

(12) **United States Patent**
Deno et al.

(10) **Patent No.:** US 6,738,667 B2
(45) **Date of Patent:** May 18, 2004

(54) **IMPLANTABLE MEDICAL DEVICE FOR TREATING CARDIAC MECHANICAL DYSFUNCTION BY ELECTRICAL STIMULATION**

(75) Inventors: **D. Curtis Deno**, Andover, MN (US); **Lawrence J. Mulligan**, Andover, MN (US); **Tom D. Bennett**, Shoreview, MN (US); **David A. Igel**, Lino Lakes, MN (US); **Michael R. S. Hill**, Minneapolis, MN (US); **Richard J. Shaw**, St. Francis, MN (US)

(73) Assignee: **Medtronic, Inc.**, Minneapolis, MN (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 568 days.

(21) Appl. No.: **09/750,631**

(22) Filed: **Dec. 28, 2000**

(65) **Prior Publication Data**

US 2003/0074029 A1 Apr. 17, 2003

(51) **Int. Cl.**⁷ **A61N 1/18**

(52) **U.S. Cl.** **607/23**

(58) **Field of Search** 607/23, 18, 17, 607/9

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,857,399	A	12/1974	Zacouto	
3,939,844	A	2/1976	Pequignot	
4,541,417	A	9/1985	Krikorian	128/1 D
4,554,922	A	11/1985	Prystowsky et al.	128/419 PG
4,674,518	A	6/1987	Salo	128/695

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

FR	2790967	10/2000	A61N/1/368
WO	97/25098	7/1997	A61N/1/00

WO	WO 98/02209	1/1998	A61N/1/375
WO	WO 00/04947	3/2000		

OTHER PUBLICATIONS

Cooper, M., "Postextrasystolic Potentiation: Do We Really Know What It Means and How to Use It?," *Circulation*, vol. 88, No. 6, p. 2962-2971 (Dec. 1993).

(List continued on next page.)

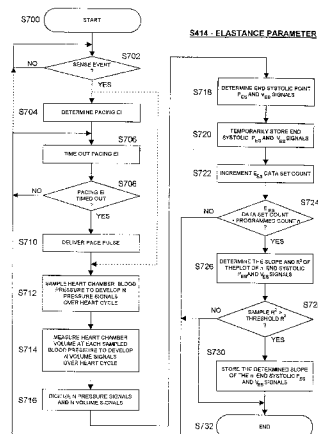
Primary Examiner—Mark Bockelman

(74) *Attorney, Agent, or Firm*—Girma Wolde-Michael; Michael C. Soldner; Paul H. McDowall

(57) **ABSTRACT**

An implantable stimulator and monitor measures a group of heart failure parameters indicative of the state of heart failure employing EGM signals, measures of blood pressure including absolute pressure P, developed pressure (DP=systolic P-diastolic P), and/or dP/dt, and measures of heart chamber volume (V) over one or more cardiac cycles. These parameters include: (1) relaxation or contraction time constant tau (τ); (2) mechanical restitution (MR), i.e., the mechanical response of a heart chamber to premature stimuli applied to the heart chamber; (3) recirculation fraction (RF), i.e., the rate of decay of PESP effects over a series of heart cycles; and (4) end systolic elastance (E_{ES}), i.e., the ratios of end systolic blood pressure P to volume V. These heart failure parameters are determined periodically regardless of patient posture and activity level. The physician can determine whether a particular therapy is appropriate, prescribe the therapy for a period of time while again accumulating the stored patient data for a later review and assessment to determine whether the applied therapy is beneficial or not, thereby enabling periodic changes in therapy, if appropriate. Drug therapies and electrical stimulation therapies, including PESP stimulation, and pacing therapies including single chamber, dual chamber and multi-chamber (bi-atrial and/or bi-ventricular) pacing can be delivered. In patient's prone to malignant tachyarrhythmias, the assessment of heart failure state can be taken into account in setting parameters of detection or classification of tachyarrhythmias and the therapies that are delivered.

8 Claims, 21 Drawing Sheets



U.S. PATENT DOCUMENTS

5,024,222 A	6/1991	Thacker	128/419 PG
5,213,098 A	5/1993	Bennett et al.	128/419 PG
5,328,442 A	7/1994	Levine	600/17
5,331,966 A	7/1994	Bennett et al.	128/696
5,417,717 A	5/1995	Salo et al.	607/18
5,564,434 A	10/1996	Halperin et al.	128/748
5,626,623 A	5/1997	Kieval et al.	607/23
5,800,464 A	9/1998	Kieval	607/9
6,021,345 A	2/2000	Karagueuzian et al.	600/518
6,090,047 A	7/2000	Kass et al.	600/485
6,104,949 A	8/2000	Pitts Crick et al.	600/547
6,141,586 A	10/2000	Mower	607/9

OTHER PUBLICATIONS

Dell'Italia, Louis, "Mechanism of Postextrasystolic Potentiation in the Right Ventricle," *Amer. Jour. Of Cardiol.*, vol. 65, p. 736-741 (Mar. 15, 1990).

Franz et al., "Electrical and Mechanical Restitution of the Human Heart at Different Rates of Stimulation," *Circulation Research*, vol. 53, No. 6, p. 815-822 (Dec. 1983).

Freeman et al., "Evaluation of Left Ventricular Mechanical Restitution in Closed-chest Dogs Based on Single-Beat Elastance," *Circulation Research*, vol. 67, No. 6, p. 1437-1445 (Dec. 1990).

Geschwind et al., "Sympathetic Nervous System Activation in Postextrasystolic Potentiation: Role of Catecholamine Release in Enhancement of Ventricular Function," *JACC*, vol. 4, No. 2, p. 215-225 (Aug. 1984).

Juggi et al., "Intracellular Kinetics of the Activator Calcium of Rat Heart after Ischemic Arrest and Cardioplegia: Quantitative Comparison of Right and Left Ventricles," *Can. J. Cardiol.*, vol. 8, No. 4, p. 387-395 (May 1992).

Kuijter et al., "Post-Extrasystolic Potentiation Without a Compensatory Pause in Normal and Diseased Hearts," Abstract (accepted for publication Dec. 20, 1989).

Mesaeri et al., "Mechanical Restitution and Post Extrasystolic Potentiation of Perfused Rat Heart: Quantitative Comparison of Normal Right and Left Ventricular Responses," *Can. J. Cardiol.*, vol. 8, No. 2, p. 164-172 (Mar. 1992).

Pidgeon, et al., "The Relationship Between the Strength of the Human Heart Beat and the Interval Between Beats," *Circulation*, vol. 65, No. 7, p. 1404-1410 (Jun. 1982).

Prabhu et al., "Effect of Tachycardia Heart Failure on the Restitution of Left Ventricular Function in Closed-Chest Dogs," *Circulation*, vol. 91, No. 1, p. 177-185 (Jan. 1, 1995).

Prabhu et al., "Kinetics of Restitution of Left Ventricular Relaxation," *Circulation Research*, vol. 70, No. 1, p. 29-38 (Jan. 1992).

ter Keurs et al., "Characterization of Decay of Frequency Induced Potentiation and Post-Extrasystolic Potentiation," *Cardiovascular Research*, vol. 24, p. 903-910 (1990).

van der Werf et al., "Postextrasystolic Potentiation in Man," *European Journal of Cardiology*, vol. 4/supplement, p. 131-141 (1976).

Wisnibaugh et al., "Mechanics of Postextrasystolic Potentiation in Normal Subjects and Patients With Valvular Heart Disease," *Circulation*, vol. 74, No. 1, p. 10-20 (Jul. 1986).

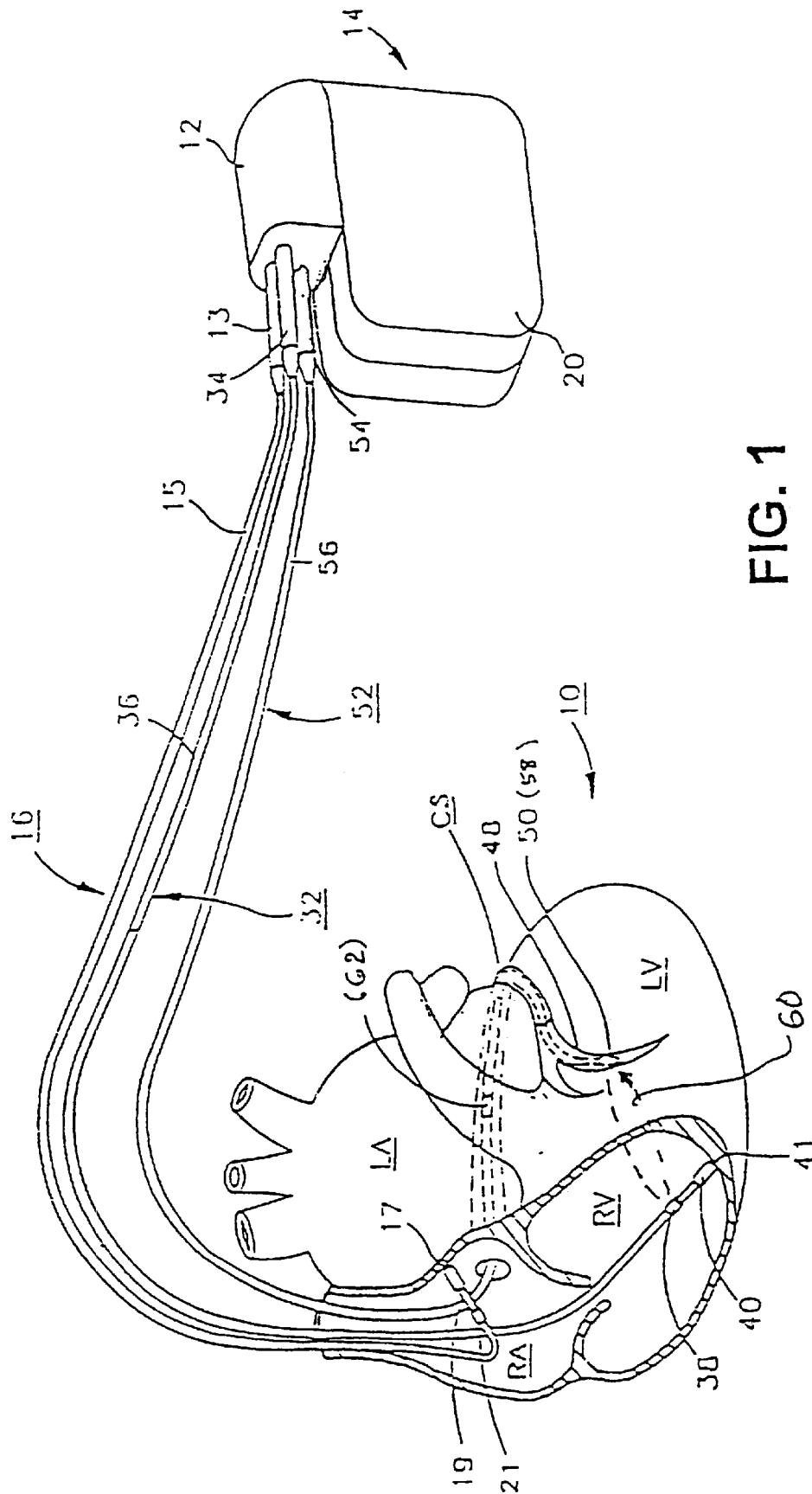


FIG. 1

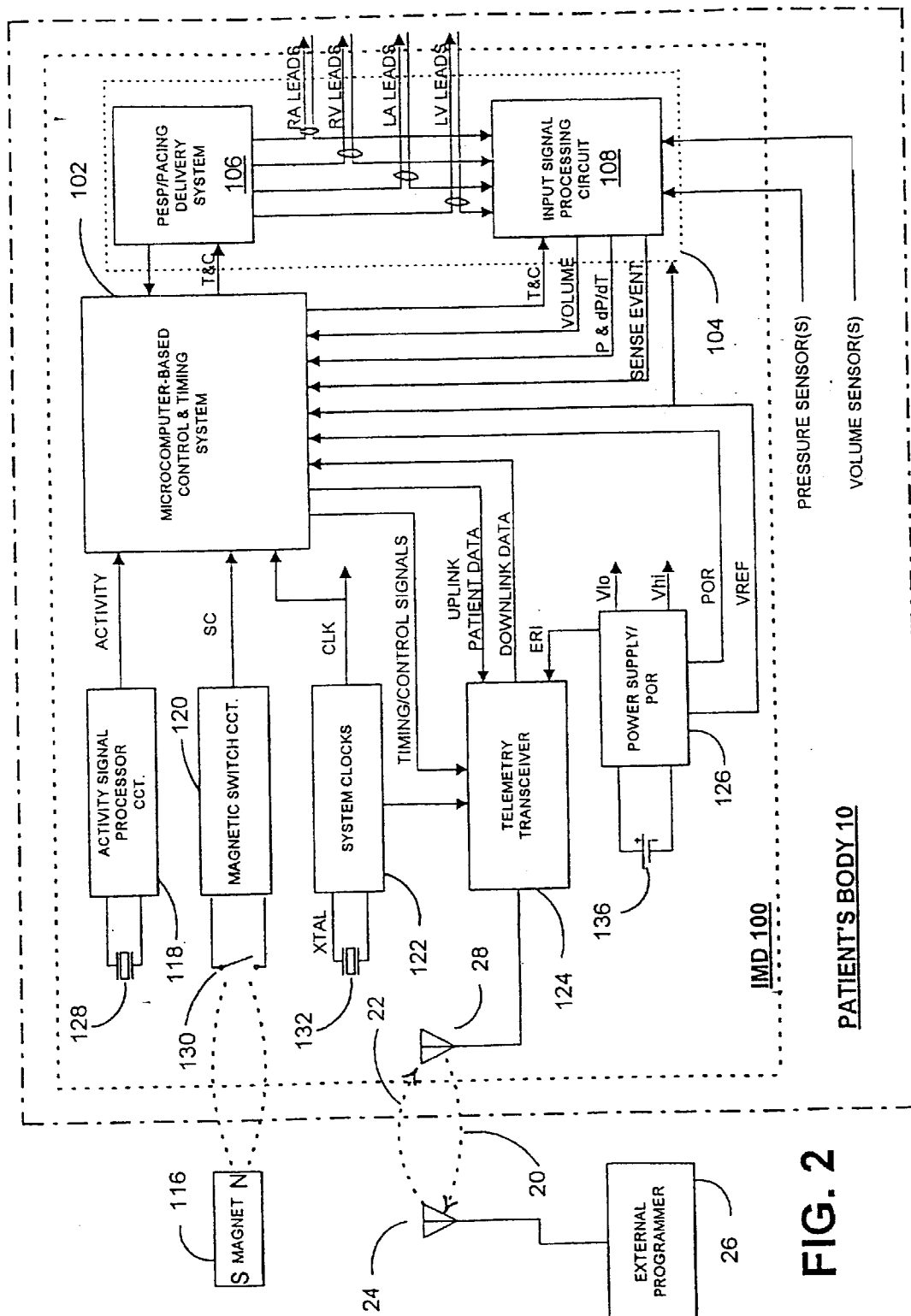


FIG. 2

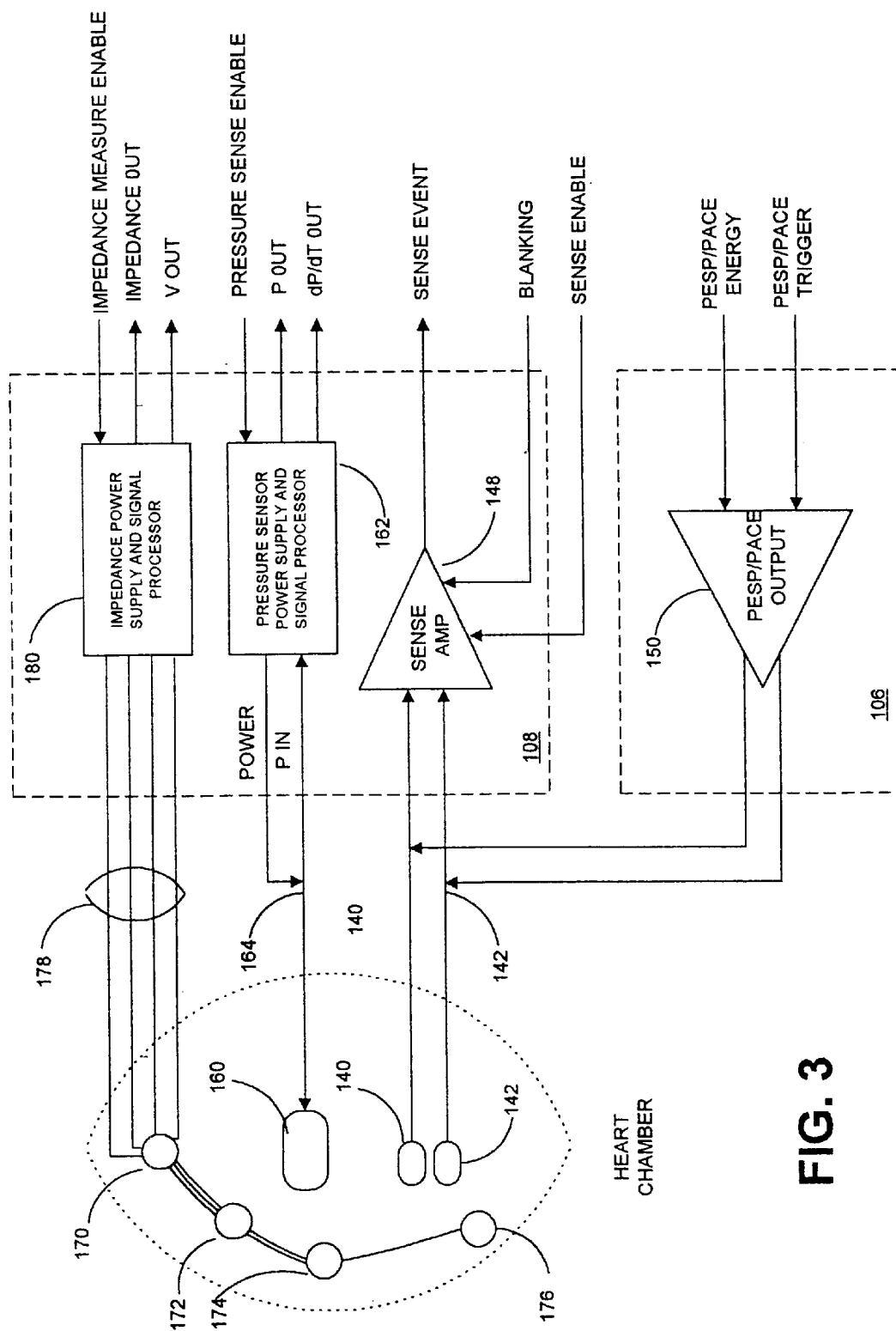


FIG. 3

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.