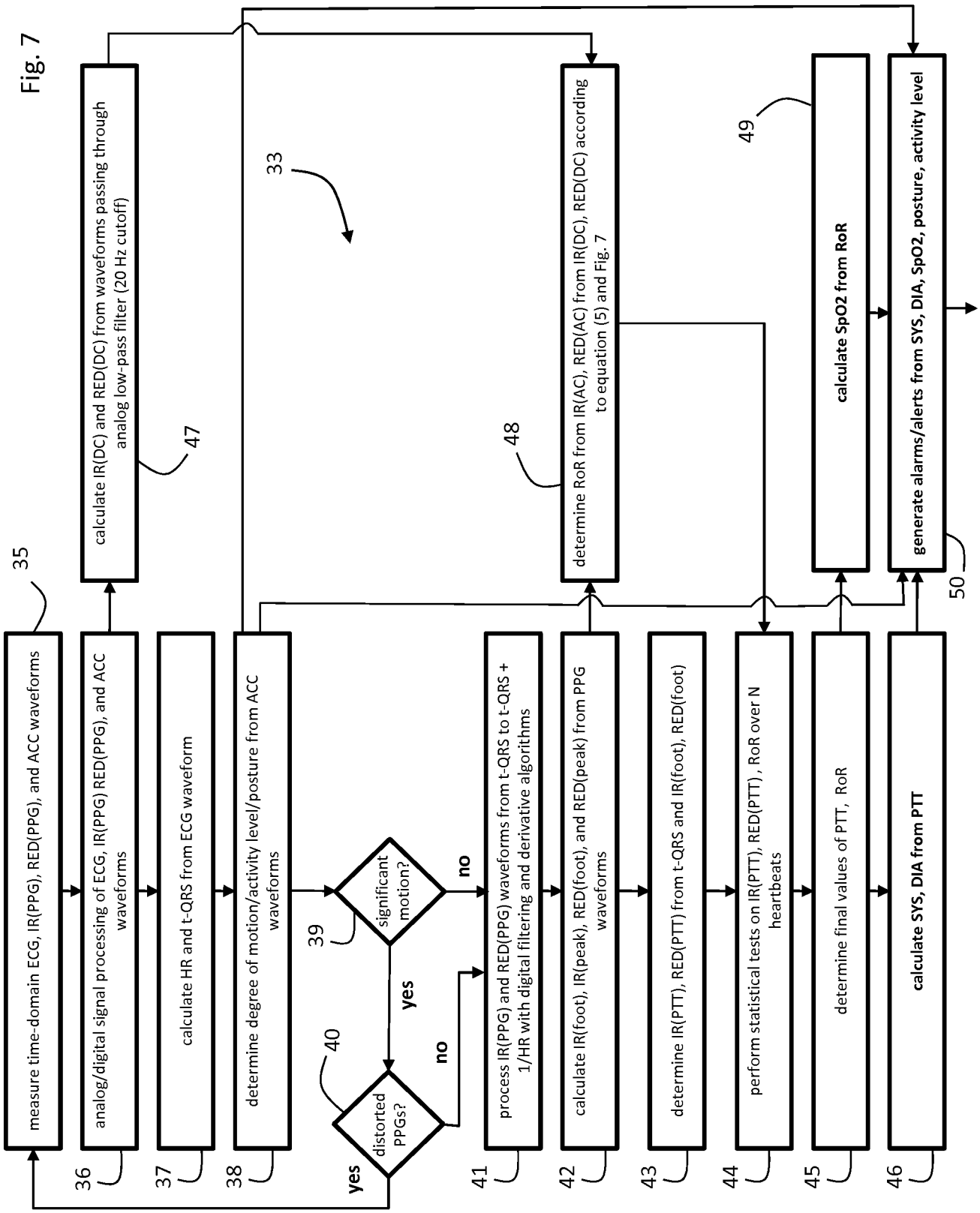

heartbeat N
heartbeat N+1
heartbeat N+2
RED(PPG)
IR(PPG)
ECG
ACC
ECG QRS - N
ECG QRS - N+1
ECG QRS - N+2
ECG/PPG Amplitude (arb.)
Time (s)
0
0.5
1
1.5
2
2.5
3

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

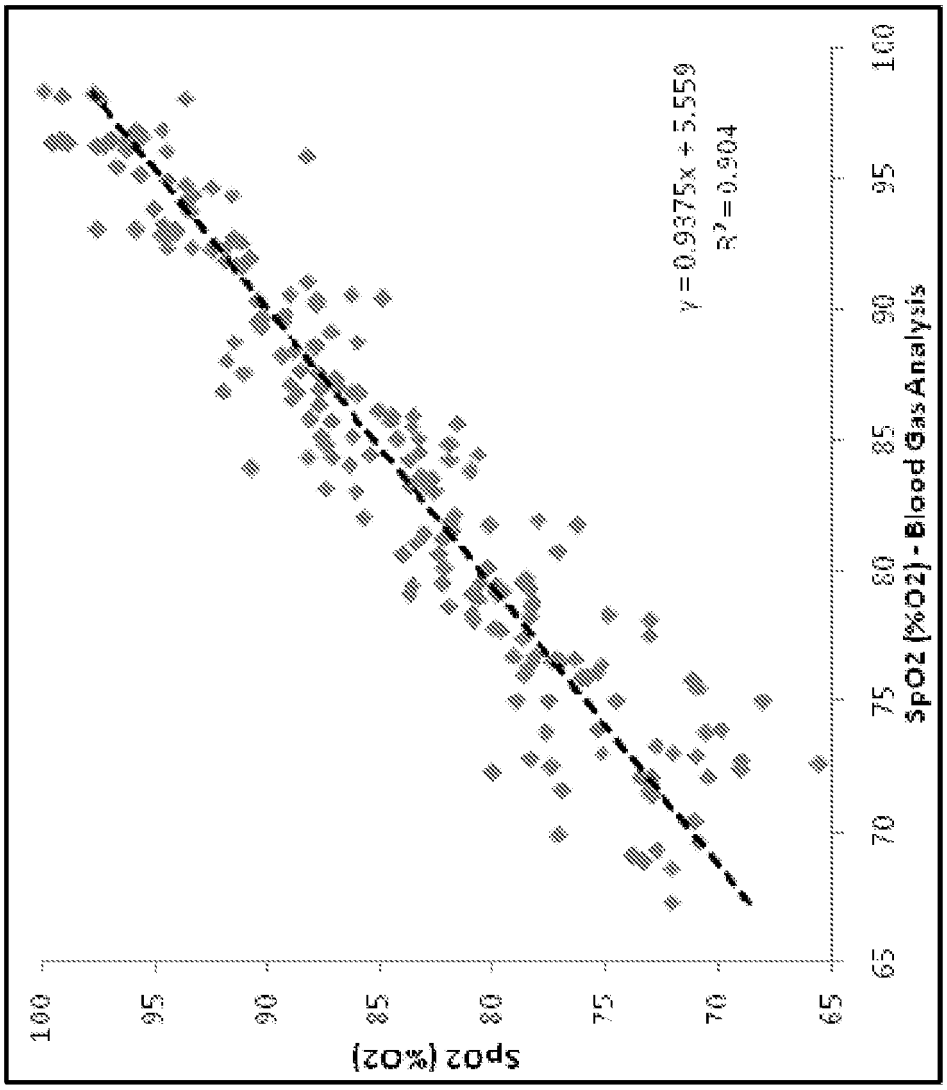

SpO2 (%O2)
100
95
90
85
80
75
70
65
65
70
75
80
85
90
95
100
SpO2 (%O2) - Blood Gas Analysis
y = 0.9375x + 5.559
R² = 0.904

Fig. 8

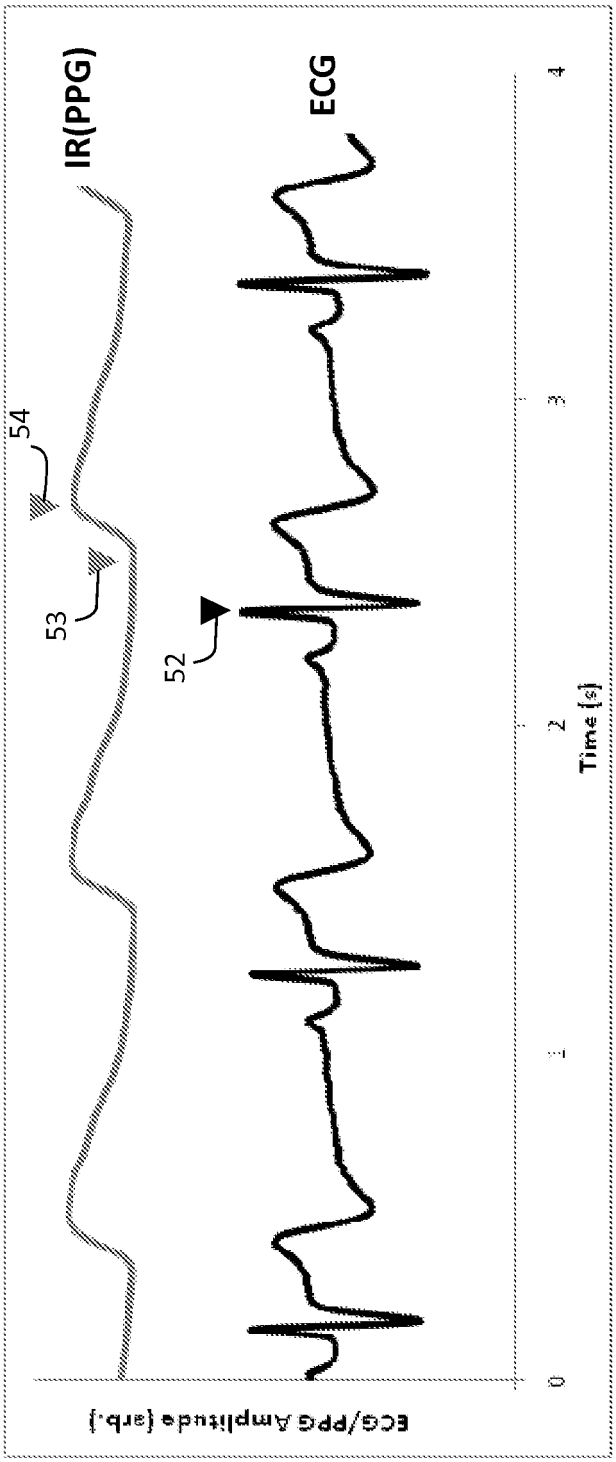

IR(PPG)
ECG
54
53
52
ECG/PPG Amplitude (arb.)
0
1
2
3
4
Time (s)

Fig. 9A

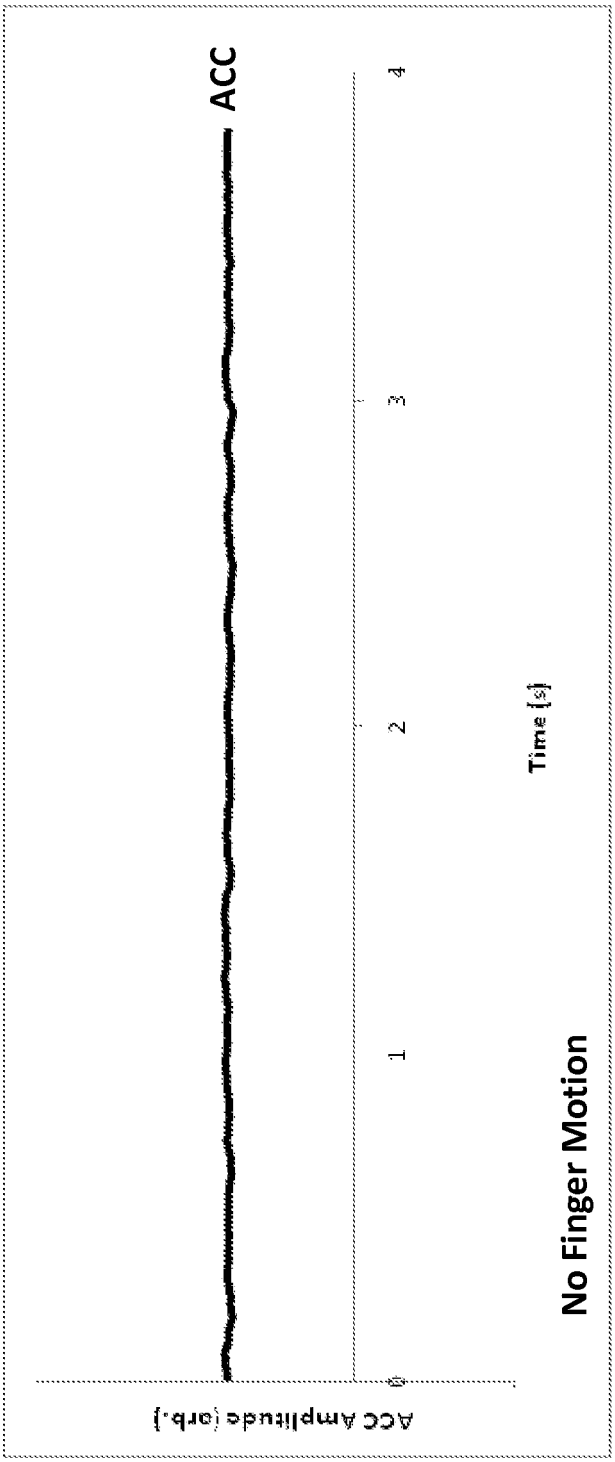

ACC
ACC Amplitude (arb.)
0
1
2
3
4
Time (s)
No Finger Motion

Fig. 9B

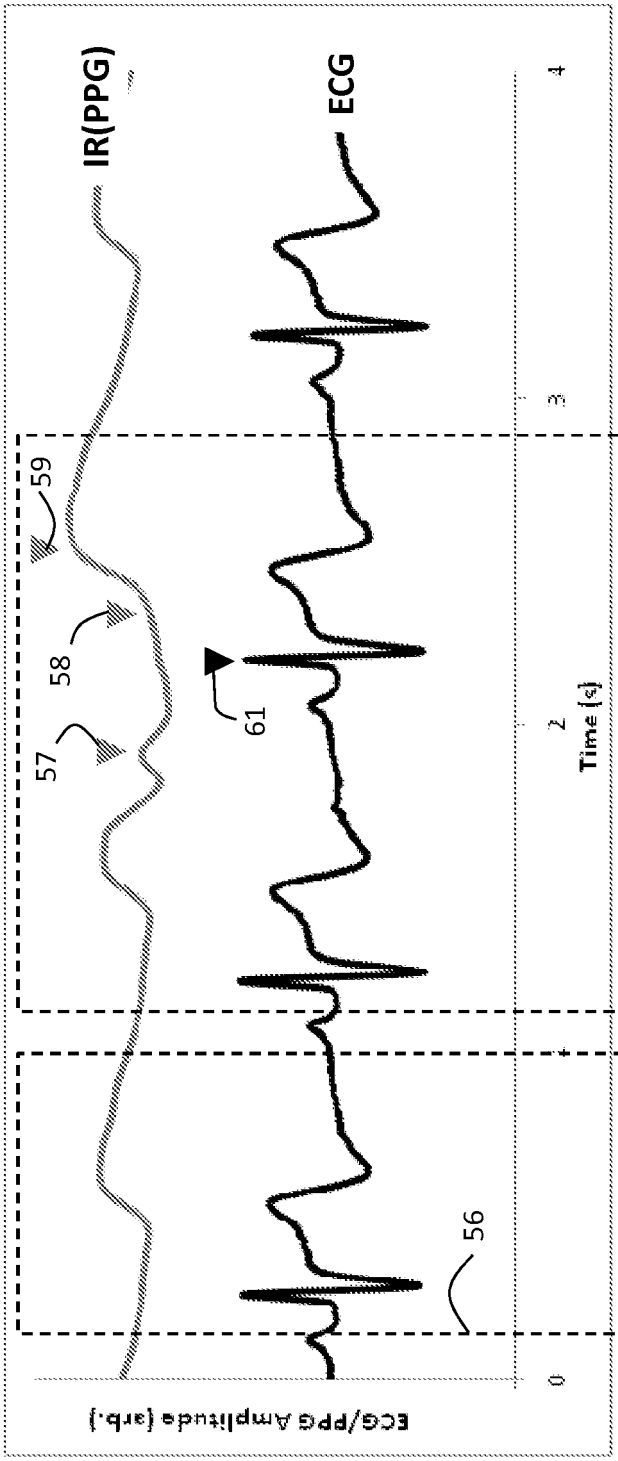


Fig. 10A

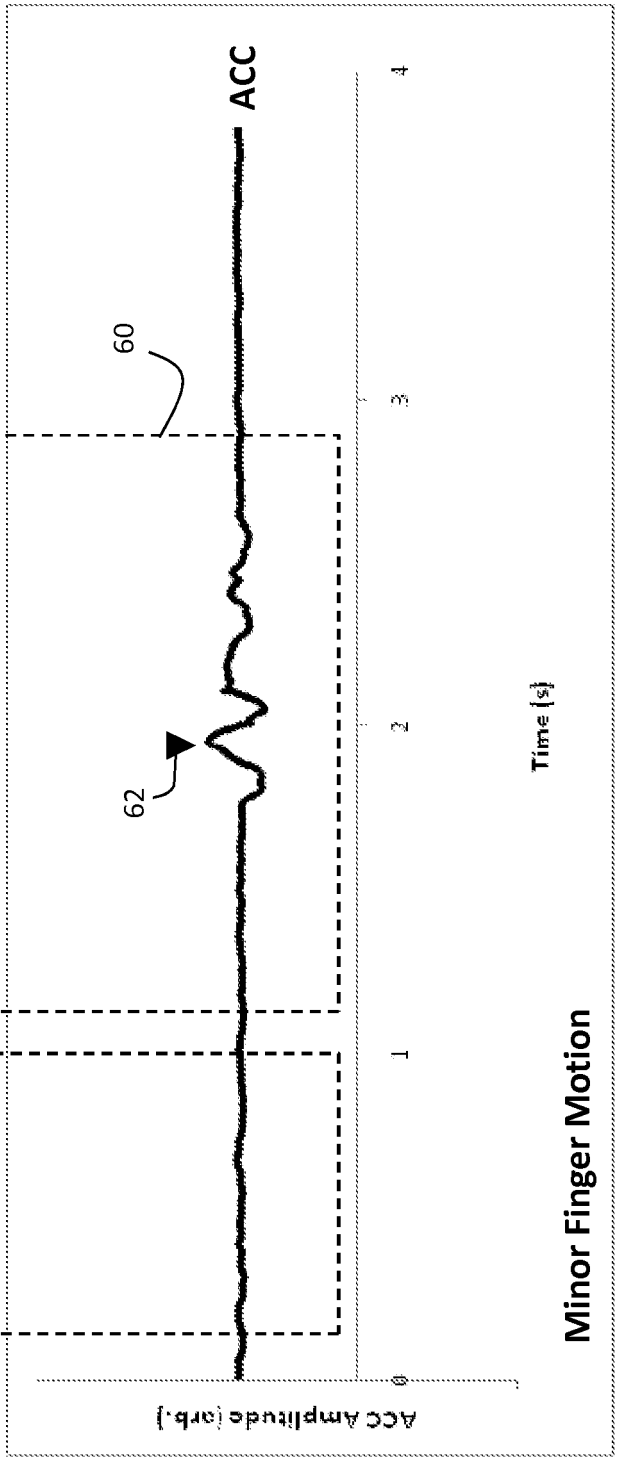


Fig. 10B

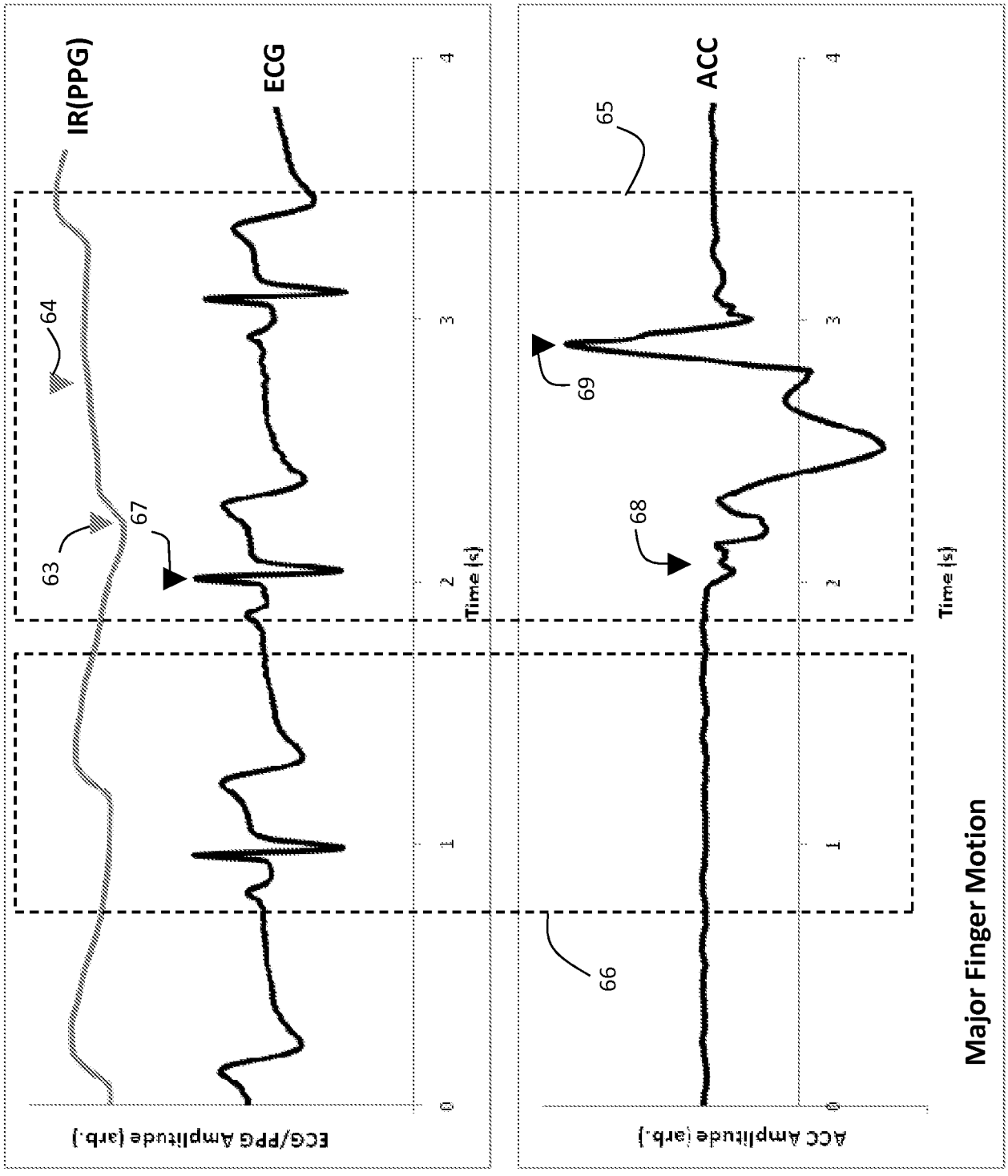


Fig. 11A

Fig. 11B

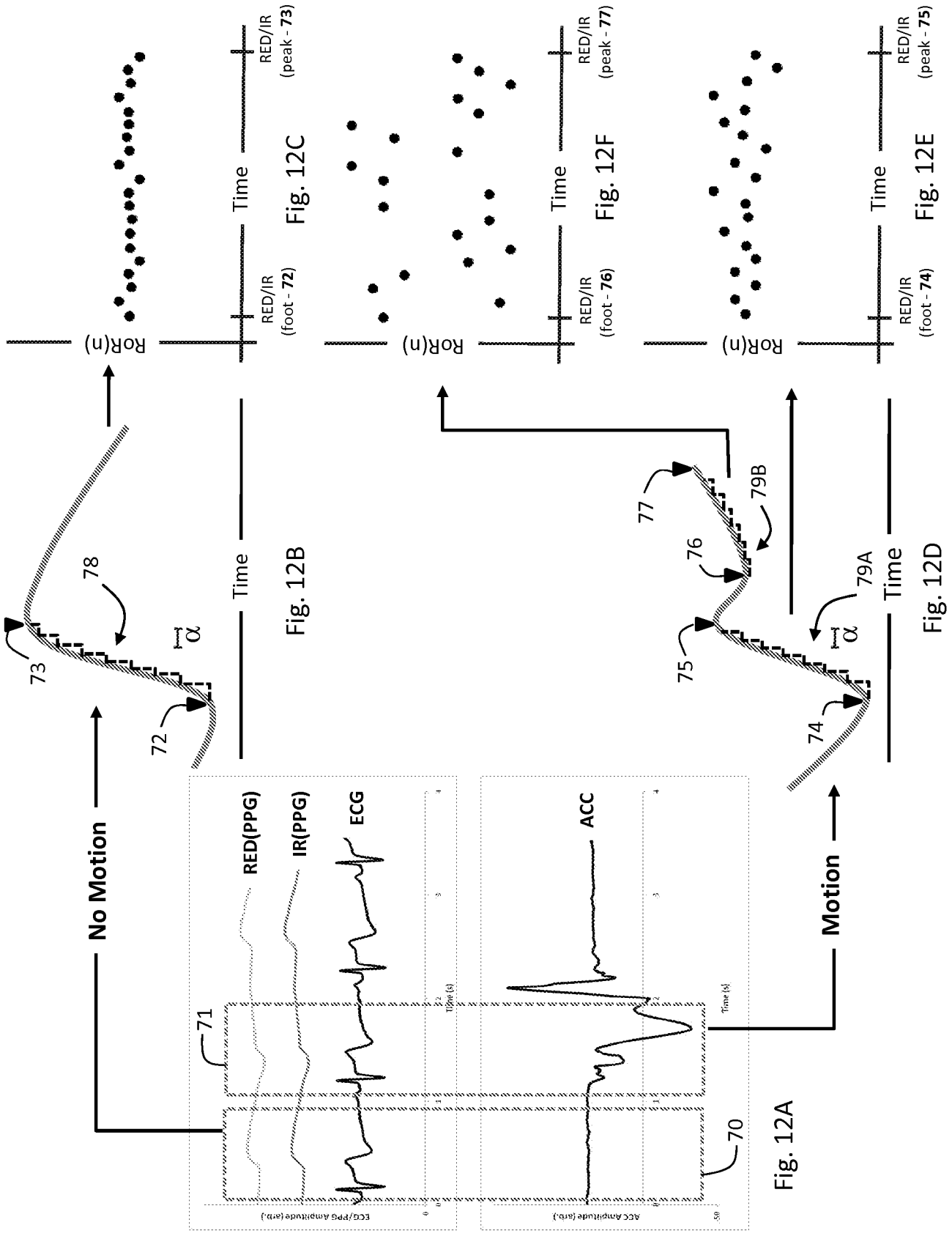


Fig. 12A

Fig. 12B

Fig. 12C

Fig. 12D

Fig. 12E

Fig. 12F

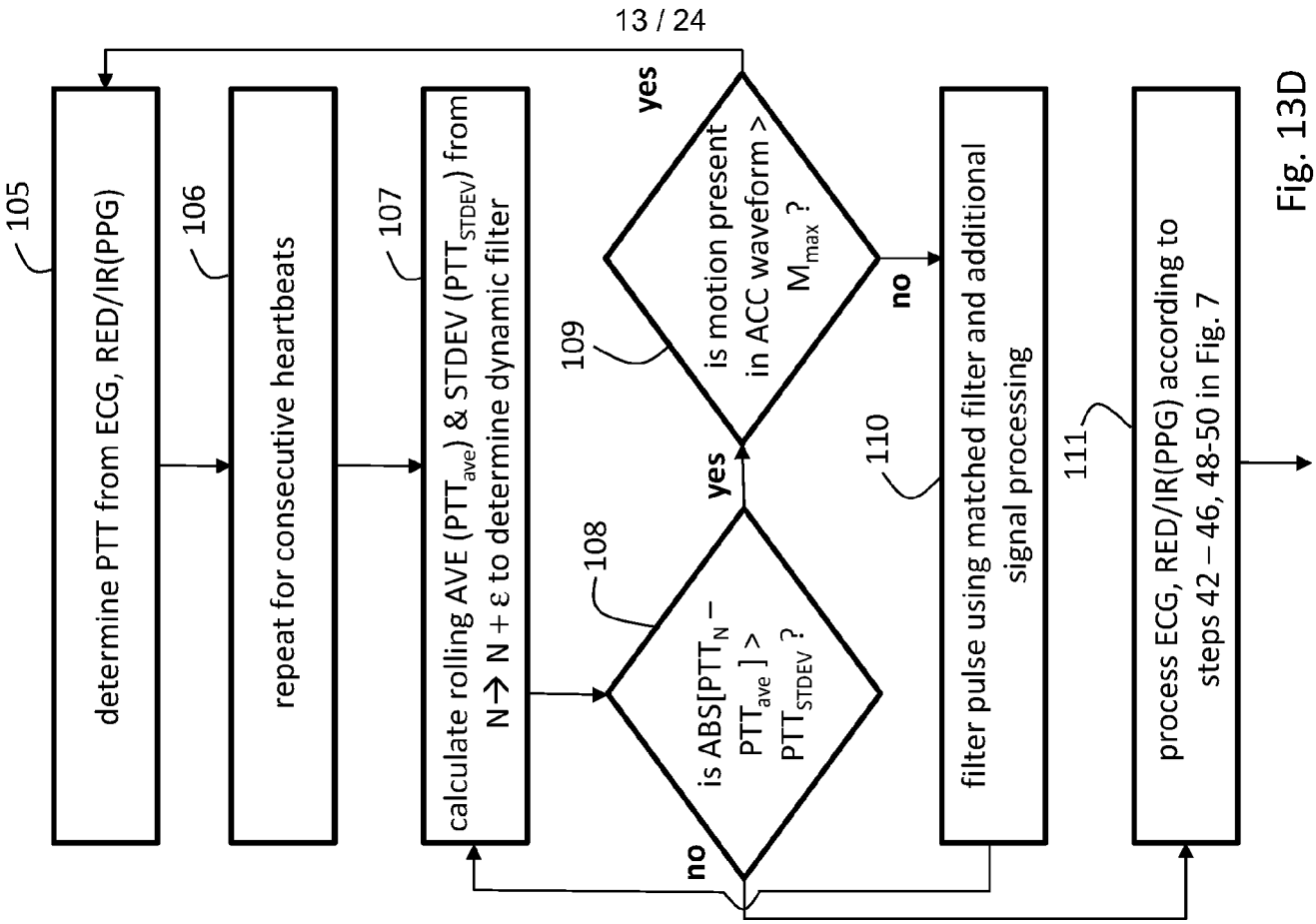


Fig. 13D

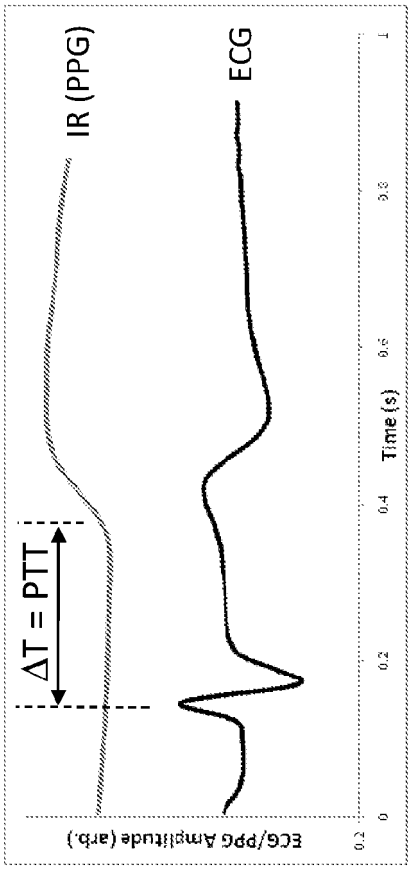


Fig. 13A

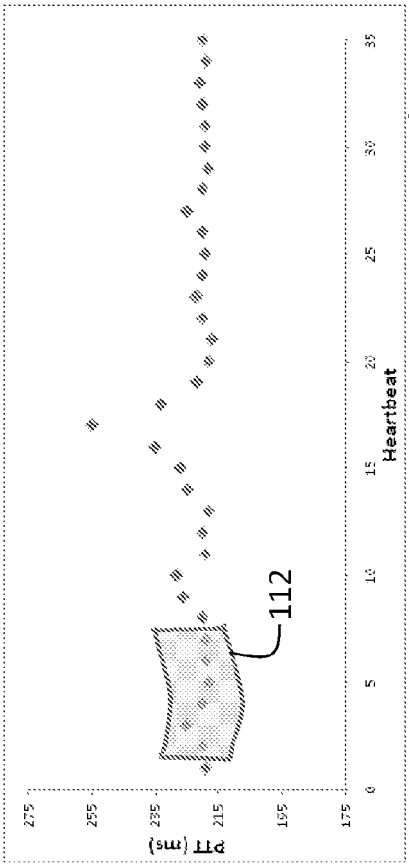


Fig. 13B

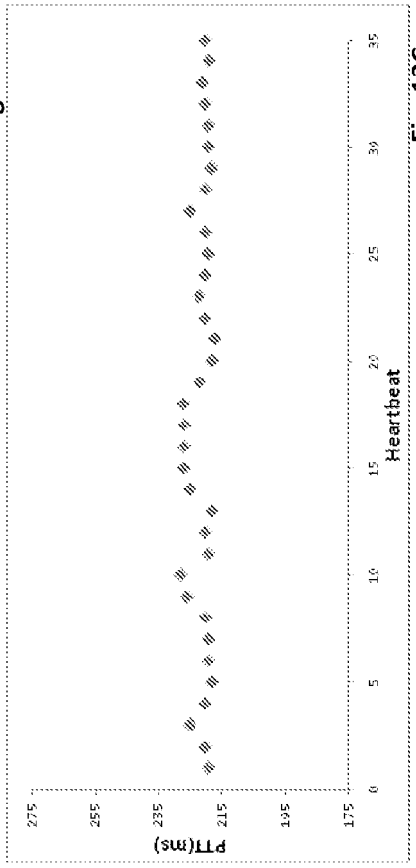


Fig. 13C

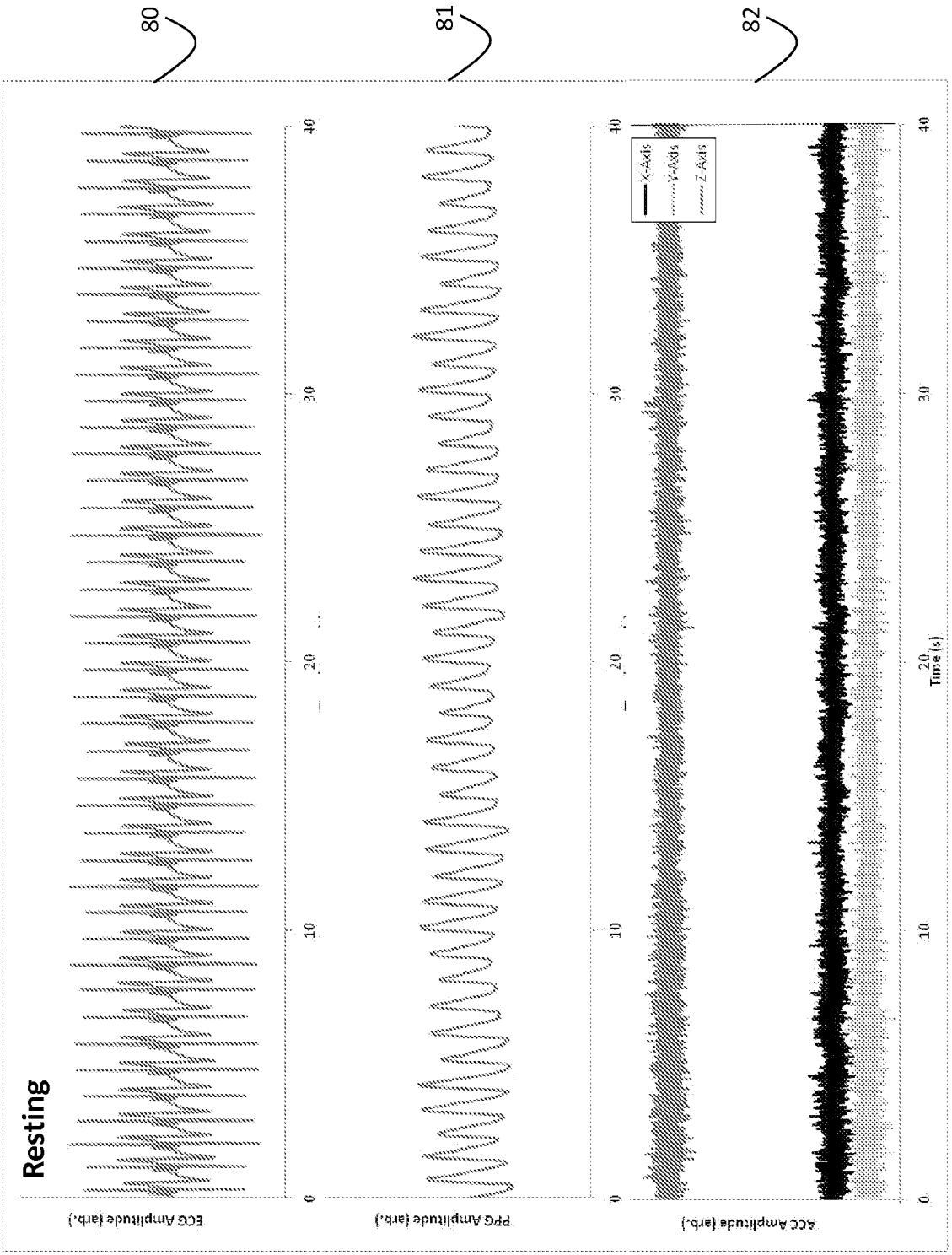

80
81
82
Resting
ECG Amplitude (arb.)
PPG Amplitude (arb.)
ACC Amplitude (arb.)
X-Axis
Y-Axis
Z-Axis
Time (s)
0
10
20
30
40

Fig. 14

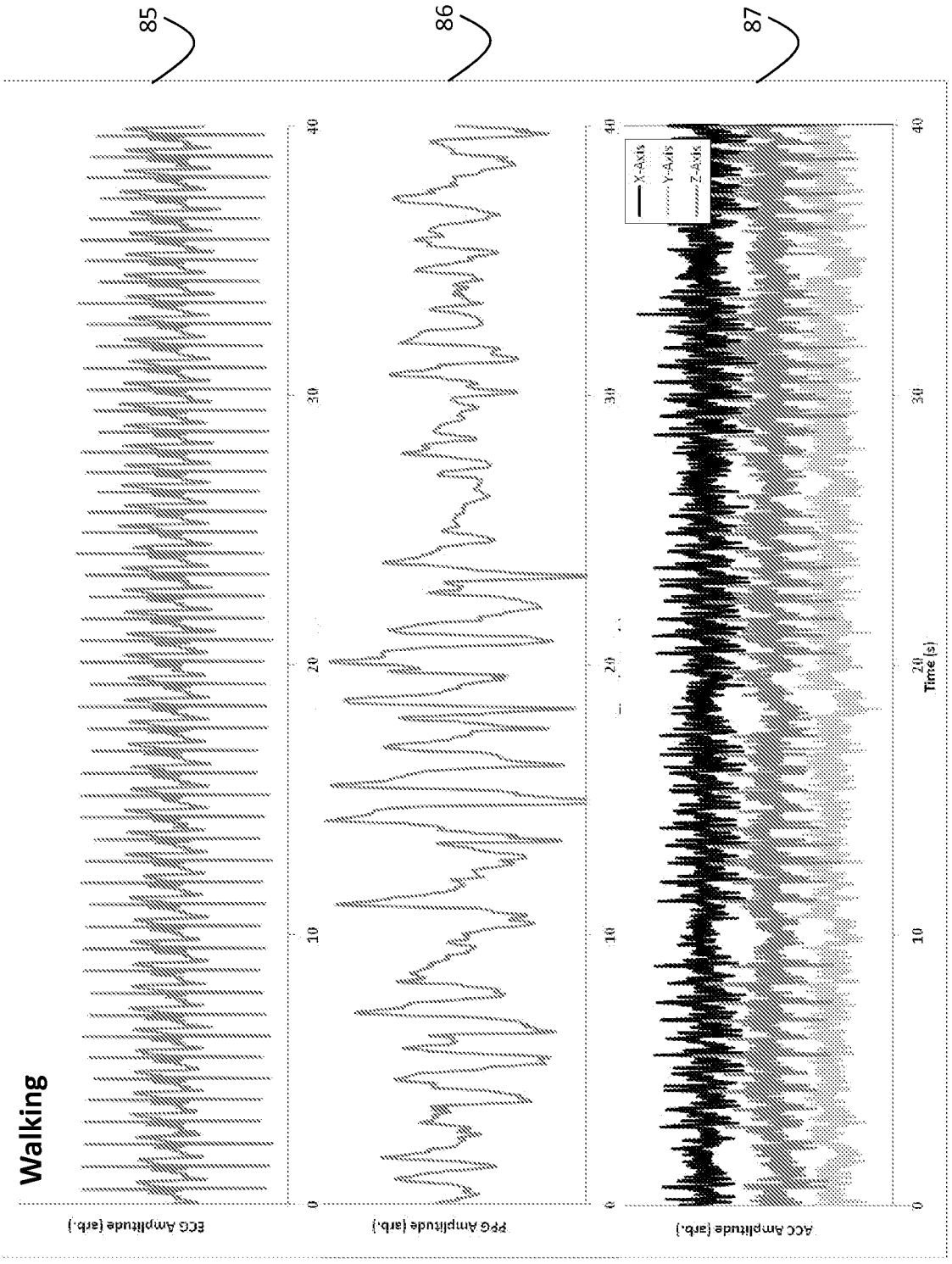

85
86
87
Walking
ECG Amplitude (arb.)
PPG Amplitude (arb.)
ACC Amplitude (arb.)
X-Axis
Y-Axis
Z-Axis
Time (s)
0
10
20
30
40

Fig. 15

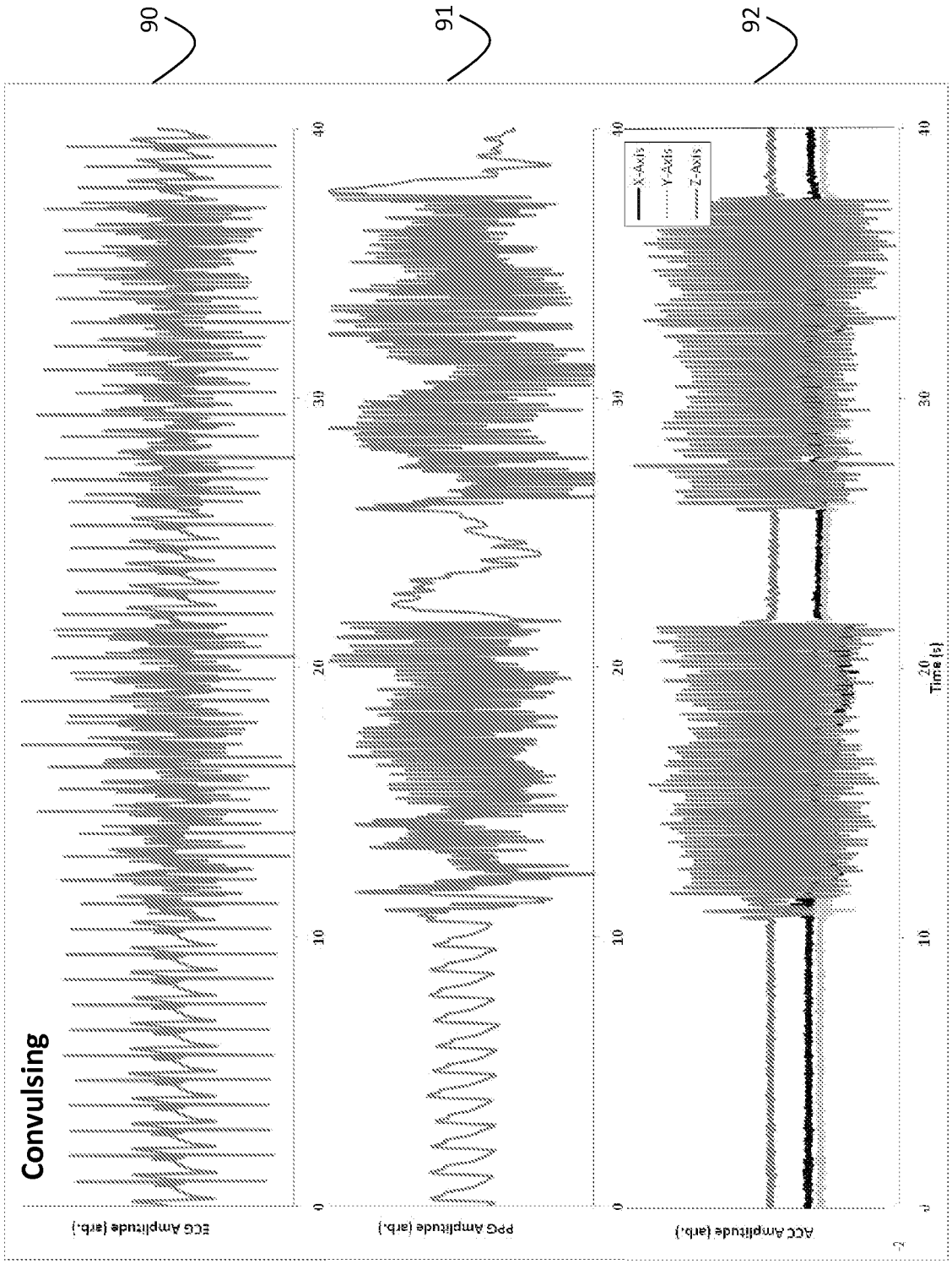

90
91
92
Convulsing
ECG Amplitude (arb.)
PPG Amplitude (arb.)
ACC Amplitude (arb.)
X-Axis
Y-Axis
Z-Axis
Time (s)

Fig. 16

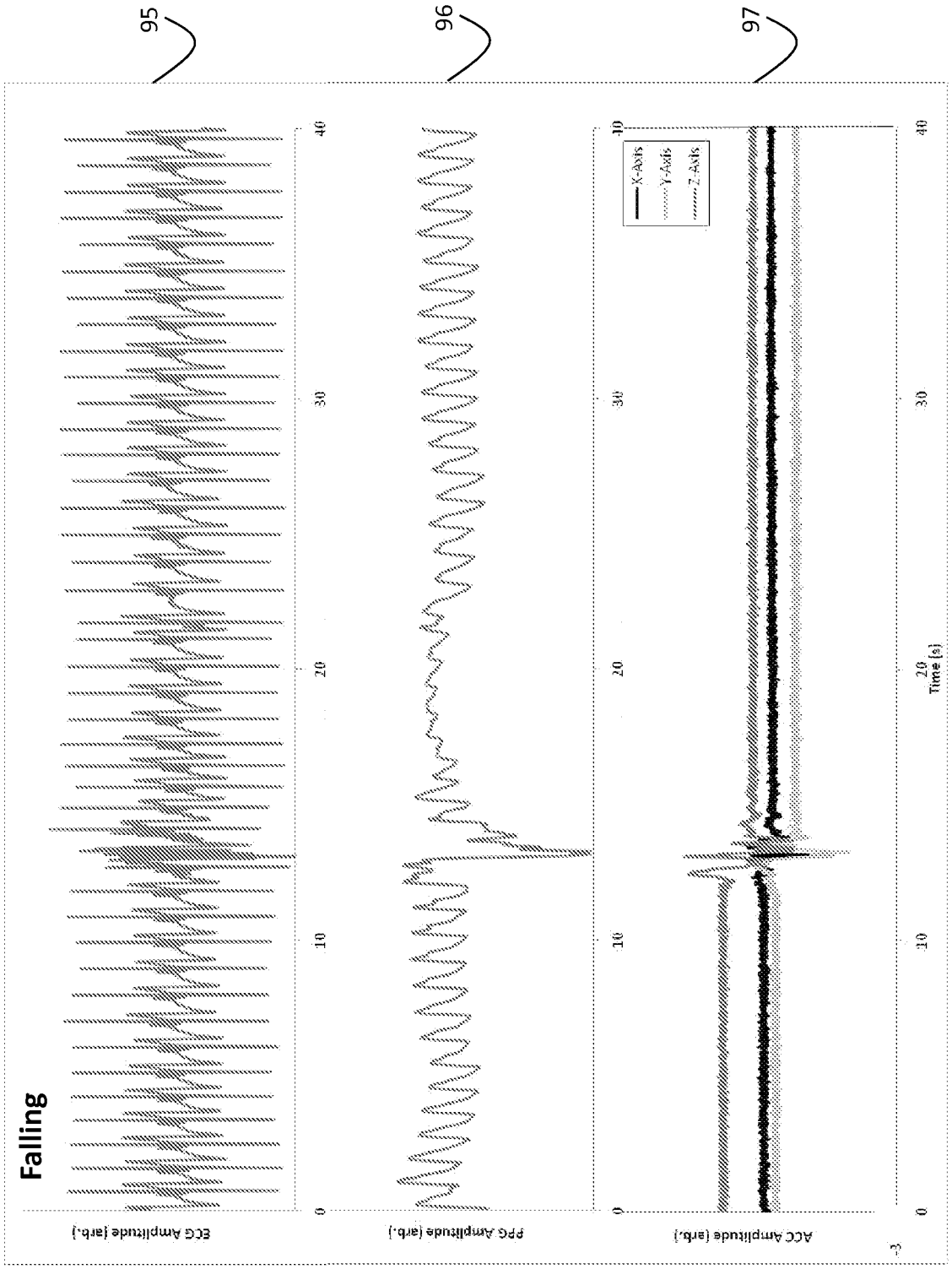

95
96
97
Falling
ECG Amplitude (arb.)
PPG Amplitude (arb.)
ACC Amplitude (arb.)
X-Axis
Y-Axis
Z-Axis
Time (s)

Fig. 17

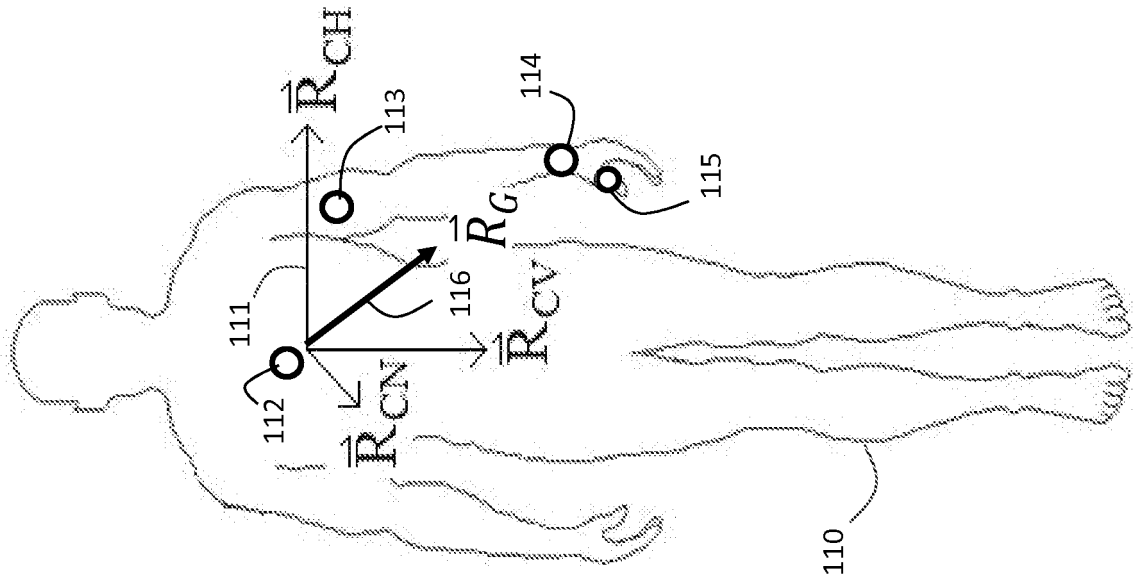


Fig. 18

Fig. 19A

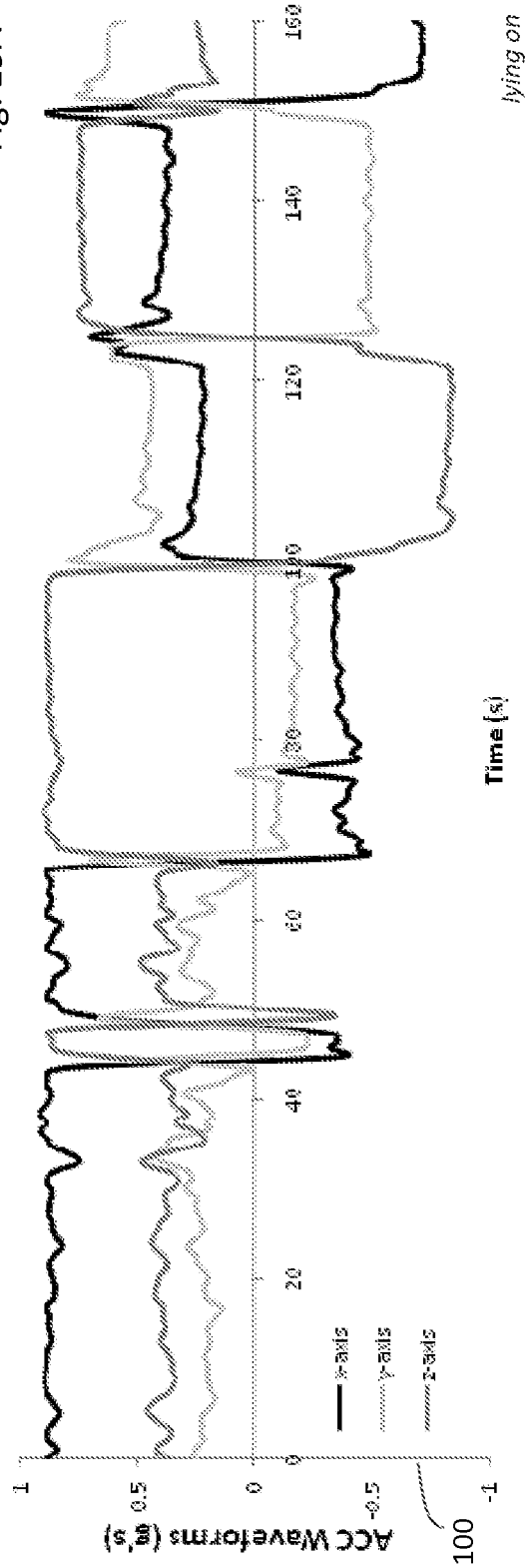
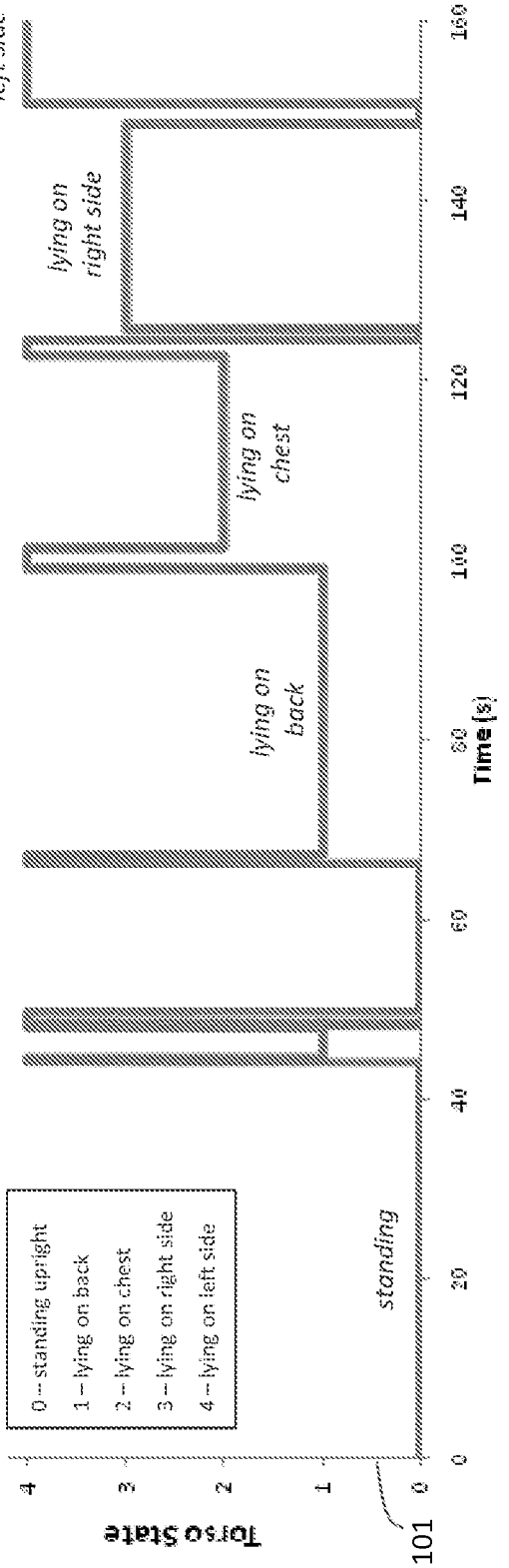


Fig. 19B



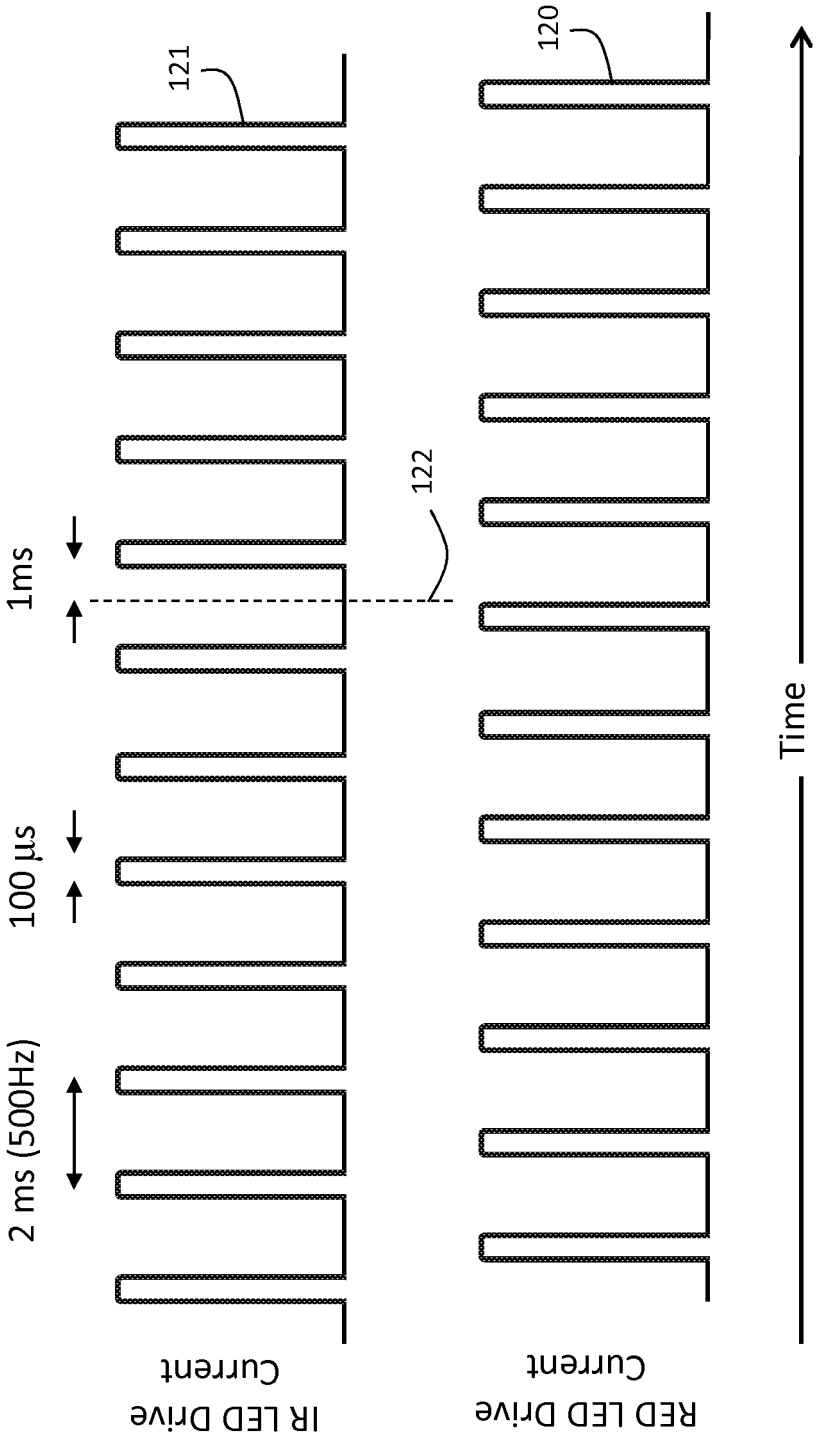

IR LED Drive Current
RED LED Drive Current
Time
121
120
122
1ms
100 µs
2 ms (500Hz)

Fig. 20

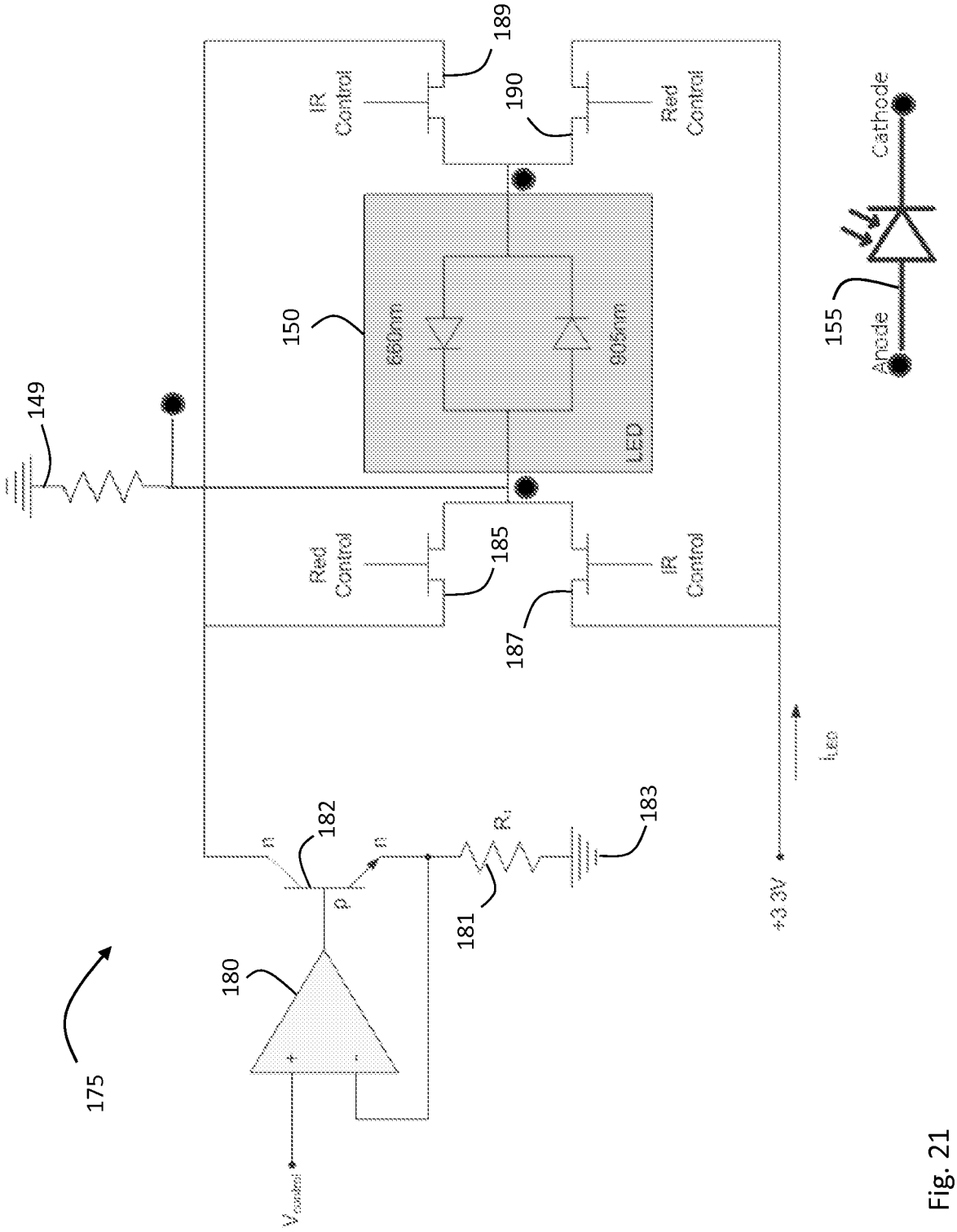

189
IR Control
190
Red Control
150
660nm
905nm
LED
Cathode
155
Anode
149
Red Control
185
IR Control
187
i_{LED}
+3.3V
182
n
n
p
R_1
183
181
180
175
$V_{control}$

Fig. 21

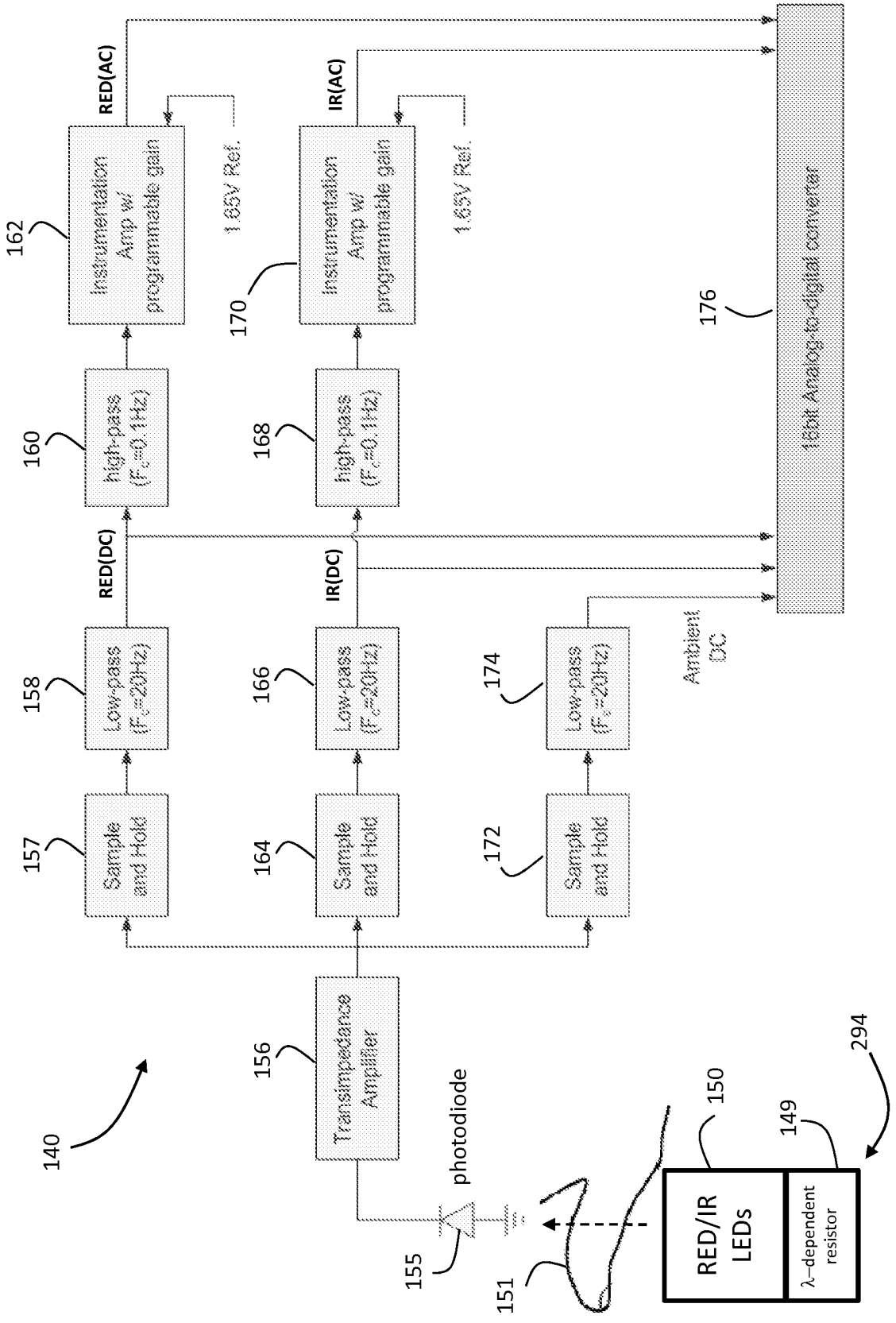

140
156
Transimpedance Amplifier
155
photodiode
151
150
RED/IR LEDs
149
λ–dependent resistor
294
157
Sample and Hold
158
Low-pass (F_c=20Hz)
RED(DC)
160
high-pass (F_c=0.1Hz)
162
Instrumentation Amp w/ programmable gain
1.65V Ref.
RED(AC)
164
Sample and Hold
166
Low-pass (F_c=20Hz)
IR(DC)
168
high-pass (F_c=0.1Hz)
170
Instrumentation Amp w/ programmable gain
1.65V Ref.
IR(AC)
172
Sample and Hold
174
Low-pass (F_c=20Hz)
Ambient DC
176
18bit Analog-to-digital converter

Fig. 22

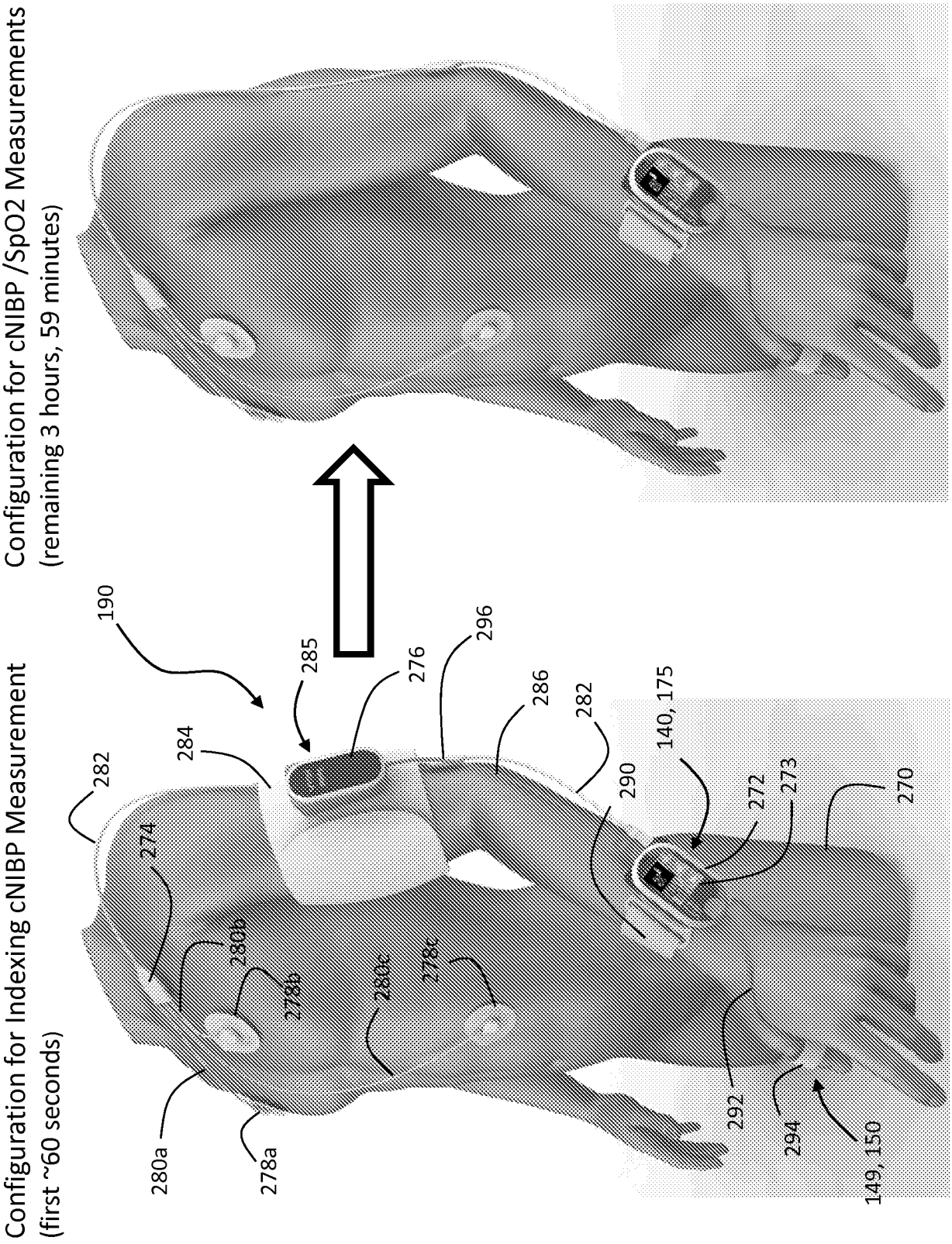


Fig. 23B

Fig. 23A

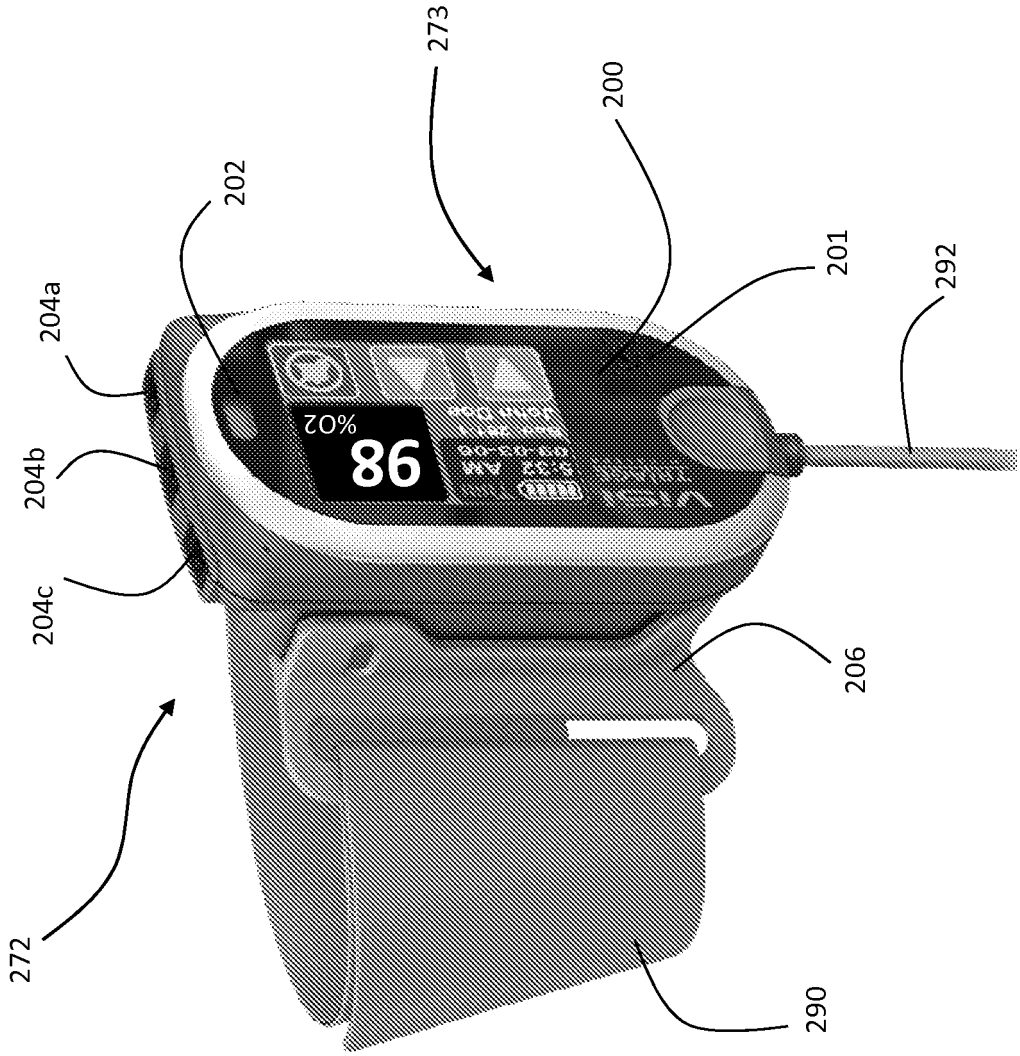


Fig. 24