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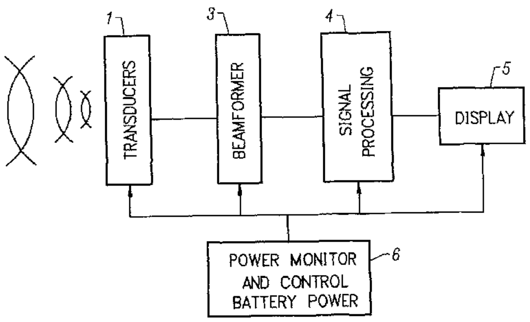
(54)【発明の名称】低電力携帯式超音波診断装置

(57)【要約】

アレイトランスジューサー（１）、ビームフォーマー（３）、信号処理画像化回路（４）、及び処理済みエコー信号用のディスプレイ（５）を含む携帯式超音波診断装置が、２５ワット以下の電力で作動する。回路機能は、装置の作動のモードに依存して、選択して設けることができ、これによって、電力消費を下げることができる。更に、電力モニター及び制御（６）がバッテリー電源からの電流をモニターすることができる。電力消費が所定のレベルに到達する時、電力モニター及び制御は、ディスプレイの作動モード、アナログーデジタル変換のクロック周波数、信号処理、カラー信号処理、３Ｄ信号処理を含む装置内の一つ以上の機能ユニットを更に変更する。電力消費は、２つ以上の所定のレベルち対してモニターすることができる。装置の機能ユニット又は作動モードは、どの電力消費レベルに到達したかに基づいて変更される。アナログビームフォーマーを有する装置においては、電力消費は１０ワットに制限することができ、デジタルビームフォーマー装置での電力消費を２５ワット以下に制限することができる。



【特許請求の範囲】
【請求項１】
超音波を送受信するための超音波トランスジューサと、送受信された波を合焦するためのビームフォーミング回路とを有している携帯式超音波診断装置を、低減された電力消費レベルで作動させる方法において、
ａ）バッテリー電源の電流を前記装置内の回路へ供給する段階と、
ｂ）前記装置の作動モードによって変化する回路機能を選択し、それによって電力消費を低減する段階とから成ることを特徴とする方法。
【請求項２】
前記装置が作動する前に、前記段階ｂ）が行われる事を特徴とする請求項１に記載の方法。
【請求項３】
前記装置が作動中にも、前記段階ｂ）が行われる事を特徴とする請求項２に記載の方法。
【請求項４】
前記装置が、信号処理回路と、処理された信号のディスプレイ表示を制御するための画像化回路と、ディスプレイと、を更に含んでいることを特徴とする請求項２に記載の方法。
【請求項５】
前記段階ｂ）が、処理された信号のディスプレイ表示を変更する段階を含んでいることを特徴とする請求項４に記載の方法。
【請求項６】
前記処理された信号のディスプレイ表示が、活動的走査モードから、フリーズとスリープの中から選択されたモードへと変更されることを特徴とする請求項５に記載の方法。
【請求項７】
前記段階ｂ）が、必要とされない機能ブロックのターンオフを更に含むことを特徴とする請求項４に記載の方法。
【請求項８】
前記必要とされない機能ブロックが、処理された信号のカラーディスプレイと３Ｄディスプレイとを含んでいることを特徴とする請求項７に記載の方法。
【請求項９】
前記段階ｂ）が、少なくとも１つの機能ユニットに対するクロック周波数を低下させる段階を更に含んでいることを特徴とする請求項４に記載の方法。
【請求項１０】
前記少なくとも１つの機能ユニットが、アナログ／デジタル信号変換を含んでいることを特徴とする請求項９に記載の方法。
【請求項１１】
前記少なくとも１つの機能ユニットが、データプロセッサを含んでいることを特徴とする請求項９に記載の方法。
【請求項１２】
前記段階ｂ）が、モニターされた電流が、電力消費が第２電力限界に達したことを示すとき、装置内の第２機能を変化させる段階を更に含んでいることを特徴とする請求項１に記載の方法。
【請求項１３】
第１機能と第２機能は、ディスプレイ作動、カラー信号処理、３Ｄ信号処理、アナログ／デジタル信号変換のためのクロック周波数、データ処理のためのクロック周波数、から選択されることを特徴とする請求項１２に記載の方法。
【請求項１４】
ａ）超音波を送受信するための超音波トランスジューサと、
ｂ）送受信された波を合焦するためのビームフォーミング回路と、
ｃ）ディスプレイと、
ｆ）バッテリー電力と、

ｄ）装置内の電力消費が２５ワットを越えないように制限するための電力制御器と、を備えていることを特徴とする携帯式超音波診断装置。
【請求項１５】
前記ビームフォーミング回路がデジタルであることを特徴とする請求項１４に記載の携帯式超音波診断装置。
【請求項１６】
前記電力制御器が、電力消費が第１限界を超えたときに、ビームフォーマー内のアナログ／デジタル変換器に対するクロック周波数を低下させることを特徴とする請求項１５に記載の携帯式超音波診断装置。
【請求項１７】
ｅ）受信された波から電気信号を処理するための信号処理回路と、
ｆ）処理された信号のディスプレイ表示を制御するための画像化回路と、
ｇ）ディスプレイと、を更に含んでいることを特徴とする請求項１６に記載の携帯式超音波診断装置。
【請求項１８】
前記電力制御器が、処理された信号のカラーディスプレイと３Ｄディスプレイをブロックすることを特徴とする請求項１４に記載の携帯式超音波診断装置。
【請求項１９】
前記電力制御器が、処理された信号のディスプレイ表示を変更することを特徴とする請求項１８に記載の携帯式超音波診断装置。
【請求項２０】
処理された信号のディスプレイ表示が、活動的走査モードから、フリーズ及びスリープから選択されたモードへとシフトされることを特徴とする請求項１９に記載の携帯式超音波診断装置。
【請求項２１】
前記ビームフォーミング回路がアナログであり、前記電力制御器が電力消費を１０ワットに制限することを特徴とする請求項１４に記載の携帯式超音波診断装置。
【請求項２２】
前記電力制御器は、電力消費が第１レベルに達したとき、１つ又はそれ以上の機能を制限することを特徴とする請求項２１に記載の携帯式超音波診断装置。
【請求項２３】
前記１つ又はそれ以上の機能が、ディスプレイ作動、カラー信号処理、３Ｄ信号処理、アナログ／デジタル変換のためのクロック周波数、データ処理のためのクロック周波数を含んでいることを特徴とする請求項２２に記載の携帯式超音波診断装置。
【請求項２４】
携帯式超音波診断装置において、
アレイトランスジューサと、
前記アレイトランスジューサの要素によって受信されたエコー信号を遅延させ合成するためのビームフォーマーと、
前記エコー信号を処理するための信号処理及び画像化回路と、
処理された信号のためのディスプレイと、を備えており、前記装置が２５ワット未満の電力で作動することを特徴とする携帯式超音波診断装置。
【請求項２５】
前記ビームフォーマーがデジタルであることを特徴とする請求項２４に記載の装置。
【請求項２６】
前記ビームフォーマーがアナログであり、前記装置が１０ワット未満の電力で作動することを特徴とする請求項２４に記載の装置。
【発明の詳細な説明】
【０００１】
本特許出願は、１９９９年5月５日出願の仮特許出願番号第６０／１３２，５５８号の恩

典を請求するものである。
【０００２】
（発明の属する技術分野）
本発明は、概括的には医療用超音波診断システムに関し、より厳密には、本発明は、低電力で作動する携帯式超音波診断装置に関する。
【０００３】
（発明の背景）
現代の超音波診断システムは、大きく複雑な装置である。今日のプレミアム超音波装置は、台車に搭載され可動性となってはいるが、未だに重量は数百ポンドもある。過去においては、アドバンストテクノロジーラボラトリ社で生産されたＡＤＲ４０００超音波システムのような超音波システムは、パソコンと殆ど同じサイズの小さなデスクトップ型の装置であった。しかしながら、このような機器は、例えばカラードップラー画像や３次元表示性能のような今日のプレミアム超音波システムの先進的な特徴の多くを欠いている。超音波システムは、複雑になるに従って、大きくなってしまった。
【０００４】
特許番号第５，７２２，４１２号は、手持ち式プレミアム超音波システムの多くの特徴を有する診断用超音波装置を開示している。この装置は、単体として製造することもできるし、ある好適な実施例では、本装置は、一方はトランスジューサビームフォーマと画像プロセッサとを含むユニット、他方はディスプレイと両ユニット用の電源とを含むユニット、の２つのユニットから構成されている。この様な構成であれば、トランスジューサ／プロセッサユニットは片手で操作することができ、後者のユニットを超音波画像が最適な状態で見えるように保持又は配置した状態で、両ユニット間のケーブルにより映像がディスプレイ装置上に表示できるようになる。ケーブルは又、ディスプレイからトランスジューサ／プロセッサユニットにエネルギーを供給する。
【０００５】
ある好適な実施例では、トランスジューサから映像出力までの超音波システムは、次に挙げる４種類の特定用途向けＩＣ（ＡＳＩＣ）即ち、アレイトランスジューサの要素に接続されている送受信ＡＳＩＣ、ビームフォーミングの送受信を実行し制御するフロントエンドＡＳＩＣ、フィルタリングのような超音波信号の処理を行うデジタル信号処理ＡＳＩＣ、処理された超音波信号を受信し、超音波画像データを作り出すバックエンドＡＳＩＣの４つで製作される。画像は、標準的モニター、又は液晶ディスプレイ（ＬＣＤ）の何れかに表示される。ＡＳＩＣを含むユニットの要素は、単一のプリント回路基板上に製作でき、従って、コネクタ及びケーブルによって従来から引き起こされてきた問題を排除することができる。この複雑な超音波装置は、５ポンド以下の重量で手持ち式のユニットとして製造することができる。
【０００６】
携帯式超音波診断装置における制約的な要因は、作動に必要な電力である。通常、デジタルビームフォーミング装置では少なくとも３５ワットの電力が必要であり、一方アナログビームフォーミング装置では最低限１５ワットの電力を必要とする。デジタルビームフォーマーは性能において精度が高いが、アナログ／デジタル、デジタル／アナログの信号変換には、変換を必要とせずビームフォーミングの位相変調に依るアナログビームフォーマーよりも、かなり多くの電力を必要とする。
【０００７】
本発明は、デジタル、アナログ、又はハイブリッドの、作動時に消費電力の少ない携帯式超音波診断装置を指向している。
【０００８】
（発明の要約）
本発明によれば、アレイトランスジューサと、アレイトランスジューサの要素によって受信されるエコー信号を遅延させ、組み合わせるためのビームフォーマーと、エコー信号を処理するための信号処理及び画像化回路と、処理されたエコー信号用のディスプレイとを

含む携帯式の超音波診断装置が提供されており、その装置は、２５ワット未満の電力で作動するようになっている。アナログビームフォーマーを備えたある実施例では、装置は１０ワット未満の電力で作動する。

【０００９】

より詳細に述べると、この携帯式超音波診断装置はバッテリー電力で作動し、電力消費を、デジタルビームフォーマー装置に対しては２５ワットに、アナログビームフォーマー装置に対しては１０ワットに制限するように電力制御が行われている。装置の作動前に、要求される回路機能に関し様々な作動のモードが評価され、その他の回路機能は、電力を維持するためにパワーダウンされるか、或いはターンオフされる。例えば、Ｂモードの走査はカラーの血管造影を必要としないので、この機能はターンオフされる。同様に、低速でサンプリングすると、アナログ／デジタル変換機能は低頻度で作動すればよいので、電力消費を低減できる。スリープモードでは、モニターのディスプレイ輝度を低下させることができる。更に、装置の作動中、バッテリ電源から装置の構成要素に流れる電流はモニターされ、電流が第１の選択電力限界に達した場合は、装置の第１機能は変更され、それにより電気消費量が低減される。例えば、その機能が処理された信号のディスプレイ表示である場合、そのディスプレイは、活動的走査から、電力が少なくて済むフリーズ及びスリープの中から選択されたモードへとシフトすることができる。加えて、処理された信号のカラーディスプレイや３次元ディスプレイのような必要とされない機能的ブロックは、ターンオフすることができる。デジタルビームフォーマーでは、超音波トランスジューサからの信号のアナログ／デジタル変換にはかなりの電力が使用され、アナログ／デジタル変換器へのクロック周波数を低下させることによって電力を維持することができる。同様に、装置のデジタル信号プロセッサに対するクロック周波数も、電力の節約を伴って減らすことができる。この様に、電力の低減は、装置作動の前、及び／又は作動の間にも行うことができる。

【００１０】

もう一つの実施例では、バッテリー電源からの電流が装置の作動中モニターされており、装置作動内の第１の機能は電力消費が第１電力限界に達したときに変更され、追加的な機能はモニターされた電流が第２電力限界に達したときに変更され、それによって装置の作動が歩調を合わせて変更される。最終的スレッショルドに到達すると、装置に起こりそうな欠陥に対するトラブルシューティングが完了するまで装置の作動が完全に停止する。

【００１１】

本発明、及びその目的と特徴は、添付図面を参照しながら、以下の詳細な説明と特許請求の範囲をお読み頂けば容易に理解できるであろう。

【００１２】

（好適な実施例の詳細な説明）

図１は、本発明が適用されている携帯式超音波診断装置の機能ブロック線図である。超音波トランスジューサ１は、全体的に２で表示されている超音波を生成し、超音波の反射を受信する。音波の生成とエコー信号の処理は、トランスジューサ１とインタフェースするビームフォーマー回路３によって行われる。次に、ビームフォーマー３からの信号は信号プロセッサ４に渡され、次に、その処理信号を使ってディスプレイ５が制御される。装置の構成要素への電力は、本発明による、電力モニター及び制御器を含むバッテリー電源６によって供給される。

【００１３】

これまで携帯式超音波診断装置は使用されてきたが、３５ワットを超える電力レベルで作動していた。本発明は、電力消費を、デジタルビームフォーマー装置については２５ワットに、アナログビームフォーマー装置については１０ワットに制限する。アナログビームフォーマー装置は、アナログビームフォーマーと比較して、正確さが改善されてきたが、アナログ／デジタル変換回路と増幅器は、アナログビームフォーマーが必要とするよりも非常に多くの電力を必要とする。例えば、１００個の要素とアナログ／デジタル回路を持ったトランスジューサアレイは、１要素当たり６４ミリワット、即ちアナログ／デジタル

変換に対し合計で６．４ワットにまで拡張している。加えて、タイムゲイン制御（ＴＧＣ）増幅器も又、トランスジューサ当たり約６４ミリワット消費し、その結果、６．４ワット追加される。

【００１４】

本発明によれば、選別された回路機能が、装置の作動モードによってパワーダウン、又はターンオフされる。例えば、Ｂモード走査の時には、カラーパワー血管回路はターンオフされる。広いアパーチャの無い走査／送信では、合成アパーチャ機能は必要とされず、ターンオフされる。同様に、作動モード中にラフな画像で十分であれば、周波数合成機能は必要ない。２次元（２Ｄ）の作動モードでは、３Ｄ処理は全く必要ない。低周波で心臓画像化を行えば、フロントエンド（ＦＥ）クロック周波数を下げることができ、全信号経路において周波数を下げられることになる。データサンプリング周波数が下がると、アナログ／デジタル変換の速度を下げることができ、従って電力を節約することができる。

従って、装置の作動モードによって装置の回路を選択的に使用することで、電力は節約される。

【００１５】

図２は、図１の電源６における電力モニター及び制御器の作動を示すグラフである。グラフは、縦座標に電力、横座標に時間を表している。この例では、電力消費は、通常の作動の間は１５－２０ワットに制限され、どんな場合でも２５ワットを超えることはないと仮定している。第１電力限界は１５ワットに、第２電力限界は２０ワットに、第３電力限界は２５ワットに設定されている。装置の作動中に、グラフのＡ点で電力消費が１０ワットから１５ワットに上がったと仮定する。本発明のある実施例によれば、図１の電力モニター及び制御器６は、装置内の第１機能を、先に示したように、しかも作動中に変更する。例えば、電力がＡ点（１５ワット）に達したとき、電力消費を低減するため、機能及び作動速度を更に低下させることができる。第１機能は、ディスプレイを活動的走査からフリーズモードへ切り替える、ディスプレイ５の作動モードを含んでいてもよい。ディスプレイは、電力の消費が大きいものの一つであるので、ディスプレイモードの切り換えは、電力消費が更に増加することを制限できる。しかしながら、電力消費が、１５ワット（Ａ点）から２０ワット（Ｂ点）に上がり続ける場合、更に電力消費を制限するために、電力モニター及び制御器は、装置の作動における第２機能を変えることになる。これらの変化は、デジタル信号プロセッサへのクロック周波数と、ビームフォーマー内のアナログ／デジタル回路へのクロック周波数を低下させることを含んでいてもよい。

【００１６】

図３は、デジタルビームフォームを有する超音波診断装置の詳しい機能ブロック線図であり、更に、電力モニター及び制御器によって変化させることのできる装置の機能を示している。この装置は、米国特許番号第５，７２２，４１２号に詳しく説明されており、ここに参考文献として援用する。この装置には、トランスジューサアレイ１０が、ソリッドステート、電子制御能力、可変アパーチャ、画像性能、信頼性のために使用されている。平面状又は曲面状何れかの線形アレイを使うことができる。ある好適な実施例では、このアレイは、広い扇形の走査範囲を持つ曲面状のアレイである。この好適な実施例は、フェイズドアレイのような平面アレイを操縦し合焦するために、十分な遅延能力を供給する一方で、曲面状アレイの幾何学的な曲率はビームフォーマー上の遅延要件を減少する。アレイの要素は、トランスジューサ要素を駆動し要素が受信したエコーを受信する送受信ＡＳＩＣ２０に接続されている。送受信ＡＳＩＣ３０は又、アレイ１０の送信及び受信アパーチャと、受信されたエコー信号のゲインを制御する。送受信ＡＳＩＣは、トランスジューサ要素から数インチ以内に位置されているのが望ましく、同じ筐体内に、トランスジューサのちょうど後方に配置されているのが望ましい。

【００１７】

送受信ＡＳＩＣ３０によって受信されたエコーは、隣接するフロントエンドＡＳＩＣ３０に供給され、そのフロントエンドＡＳＩＣ３０は、個々のトランスジューサ要素から走査線信号へとエコーをビーム成形する。フロントエンドＡＳＩＣ３０は又、送信波形、タイ

ミング、アパーチャ、合焦を制御する。図示されている実施例では、フロントエンドＡＳＩＣ３０は、他のＡＳＩＣ、タイムゲインコントロール、モニターにタイミング信号を供給し、トランスジューサアレイに掛けられた電力を制御し、それにより、患者に適用される音響エネルギーを制御し、ユニットの電力消費を最小化する。メモリー装置３２は、フロントエンドＡＳＩＣ３０に接続され、ビームフォーマーが使用するデータを記憶する。

【００１８】

ビームフォーマー走査線信号は、フロンとエンドＡＳＩＣ３０から隣接するデジタル信号処理ＡＳＩＣ４０に連結される。デジタル信号処理ＡＳＩＣ４０は、走査線信号をろ過し、好適な実施例では、合成アパーチャ形成、周波数合成、電力ドップラ（カラーパワー血管）処理のようなドップラー処理、斑点低減、を含むいくつかの進歩した特徴を提供する次に、超音波Ｂモード及びドップラーの情報は、走査変換とビデオ出力信号を作るために隣接するバックエンドＡＳＩＣ５０に連結される。メモリー装置４２は、３次元パワードップラー（３Ｄ　ＣＤＡ）画像化に使用される記憶装置を提供するため、バックエンドＡＳＩＣ５０に連結される。バックエンドＡＳＩＣは又、時刻、日付、患者識別のような英数字情報をディスプレイに付加する。図形プロセッサーは、超音波画像に、深度及び焦点マーカー、及びカーソルのような情報を重ね合わせる。超音波画像のフレームは、バックエンドＡＳＩＣ５０に連結されたビデオメモリ５４内に記憶され、生のシネループのリアルタイムシーケンスに呼び出し、再生される。ビデオ情報は、ビデオ出力で、ＮＴＳＣ及びＰＡＬテレビフォーマット、及びＬＣＤディスプレイ６０即ちビデオモニターへのＲＧＢ駆動信号を含む幾つかのフォーマットで使用される。

【００１９】

バックエンドＡＳＩＣ５０は、超音波システム用の中央プロセッサ、即ちＲＩＳＣ（縮小命令セットコントローラ）プロセッサーも含んでいる。ＲＩＳＣプロセッサは、手持ち式ユニットを通して処理及び制御機能を制御し、同期化するために、フロントエンド及びデジタル信号処理ＡＳＩＣに連結されている。プログラムメモリ５２は、ユニットを操作し制御するためにＲＩＳＣプロセッサーによって使用されるプログラムデータを記憶するために、バックエンドＡＳＩＣ５０に連結されている。バックエンドＡＳＩＣ５２は、ＰＣＭＣＩＡインタフェース５６として構成されているデータポートにも接続されている。このインタフェースによって、他のモジュール及び機能を手持ちの超音波ユニットに取り付けることができる。インタフェース５６は、離れた場所からの超音波情報を送受信するために、モデム又はコミュニケーションリンクに接続することができる。このインタフェースには、他のデータ記憶装置を取り付けて、超音波情報分析パッケージのような新しい機能性をユニットに付加することもできる。

【００２０】

ＲＩＳＣプロセッサーは、手持ち式の超音波装置の作動を指示し制御するために、ユーザーのインプットを受け付けるためのユニットのユーザー制御器７０にも連結されている。

【００２１】

ある好適な実施例では、手持ち式の超音波システム用の電力は、再充電可能なバッテリーによって供給される。バッテリー電力は保持され、電力サブシステム８０からユニットの構成要素に掛けられる。電力サブシステム８０は、低バッテリー電圧を高電圧に変換するためのＤＣ変換器を含んでおり、高電圧が、トランスジューサアレイ１０の要素を駆動するため送受信ＡＳＩＣ２０に掛けられる。

【００２２】

ユニット８０内の電力モニター及び制御器は、図２を参照して説明したことに従って作動し、ＬＣＤディスプレイ６０とユニット５０内のビデオ回路の作動モードを、ユニット５０内のＲＩＳＣプロセッサのクロック周波数、ビームフォーマー回路３０内のＶＣＡ及びＡＤＣユニットのクロック周波数と共に制御する。カラーパワー及びジオグラフィ機能ユニットと、ＤＳＰユニット４０の３Ｄ信号処理とは、電力モニター及び制御器によって同様に制御される。

【００２３】

図３において、電力消費は、共にブロック５０内のＲＩＳＣプロセッサによって制御されている、電力モニター及び制御ブロック８０と、マスタークロック制御器９０とによって制御されている。図３に示されている全体信号経路は、ブロック３０内のアナログ／デジタル変換器（ＡＤＣ）３４、ブロック４０内のカラーパワー血管プロセッサ４４、ブロック４０内の周波数合成プロセッサ４６のような各種の機能ブロックを含んでいる。このような機能ブロックはそれぞれ、電力モニター及び制御ブロック８０によって個別にターンオフすることができる。例えば、超音波システムがＢモードでだけ画像化しているときには、カラーパワー血管ブロック４４は不要であり、ターンオフされる。

【００２４】

機能ブロックがオンかオフかを制御することに加えて、電力モニター及び制御ブロック８０は、ＡＤＣブロック３４に供給されるバイアス電流を制御する。低周波数の作動であれば、通常バイアス電流は少なくて済む。同様に、送受信ブロック２０に供給される電圧及び電流も、適切に制御される。例えば、表面の画像化は、通常、深い腹腔の画像化よりも送信電力が少なくて済む。

【００２５】

電力モニター及び制御ブロック８０は、ＬＣＤディスプレイ６０、特にＬＣＤディスプレイに関わるバックライトへの電力も制御する。電力を保護するため、ディスプレイには少ない電流（薄暗い）が供給される。

【００２６】

全体システム作動に関していえば、システムは、何れの特定に時間においても幾つかの電力保護モードの１つに在る。例えば、全作動モードは最大電力を消費するが、一方、記憶されている画像を見直すことはできるが活動的な走査はできない「フリーズ」モードは、少ない電力しか消費しない。ディスプレイ及び大部分の機能が使用禁止であるスリープモードでは、更に消費電力が少なく、パワーオフモードでは電力を消費しない。電力モニター及び制御ブロック８０は、ブロック５０内に含まれているＲＩＳＣプロセッサの実行するアルゴリズムに基づいて、これらの状態の間の遷移を制御する。

【００２７】

好適な実施例では、説明した機能ブロックの多くが、図１の特定用途向けＩＣ（ＡＳＩＣ）２０、３０、４０、５０に埋め込まれている。各ＡＳＩＣにどの機能を統合するかの選定は、電力消費に関係する。例えば、ＡＤＣブロック３４と遅延及び合計ブロック３６及び３８との統合は、電力を保護するための同一ＡＳＩＣ内への統合である。これらの要素を分離すると、ブロック間での通信のために高電流ドライバ回路が必要になる。

【００２８】

携帯式超音波診断装置に電力モニター及び制御機能を使えば、電力消費が押さえられ、限られた電力範囲内で装置を作動させることができる。以上、本発明を特定の実施例を取り上げて説明してきたが、以上の記述は、説明のためのものであり、本発明に制約を加えるものではないと理解されたい。当業者には、特許請求の範囲に定義する本発明の真の精神と範囲から逸脱することなく、様々な修正を加え、応用が行えることは自明であろう。

【図面の簡単な説明】

【図１】

本発明による、電力モニター及び制御器を含む携帯式超音波診断装置の機能ブロック線図である。

【図２】

図１の電力モニターの作動を示すグラフである。

【図３】

本発明による、デジタルビームフォーマーと電力モニターを有する超音波診断装置の、詳細な機能ブロック線図である。

【図１】

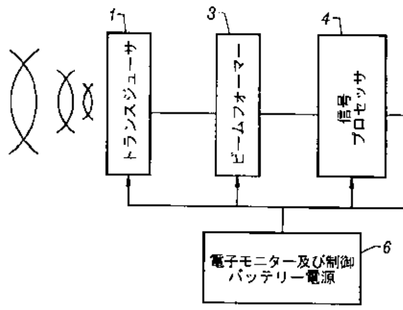


FIG. 1

【図２】

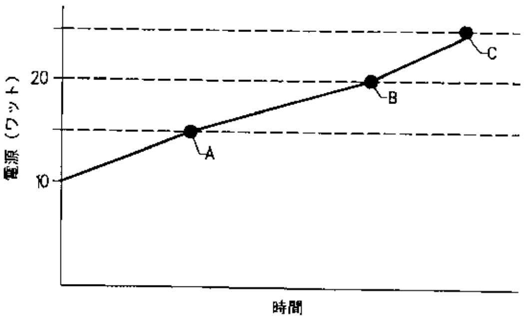


FIG. 2

【図３】

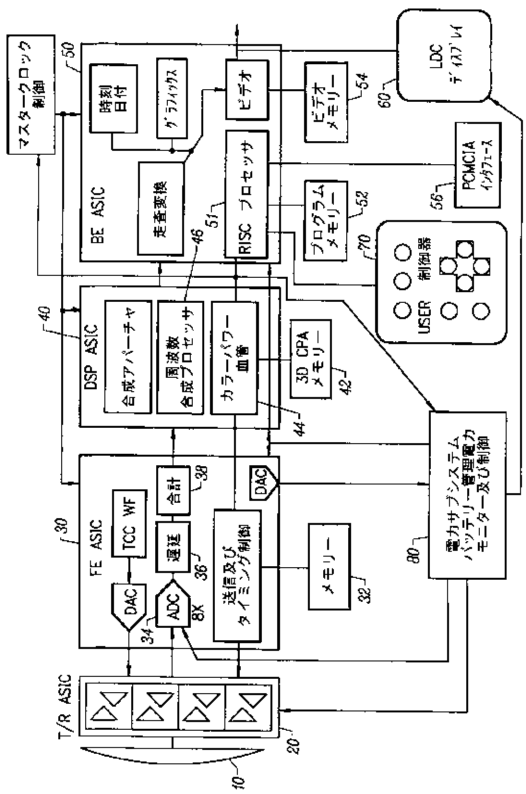


FIG. 3

【国際公開パンフレット】

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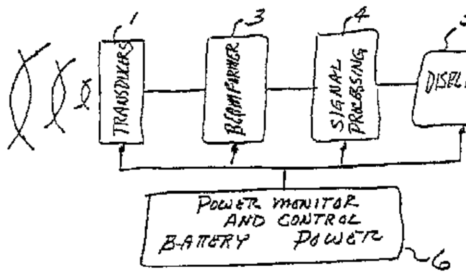

(57) Abstract

A portable ultrasonic diagnostic instrument including an array transducer (1), a beam former (3), signal processing, imaging circuitry (4), and a display (5) for the processed echo signals operates on no more than 25 watts of electrical power. Circuit functions can be select attend depending on mode of operation of the instrument to thereby reduce power consumption. Further, a power monitor and control (6) can monitor electrical current from a battery power source. When power consumption reaches a predetermined level the power monitor and control further alters one or more functional units in the instrument including display mode of operation, clock frequency for analog to digital conversion, signal processing, color signal processing, and 3D signal processing. Power consumption can be monitored against two or more predetermined levels wherein instrument functional units or mode of operation are altered depending on which level of power consumption has been reached. In an instrument with an analog beam former, power consumption can be limited to 10 watts, whereas in a digital beam former instrument power consumption can be limited to no more than 25 watts.

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LOW POWER PORTABLE ULTRASONIC DIAGNOSTIC INSTRUMENT

This patent application claims the benefit of Provisional Patent Application Serial No. 60/132,558, filed May 5, 1999.

BACKGROUND OF THE INVENTION

This invention relates generally to medical ultrasonic diagnostic systems, and more particularly the invention relates to a portable ultrasonic diagnostic instrument which operates at low power.

Modern ultrasonic diagnostic systems are large, complex instruments. Today's premium ultrasound systems, while mounted in carts for portability, continue to weigh several hundred pounds. In the past, ultrasound systems such as the ADR 4000 ultrasound system produced by Advanced Technology Laboratories, Inc., were smaller desktop units about the size of a personal computer. However, such instruments lacked many of the advanced features of today's premium ultrasound systems such as color Doppler imaging and three dimensional display capabilities. As ultrasound systems have become more sophisticated they have also become bulkier.

Disclosed in Patent No. 5,722,412 is a diagnostic ultrasound instrument which exhibits many of the features of a premium ultrasound system in a hand-held unit. The instrument can be produced as a single unit or, in a preferred embodiment, the instrument is a two part unit one including a transducer beamformer an image processor and the other including a display and power source for both units. In such a configuration the transducer/processor unit can be manipulated with one hand while a cable between the two units enables the video to be shown on the display unit while the latter unit is held or positioned for optimal viewing of the ultrasound image. The cable also provides energy for the transducer/processor unit from the display.

In a preferred embodiment the ultrasound system from the transducer to the video output is fabricated on four types of application specific integrated circuits (ASICs): a transmit/receive ASIC which is connected to the elements of an array transducer, a front end ASIC which performs and controls transmit and receive beamforming, a digital signal processing ASIC which provides processing of the ultrasound signals such as filtering, and a back end ASIC which receives processed ultrasound signals and produces ultrasound image data. The image can be displayed on either a standard monitor or on a liquid crystal display (LCD). The elements of the unit including the ASIC can be fabricated on a single printed circuit board, thus eliminating the problems conventionally posed by connectors and cables. This sophisticated ultrasound instrument can be manufactured as a hand held unit weighing less than five pounds.

A limiting factor in portable ultrasonic diagnostic instruments is the power required for operation. Typically at least 35 watts of power are required for digital beamforming instrument whereas an analog beamforming instrument requires a minimum of 15 watts of power. The digital beamformer is more precise in performance, but the analog to digital and digital to analog signal conversions require considerably more power than the analog beamformer which requires no conversion and relies on phase modulation in beamforming.

The present invention is directed to providing a portable ultrasonic diagnostic instrument, either digital, analog or hybrid, with reduced power in operation.

SUMMARY OF THE INVENTION

In accordance with the invention a portable ultrasonic diagnostic instrument is provided which includes an array transducer, a beamformer for delaying and combining echo signals received by elements of the array transducer, signal processing and imaging circuitry for processing the echo signals, and a display for the processed echo signals, wherein the instrument operates on no more than 25 watts of electrical power. In one embodiment with an analog beamformer, the instrument operates on no more than 10 watts of power.

More particularly, the portable ultrasonic diagnostic instrument operates from battery power, and power control is provided for limiting power consumption in the instrument to 25 watts for a digital beamformer instrument or 10 watts for an analog beamformer instrument. Before operation of the instrument, various modes of operation are evaluated for required circuit functions, and other circuit functions are powered down or turned-off to conserve power. For example, B mode scanning does not require color power angiography and this function is turned-off. Similarly, sampling at a lower rate allows the analog to digital function to operate at a lower frequency thus reducing power consumption. In a sleep mode, the monitor display intensity can be diminished. Further, during operation of the instrument current from the battery source to the instrument components is monitored, and when the current reaches a first selected power limit, first functions in the instrument are altered to thereby reduce power consumption. For example, function can be the display of processed signals, and the display can be shifted in mode from active scanning to a mode selected from freeze and sleep which require less power. Additionally, un-needed functional blocks such as color display and 3D display of processed signals can be turned off. In a digital beamformer instrument, considerable power is expended in the analog to digital conversion of signals from the ultrasound transducers, and power can be conserved by reducing the clock frequency to the analog to digital converters. Similarly, the clock frequency to the digital signal processor of the instrument can reduced with attendant power savings. Thus, power reduction can be effected before instrument operation and/or during operation.

In an alternative embodiment, current from the battery source is monitored during instrument operation and first functions in the instrument operation are altered when the power consumption has reached a first power limit, and additional functions when monitored current reaches a second power limit whereby instrument operation is altered in steps. An ultimate threshold can be reached wherein the instrument operation is terminated entirely until troubleshooting of the instrument for possible failure is completed.

The invention and objects and features thereof will be more readily apparent from the following detailed description and appended claims when taken with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a functional block diagram of a portable ultrasonic diagnostic instrument including a power monitor and control in accordance with the invention.

Fig. 2 is a graphic illustrating operation of the power monitor in Fig. 1.

Fig. 3 is a more detailed functional block diagram of a ultrasonic diagnostic instrument having a digital beamformer and a power monitor in accordance with the invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Fig. 1 is a functional block diagram of a portable ultrasonic diagnostic instrument in which the present invention is employed. Ultrasound transducers 1 generate ultrasonic waves shown generally at 2 and receive reflections of the ultrasonic waves. Wave generation and echo signal processing is accomplished by a beamformer circuit 3 which interfaces with the transducers 1. Signals from beamformer 3 are then passed to a signal processor 4, and the process signals are then used to control a display 5. Electric power for the components of the instrument provided by a battery source 6 which includes a power monitor and control in accordance with the present invention.

Heretofore, portable ultrasonic diagnostic instruments have been available but have operated at power levels exceeding 35 watts. The present invention limits power consumption to 25 watts for a digital beamformer instrument and 10 watts for an analog beamformer instrument. The analog beamformer instrument has improved fidelity when compared with the analog beamformer, but the analog to digital conversion circuits and amplifiers require considerably more power than does an analog beamformer. For example, a transducer array with 100 elements and analog to digital circuits can expand 64 milliwatts per element or 6.4 watts total just for the analog to digital conversion. Additionally, a time gain control (TGC) amplifier also expends approximately 64 milliwatts per transducer which is an additional 6.4 watts.

In accordance with the invention, selected circuit functions are powered down or turned-off depending on the operating mode of the instrument. For example, for B mode scanning, the Color Power Angio circuitry is turned-off. For Scan/Transmit without Wide Aperture, the Synthetic Aperture function is not needed and is turned-off. Similarly, if a rough image is sufficient during an operating mode, the Frequency Compounding function is not needed. Two dimensional (2D) mode of operation does not require any 3D processing. Low frequency cardiac imaging permits a reduction in Front End (FE) clock frequency and possibly a reduced frequency for the entire signal path. Analog to Digital conversion speed can be reduced and thus save power when data sampling frequency is reduced.

Accordingly, power is saved by selective use of instrument circuitry depending on mode of operation of the instrument.

Fig. 2 is a graph illustrating operation of the power monitor and control in power source 6 of Fig. 1. The graph illustrates power along the coordinate and time along the abscissa. In this example it is assumed that power consumption is to be limited to 15-20 watts during normal operation and in no event exceed 25 watts of power. A first power limit is defined at 15 watts, a second power limit is defined at 20 watts, and a third power limit is defined at 25 watts. Assume that during instrument operation power consumption rises from 10 watts to 15 watts at Point A on the graph. In accordance with one embodiment of the invention the power monitor and control 6 in Fig. 1 alters first functions in the instruments, as described above, and additionally during operation. For example, when the power reaches Point A (15 watts) function and operating speed can be further reduced in order to reduce power consumption. The first functions can include mode of operation of display 5 with the display switched from active scanning to a freeze mode. Since the display is one of the larger consumers of electrical power, the switch of display mode can limit further increase in power consumption. However, assuming power consumption continues to rise from 15 watts (Point A) to 20 watts (Point B), the power monitor and control will then alter second functions in the instrument operation to further limit power consumption. These alterations can include reducing clock frequency to the digital signal processor and clock frequency to analog to digital circuitry in the beamformer.

Fig. 3 is a more detailed functional block diagram of a ultrasonic diagnostic instrument having a digital beamform and further illustrates functions in the instrument which can be altered by the power monitor and control. The instrument is described in more detail in U.S. Patent No. 5,722,412, which is incorporated herein by reference. In this instrument a transducer array 10 is used for a solid state, electronic control capabilities, variable aperture, image performance and reliability. Either a flat or curved linear array can b e used. In a preferred embodiment the array is a curved array, which affords a broad sector scanning field. While the preferred embodiment provides sufficient delay capability to both steer and focus a flat array such as a phased array, the geometric curvature of the curved array reduces the delay requirements on the beamformer. The elements of the array are connected to a transmit/receive ASIC 20 which drives the transducer elements and receives echoes received by the elements. The transmit/receive ASIC 30 also controls the transmit and receive apertures of the array 10 and the gain of the received echo signals. The transmit/receive ASIC is preferably located within inches of the transducer elements, preferably in the same enclosure, and just behind the transducer.

Echoes received by the transmit/receive ASIC 20 are provided to the adjacent front end ASIC 30, which beamforms the echoes from the individual transducer elements into scanline signals. The front end ASIC 30 also controls the transmit waveform, timing, aperture and focusing. In the illustrated embodiment the front end ASIC 30 provides timing signals for the other ASICs, time gain control, and monitors and controls the power applied to the transducer array, thereby controlling the acoustic energy which is applied to the patient and minimizing power consumption of the unit. A memory device 32 is connected to the front end ASIC 30, which stores data used by the beamformer.

Beamformer scanline signals are coupled from the front end ASIC 30 to the adjacent digital signal processing ASIC 40. The digital signal processing ASIC 40 filters the scanline signals and in the preferred embodiment also provides several advanced features including synthetic aperture formation, frequency compounding, Doppler processing such as power Doppler (color power angio) processing, and speckle reduction.

The ultrasound B mode and Doppler information is then coupled to the adjacent back end ASIC 50 for scan conversion and the production of video output signals. A memory device 42 is coupled to the back end ASIC 50 to provide storage used in three dimensional power Doppler (3D CPA) imaging. The back end ASIC also adds alphanumeric information to the display such as the time, date, and patient identification. A graphics processor overlays the ultrasound image with information such as depth and focus markers and cursors. Frames of ultrasonic images are stored in a video memory 54 coupled to the back end ASIC 50, enabling them to be recalled and replayed in a live Cineloop® realtime sequence. Video information is available at a video output in several formats, including NTSC and PAL television formats and RGB drive signals for an LCD display 60 or a video monitor.

The back end ASIC 50 also includes the central processor for the ultrasound system, a RISC (reduced instruction set controller) processor. The RISC processor is coupled to the front end and digital signal processing ASICs to control and synchronize the processing and control functions throughout the hand-held unit. A program memory 52 is coupled to the back end ASIC 50 to store program data which is used by the RISC processor to operate and control the unit. The back end ASIC 50 is also coupled to a data port configured as a PCMCIA interface 56. This interface allows other modules and functions to be attached to the hand-held ultrasound unit. The interface 56 can connect to a modem or communications link to transmit and receive ultrasound information from remote locations. The interface can accept other data storage devices to add new functionality to the unit, such as an ultrasound information analysis package.

The RISC processor is also coupled to the user controls 70 of the unit to accept user inputs to direct and control the operations of the hand-held ultrasound system.

Power for the hand-held ultrasound system in a preferred embodiment is provided by a rechargeable battery. Battery power is conserved and applied to the components of the unit from a power subsystem 80. The power subsystem 80 includes a DC converter to convert the low battery voltage to a higher voltage which is applied to the transmit/receive ASIC 20 to drive the elements of the transducer array 10.

The power monitor and control in unit 80 operates in accordance with the description with reference to Fig. 2 and controls the operating mode of the LCD display 60 and video circuitry in unit 50 along with the clock frequency of the RISC processor in unit 50 and the clock frequencies of the VCA and ADC units in beamformer circuitry 30. The color power and geography function unit and 3D signal processing of DSP unit 40 are similarly controlled by the power monitor and control.

In Fig. 3, power consumption is controlled by power monitor and control block 80 and master clock control 90 which are both controlled by the RISC processor in block 50. The overall signal path depicted in Fig. 3 contains various functional blocks such as the analog to digital converters (ADC) 34 in block 30, the color power angio processor 44 in block 40, and the frequency compounding processor 46 in block 40. Each such functional block may be turned off individually by the power monitor and control circuit 80. As an example, when the ultrasound system is imaging in B-mode only, the color power angio block 44 is not needed and is turned off.

In addition to controlling whether functional blocks are on or off, power monitor and control block 80 controls the bias current supplied to ADC block 34. Lower frequency operation typically requires less bias current. Similarly, voltage and current supplied to transmit/receive block 20 is controlled as appropriate. As an example, superficial imaging typically will require less transmitted power than deep abdominal imaging.

Power monitor and control block 80 also controls power to LCD display 60, and in particular to the backlight associated with the LCD display. The display may be provided with less current (dimmed) to conserve power.

In terms of overall system operation, the system may be in one of several power conservation modes at any particular time. For example, a full operation mode may draw the most power, while a "freeze" mode that allows review of stored images but not active scanning would draw less power. A sleep mode where the display and most other functions are disabled would draw even less power, while a power-off mode would draw no power. Power monitor and control block 80 controls transitions between these states based on algorithms executed by the RISC processor contained in block 50.

In the preferred embodiment, many of the functional blocks described are embedded in Application Specific Integrated circuits (ASICs) 20,30, 40, and 50 in Fig. 1. The choice of which functions to integrate on each ASIC relates to power consumption. For example, the integration of ADC blocks 34 and delay and sum blocks 36 and 38 are integrated in the same ASIC to conserve power. Separation of these elements would require higher current driver circuitry for communication between blocks.

The use of power monitor and control functions in a portable ultrasonic diagnostic instrument limits power consumption and enables an instrument operating within a limited power range. While the invention has been described with reference to specific embodiments the description illustrative of the invention and is not to be construed as limiting the invention. Various modifications and applications may occur to those skilled in the art without departing from the true spirit and scope of the invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1. In a portable ultrasonic diagnostic instrument having ultrasound transducers for transmitting and receiving ultrasonic waves and beamforming circuitry for focusing transmitted and received waves, a method of operating the instrument at a reduced power consumption level comprising the steps of:

a) providing a battery source of electrical current for circuitry in the instrument, and

b) selecting altering circuitry functions depending on mode of operation of the instrument thereby reducing power consumption.

2. The method as defined by claim 1 wherein step b) is performed before instrument operation.

3. The method as defined by claim 2 wherein step b) is performed also during instrument operation.

4. The method as defined by claim 2 wherein the instrument further includes signal processing circuitry, imaging circuitry for controlling a display of processed signals, and a display.

5. The method as defined by claim 4 wherein step b) includes altering display of processed signals.

6. The method as defined by claim 5 wherein the display of processed signals is shifted in mode from active scanning to a mode selected from freeze and sleep.

7. The method as defined by claim 4 wherein step b) further includes turning off un-needed functional blocks.

8. The method as defined by claim 7 wherein un-needed functional blocks includes color display and 3D display of processed signals.

9. The method as defined by claim 4 wherein step b) further includes reducing clock frequency for at least one functional unit.

10. The method as defined by claim 9 wherein the at least one functional unit includes analog to digital signal conversion.

11. The method as defined by claim 9 wherein the at least one functional unit includes a data processor.

12. The method as defined by claim 1 wherein step b) further includes altering second functions in instrument operation when monitored current indicates the power consumption has reached a second power limit.

13. The method as defined by claim 12 wherein first functions and second functions selected from display operation, color signal processing, 3D signal processing, clock frequency for analog to digital signal conversion, and clock frequency for data processing.

14. A portable ultrasonic diagnostic instrument comprising:

a) ultrasound transducers for transmitting and receiving ultrasonic waves,

b) beamforming circuitry for focusing transmitted and received waves,

c) a display,

f) battery power, and

d) power control for limiting power consumption in the instrument not to exceed 25 watts.

15. The portable ultrasonic diagnostic instrument as defined by claim 14 wherein the beamforming circuitry is digital.

16. The portable ultrasonic diagnostic instrument as defined by claim 15 wherein the power control reduces clock frequency to analog to digital converter circuitry in the beamformer when power consumption exceeds a first limit.

17. The portable ultrasonic diagnostic instrument as defined by claim 16 and further including:

e) signal processing circuitry for processing electrical signals from received waves,

f) imaging circuitry for controlling a display of processed signals, and

g) a display.

18. The portable ultrasonic diagnostic instrument as defined by claim 13 wherein the power control blocks color display and 3D display of processed signals.

19. The portable ultrasonic diagnostic instrument as defined b claim 18 wherein power control alters display of processed signals.

20. The portable ultrasonic diagnostic instrument as defined by claim 19 wherein the display of processed signals is shifted in mode from active scanning to a mode selected from freeze and sleep.

21. The portable ultrasonic diagnostic instrument as defined by claim 14 wherein the beamforming circuitry is analog and the power control limits power consumption to 10 watts.

22. The portable ultrasonic diagnostic instrument as defined by claim 21 wherein power control limits one or more functions when power consumption reaches a first level.

23. The portable ultrasonic diagnostic instrument as defined by claim 22 wherein the one or more functions include display operation, color signal processing, 3D signal processing, clock frequency for analog to digital conversion, and clock frequency for data processing.

24. A portable ultrasonic diagnostic instrument comprising:

an array transducer,

a beamformer for delaying and combining echo signals received by elements of the array transducer,

signal processing and imaging circuitry for processing the echo signals, and

a display for the processed signals, wherein the instrument operates on no more than 25 watts of electrical power.

25. The instrument as defined by claim 24 wherein the beamformer is digital.

26. The instrument as defined by claim 24 wherein the beamformer is analog, wherein the instrument operates on no more than 10 watts of electrical power.

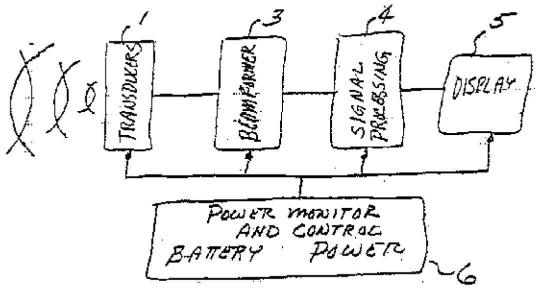
1
3
4
5
TRANSDUCERS
BEAMFORMER
SIGNAL PROCESSING
DISPLAY
POWER MONITOR AND CONTROL
BATTERY POWER
6

FIG. 1

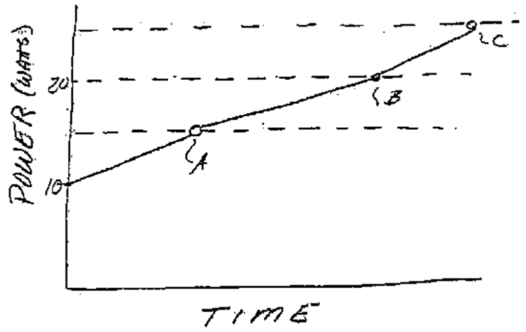
POWER (WATTS)
20
10
A
B
C
TIME

FIG. 2

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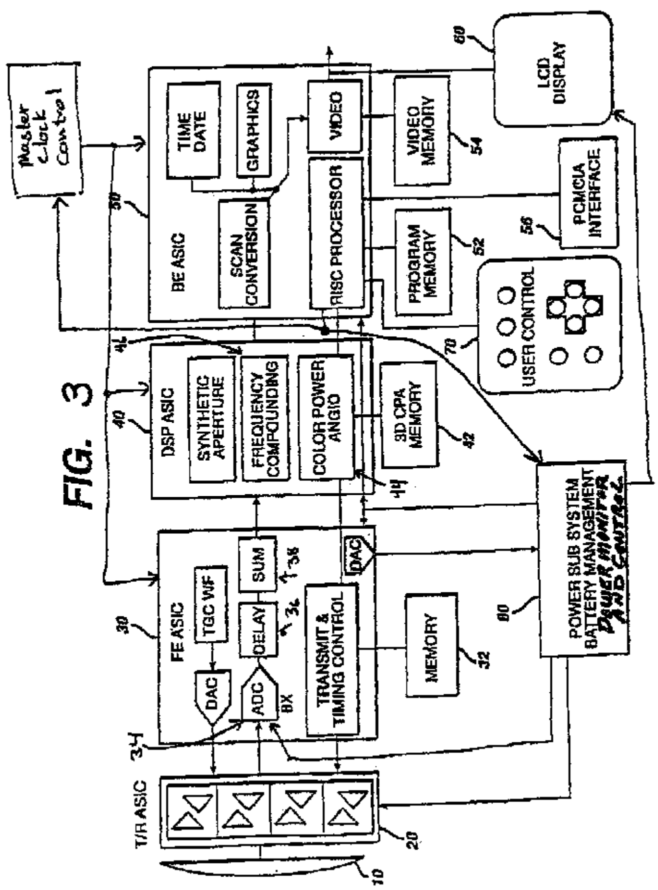

FIG. 3

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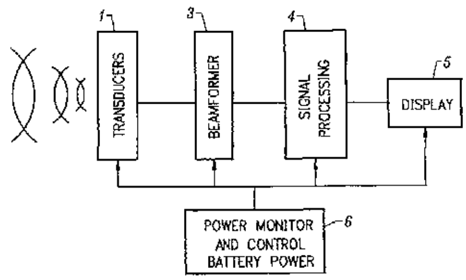
(54) Title: LOW POWER PORTABLE ULTRASONIC DIAGNOSTIC INSTRUMENT



(57) Abstract: A portable ultrasonic diagnostic instrument including an array transducer (1), a beam former (3), signal processing, imaging circuitry (4), and a display (5) for the processed echo signals operates on no more than 25 watts of electrical power. Circuit functions can be select altend depending on mode of operation of the instrument to thereby reduce power consumption. Further, a power monitor and control (6) can monitor electrical current from a battery power source. When power consumption reaches a predetermined level the power monitor and control further alters one or more functional units in the instrument including display mode of operation, clock frequency for analog to digital conversion, signal processing, color signal processing, and 3D signal processing. Power consumption can be monitored against two or more predetermined levels wherein instrument functional units or mode of operation are altered depending on which level of power consumption has been reached. In an instrument with an analog beam former, power consumption can be limited to 10 watts, whereas in a digital beam former instrument power consumption can be limited to no more than 25 watts.

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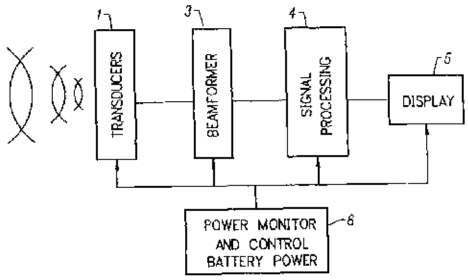

WO 00/66001 A1

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LOW POWER PORTABLE ULTRASONIC DIAGNOSTIC INSTRUMENT

This patent application claims the benefit of Provisional Patent Application Serial No. 60/132,558, filed May 5, 1999.

BACKGROUND OF THE INVENTION

This invention relates generally to medical ultrasonic diagnostic systems, and more particularly the invention relates to a portable ultrasonic diagnostic instrument which operates at low power.

Modern ultrasonic diagnostic systems are large, complex instruments. Today's premium ultrasound systems, while mounted in carts for portability, continue to weigh several hundred pounds. In the past, ultrasound systems such as the ADR 4000 ultrasound system produced by Advanced Technology Laboratories, Inc., were smaller desktop units about the size of a personal computer. However, such instruments lacked many of the advanced features of today's premium ultrasound systems such as color Doppler imaging and three dimensional display capabilities. As ultrasound systems have become more sophisticated they have also become bulkier.

Disclosed in Patent No. 5,722,412 is a diagnostic ultrasound instrument which exhibits many of the features of a premium ultrasound system in a hand-held unit. The instrument can be produced as a single unit or, in a preferred embodiment, the instrument is a two part unit one including a transducer beamformer an image processor and the other including a display and power source for both units. In such a configuration the transducer/processor unit can be manipulated with one hand while a cable between the two units enables the video to be shown on the display unit while the latter unit is held or positioned for optimal viewing of the ultrasound image. The cable also provides energy for the transducer/processor unit from the display.

In a preferred embodiment the ultrasound system from the transducer to the video output is fabricated on four types of application specific integrated circuits (ASICs): a transmit/receive ASIC which is connected to the elements of an array transducer, a front end ASIC which performs and controls transmit and receive beamforming, a digital signal processing ASIC which provides processing of the ultrasound signals such as filtering, and a back end ASIC which receives processed ultrasound signals and produces ultrasound image data. The image can be displayed on either a standard monitor or on a liquid crystal display (LCD). The elements of the unit including the ASIC can be fabricated on a single printed circuit board, thus eliminating the problems conventionally posed by connectors and cables. This sophisticated ultrasound instrument can be manufactured as a hand held unit weighing less than five pounds.

A limiting factor in portable ultrasonic diagnostic instruments is the power required for operation. Typically at least 35 watts of power are required for digital beamforming instrument whereas an analog beamforming instrument requires a minimum of 15 watts of power. The digital beamformer is more precise in performance, but the analog to digital and digital to analog signal conversions require considerably more power than the analog beamformer which requires no conversion and relies on phase modulation in beamforming.

The present invention is directed to providing a portable ultrasonic diagnostic instrument, either digital, analog or hybrid, with reduced power in operation.

SUMMARY OF THE INVENTION

In accordance with the invention a portable ultrasonic diagnostic instrument is provided which includes an array transducer, a beamformer for delaying and combining echo signals received by elements of the array transducer, signal processing and imaging circuitry for processing the echo signals, and a display for the processed echo signals, wherein the instrument operates on no more than 25 watts of electrical power. In one embodiment with an analog beamformer, the instrument operates on no more than 10 watts of power.

More particularly, the portable ultrasonic diagnostic instrument operates from battery power, and power control is provided for limiting power consumption in the instrument to 25 watts for a digital beamformer instrument or 10 watts for an analog beamformer instrument. Before operation of the instrument, various modes of operation are evaluated for required circuit functions, and other circuit functions are powered down or turned-off to conserve power. For example, B mode scanning does not require color power angiography and this function is turned-off. Similarly, sampling at a lower rate allows the analog to digital function to operate at a lower frequency thus reducing power consumption. In a sleep mode, the monitor display intensity can be diminished. Further, during operation of the instrument current from the battery source to the instrument components is monitored, and when the current reaches a first selected power limit, first functions in the instrument are altered to thereby reduce power consumption. For example, function can be the display of processed signals, and the display can be shifted in mode from active scanning to a mode selected from freeze and sleep which require less power. Additionally, un-needed functional blocks such as color display and 3D display of processed signals can be turned off. In a digital beamformer instrument, considerable power is expended in the analog to digital conversion of signals from the ultrasound transducers, and power can be conserved by reducing the clock frequency to the analog to digital converters. Similarly, the clock frequency to the digital signal processor of the instrument can reduced with attendant power savings. Thus, power reduction can be effected before instrument operation and/or during operation.

In an alternative embodiment, current from the battery source is monitored during instrument operation and first functions in the instrument operation are altered when the power consumption has reached a first power limit, and additional functions when monitored current reaches a second power limit whereby instrument operation is altered in steps. An ultimate threshold can be reached wherein the instrument operation is terminated entirely until troubleshooting of the instrument for possible failure is completed.

The invention and objects and features thereof will be more readily apparent from the following detailed description and appended claims when taken with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a functional block diagram of a portable ultrasonic diagnostic instrument including a power monitor and control in accordance with the invention.

Fig. 2 is a graphic illustrating operation of the power monitor in Fig. 1.

Fig. 3 is a more detailed functional block diagram of a ultrasonic diagnostic instrument having a digital beamformer and a power monitor in accordance with the invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Fig. 1 is a functional block diagram of a portable ultrasonic diagnostic instrument in which the present invention is employed. Ultrasound transducers 1 generate ultrasonic waves shown generally at 2 and receive reflections of the ultrasonic waves. Wave generation and echo signal processing is accomplished by a beamformer circuit 3 which interfaces with the transducers 1. Signals from beamformer 3 are then passed to a signal processor 4, and the process signals are then used to control a display 5. Electric power for the components of the instrument provided by a battery source 6 which includes a power monitor and control in accordance with the present invention.

Heretofore, portable ultrasonic diagnostic instruments have been available but have operated at power levels exceeding 35 watts. The present invention limits power consumption to 25 watts for a digital beamformer instrument and 10 watts for an analog beamformer instrument. The analog beamformer instrument has improved fidelity when compared with the analog beamformer, but the analog to digital conversion circuits and amplifiers require considerably more power than does an analog beamformer. For example, a transducer array with 100 elements and analog to digital circuits can expand 64 milliwatts per element or 6.4 watts total just for the analog to digital conversion. Additionally, a time gain control (TGC) amplifier also expends approximately 64 milliwatts per transducer which is an additional 6.4 watts.

In accordance with the invention, selected circuit functions are powered down or turned-off depending on the operating mode of the instrument. For example, for B mode scanning, the Color Power Angio circuitry is turned-off. For Scan/Transmit without Wide Aperture, the Synthetic Aperture function is not needed and is turned-off. Similarly, if a rough image is sufficient during an operating mode, the Frequency Compounding function is not needed. Two dimensional (2D) mode of operation does not require any 3D processing. Low frequency cardiac imaging permits a reduction in Front End (FE) clock frequency and possibly a reduced frequency for the entire signal path. Analog to Digital conversion speed can be reduced and thus save power when data sampling frequency is reduced.

Accordingly, power is saved by selective use of instrument circuitry depending on mode of operation of the instrument.

Fig. 2 is a graph illustrating operation of the power monitor and control in power source 6 of Fig. 1. The graph illustrates power along the coordinate and time along the abscissa. In this example it is assumed that power consumption is to be limited to 15-20 watts during normal operation and in no event exceed 25 watts of power. A first power limit is defined at 15 watts, a second power limit is defined at 20 watts, and a third power limit is defined at 25 watts. Assume that during instrument operation power consumption rises from 10 watts to 15 watts at Point A on the graph. In accordance with one embodiment of the invention the power monitor and control 6 in Fig. 1 alters first functions in the instruments, as described above, and additionally during operation. For example, when the power reaches Point A (15 watts) function and operating speed can be further reduced in order to reduce power consumption. The first functions can include mode of operation of display 5 with the display switched from active scanning to a freeze mode. Since the display is one of the larger consumers of electrical power, the switch of display mode can limit further increase in power consumption. However, assuming power consumption continues to rise from 15 watts (Point A) to 20 watts (Point B), the power monitor and control will then alter second functions in the instrument operation to further limit power consumption. These alterations can include reducing clock frequency to the digital signal processor and clock frequency to analog to digital circuitry in the beamformer.

Fig. 3 is a more detailed functional block diagram of a ultrasonic diagnostic instrument having a digital beamform and further illustrates functions in the instrument which can be altered by the power monitor and control. The instrument is described in more detail in U.S. Patent No. 5,722,412, which is incorporated herein by reference. In this instrument a transducer array 10 is used for a solid state, electronic control capabilities, variable aperture, image performance and reliability. Either a flat or curved linear array can b e used. In a preferred embodiment the array is a curved array, which affords a broad sector scanning field. While the preferred embodiment provides sufficient delay capability to both steer and focus a flat array such as a phased array, the geometric curvature of the curved array reduces the delay requirements on the beamformer. The elements of the array are connected to a transmit/receive ASIC 20 which drives the transducer elements and receives echoes received by the elements. The transmit/receive ASIC 30 also controls the transmit and receive apertures of the array 10 and the gain of the received echo signals. The transmit/receive ASIC is preferably located within inches of the transducer elements, preferably in the same enclosure, and just behind the transducer.

Echoes received by the transmit/receive ASIC 20 are provided to the adjacent front end ASIC 30, which beamforms the echoes from the individual transducer elements into scanline signals. The front end ASIC 30 also controls the transmit waveform, timing, aperture and focusing. In the illustrated embodiment the front end ASIC 30 provides timing signals for the other ASICs, time gain control, and monitors and controls the power applied to the transducer array, thereby controlling the acoustic energy which is applied to the patient and minimizing power consumption of the unit. A memory device 32 is connected to the front end ASIC 30, which stores data used by the beamformer.

Beamformer scanline signals are coupled from the front end ASIC 30 to the adjacent digital signal processing ASIC 40. The digital signal processing ASIC 40 filters the scanline signals and in the preferred embodiment also provides several advanced features including synthetic aperture formation, frequency compounding. Doppler processing such as power Doppler (color power angio) processing, and speckle reduction.

The ultrasound B mode and Doppler information is then coupled to the adjacent back end ASIC 50 for scan conversion and the production of video output signals. A memory device 42 is coupled to the back end ASIC 50 to provide storage used in three dimensional power Doppler (3D CPA) imaging. The back end ASIC also adds alphanumeric information to the display such as the time, date, and patient identification. A graphics processor overlays the ultrasound image with information such as depth and focus markers and cursors. Frames of ultrasonic images are stored in a video memory 54 coupled to the back end ASIC 50, enabling them to be recalled and replayed in a live Cineloop® realtime sequence. Video information is available at a video output in several formats, including NTSC and PAL television formats and RGB drive signals for an LCD display 60 or a video monitor.

The back end ASIC 50 also includes the central processor for the ultrasound system, a RISC (reduced instruction set controller) processor. The RISC processor is coupled to the front end and digital signal processing ASICs to control and synchronize the processing and control functions throughout the hand-held unit. A program memory 52 is coupled to the back end ASIC 50 to store program data which is used by the RISC processor to operate and control the unit. The back end ASIC 50 is also coupled to a data port configured as a PCMCIA interface 56. This interface allows other modules and functions to be attached to the hand-held ultrasound unit. The interface 56 can connect to a modem or communications link to transmit and receive ultrasound information from remote locations. The interface can accept other data storage devices to add new functionality to the unit, such as an ultrasound information analysis package.

The RISC processor is also coupled to the user controls 70 of the unit to accept user inputs to direct and control the operations of the hand-held ultrasound system.

Power for the hand-held ultrasound system in a preferred embodiment is provided by a rechargeable battery. Battery power is conserved and applied to the components of the unit from a power subsystem 80. The power subsystem 80 includes a DC converter to convert the low battery voltage to a higher voltage which is applied to the transmit/receive ASIC 20 to drive the elements of the transducer array 10.

The power monitor and control in unit 80 operates in accordance with the description with reference to Fig. 2 and controls the operating mode of the LCD display 60 and video circuitry in unit 50 along with the clock frequency of the RISC processor in unit 50 and the clock frequencies of the VCA and ADC units in beamformer circuitry 30. The color power and geography function unit and 3D signal processing of DSP unit 40 are similarly controlled by the power monitor and control.

In Fig. 3, power consumption is controlled by power monitor and control block 80 and master clock control 90 which are both controlled by the RISC processor in block 50. The overall signal path depicted in Fig. 3 contains various functional blocks such as the analog to digital converters (ADC) 34 in block 30, the color power angio processor 44 in block 40, and the frequency compounding processor 46 in block 40. Each such functional block may be turned off individually by the power monitor and control circuit 80. As an example, when the ultrasound system is imaging in B-mode only, the color power angio block 44 is not needed and is turned off.

In addition to controlling whether functional blocks are on or off, power monitor and control block 80 controls the bias current supplied to ADC block 34. Lower frequency operation typically requires less bias current. Similarly, voltage and current supplied to transmit/receive block 20 is controlled as appropriate. As an example, superficial imaging typically will require less transmitted power than deep abdominal imaging.

Power monitor and control block 80 also controls power to LCD display 60, and in particular to the backlight associated with the LCD display. The display may be provided with less current (dimmed) to conserve power.

In terms of overall system operation, the system may be in one of several power conservation modes at any particular time. For example, a full operation mode may draw the most power, while a "freeze" mode that allows review of stored images but not active scanning would draw less power. A sleep mode where the display and most other functions are disabled would draw even less power, while a power-off mode would draw no power. Power monitor and control block 80 controls transitions between these states based on algorithms executed by the RISC processor contained in block 50.

In the preferred embodiment, many of the functional blocks described are embedded in Application Specific Integrated circuits (ASICs) 20,30, 40, and 50 in Fig. 1. The choice of which functions to integrate on each ASIC relates to power consumption. For example, the integration of ADC blocks 34 and delay and sum blocks 36 and 38 are integrated in the same ASIC to conserve power. Separation of these elements would require higher current driver circuitry for communication between blocks.

The use of power monitor and control functions in a portable ultrasonic diagnostic instrument limits power consumption and enables an instrument operating within a limited power range. While the invention has been described with reference to specific embodiments the description illustrative of the invention and is not to be construed as limiting the invention. Various modifications and applications may occur to those skilled in the art without departing from the true spirit and scope of the invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1. In a portable ultrasonic diagnostic instrument having ultrasound transducers for transmitting and receiving ultrasonic waves and beamforming circuitry for focusing transmitted and received waves, a method of operating the instrument at a reduced power consumption level comprising the steps of:

a) providing a battery source of electrical current for circuitry in the instrument, and

b) selecting altering circuitry functions depending on mode of operation of the instrument thereby reducing power consumption.

2. The method as defined by claim 1 wherein step b) is performed before instrument operation.

3. The method as defined by claim 2 wherein step b) is performed also during instrument operation.

4. The method as defined by claim 2 wherein the instrument further includes signal processing circuitry, imaging circuitry for controlling a display of processed signals, and a display.

5. The method as defined by claim 4 wherein step b) includes altering display of processed signals.

6. The method as defined by claim 5 wherein the display of processed signals is shifted in mode from active scanning to a mode selected from freeze and sleep.

7. The method as defined by claim 4 wherein step b) further includes turning off un-needed functional blocks.

8. The method as defined by claim 7 wherein un-needed functional blocks includes color display and 3D display of processed signals.

9. The method as defined by claim 4 wherein step b) further includes reducing clock frequency for at least one functional unit.

10. The method as defined by claim 9 wherein the at least one functional unit includes analog to digital signal conversion.

11. The method as defined by claim 9 wherein the at least one functional unit includes a data processor.

12. The method as defined by claim 1 wherein step b) further includes altering second functions in instrument operation when monitored current indicates the power consumption has reached a second power limit.

13. The method as defined by claim 12 wherein first functions and second functions selected from display operation, color signal processing, 3D signal processing, clock frequency for analog to digital signal conversion, and clock frequency for data processing.

14. A portable ultrasonic diagnostic instrument comprising:

a) ultrasound transducers for transmitting and receiving ultrasonic waves,

b) beamforming circuitry for focusing transmitted and received waves,

c) a display,

f) battery power, and

d) power control for limiting power consumption in the instrument not to exceed 25 watts.

15. The portable ultrasonic diagnostic instrument as defined by claim 14 wherein the beamforming circuitry is digital.

16. The portable ultrasonic diagnostic instrument as defined by claim 15 wherein the power control reduces clock frequency to analog to digital converter circuitry in the beamformer when power consumption exceeds a first limit.

17. The portable ultrasonic diagnostic instrument as defined by claim 16 and further including:

e) signal processing circuitry for processing electrical signals from received waves,

f) imaging circuitry for controlling a display of processed signals, and

g) a display.

18. The portable ultrasonic diagnostic instrument as defined by claim 13 wherein the power control blocks color display and 3D display of processed signals.

19. The portable ultrasonic diagnostic instrument as defined b claim 18 wherein power control alters display of processed signals.

20. The portable ultrasonic diagnostic instrument as defined by claim 19 wherein the display of processed signals is shifted in mode from active scanning to a mode selected from freeze and sleep.

21. The portable ultrasonic diagnostic instrument as defined by claim 14 wherein the beamforming circuitry is analog and the power control limits power consumption to 10 watts.

22. The portable ultrasonic diagnostic instrument as defined by claim 21 wherein power control limits one or more functions when power consumption reaches a first level.

23. The portable ultrasonic diagnostic instrument as defined by claim 22 wherein the one or more functions include display operation, color signal processing, 3D signal processing, clock frequency for analog to digital conversion, and clock frequency for data processing.

24. A portable ultrasonic diagnostic instrument comprising:

an array transducer,

a beamformer for delaying and combining echo signals received by elements of the array transducer,

signal processing and imaging circuitry for processing the echo signals, and

a display for the processed signals, wherein the instrument operates on no more than 25 watts of electrical power.

25. The instrument as defined by claim 24 wherein the beamformer is digital.

26. The instrument as defined by claim 24 wherein the beamformer is analog, wherein the instrument operates on no more than 10 watts of electrical power.

1/2

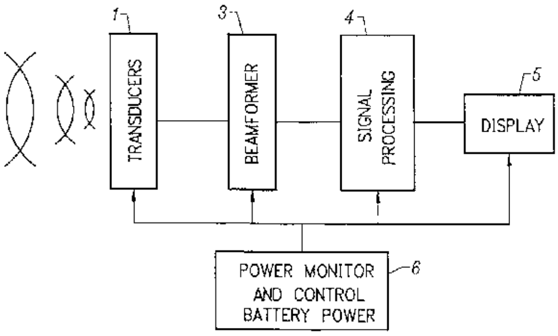
1
3
4
5
TRANSDUCERS
BEAMFORMER
SIGNAL PROCESSING
DISPLAY
POWER MONITOR AND CONTROL BATTERY POWER
6

FIG. 1

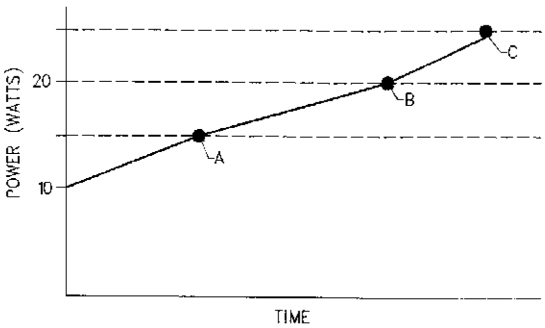
POWER (WATTS)
20
10
A
B
C
TIME

FIG. 2

2/2

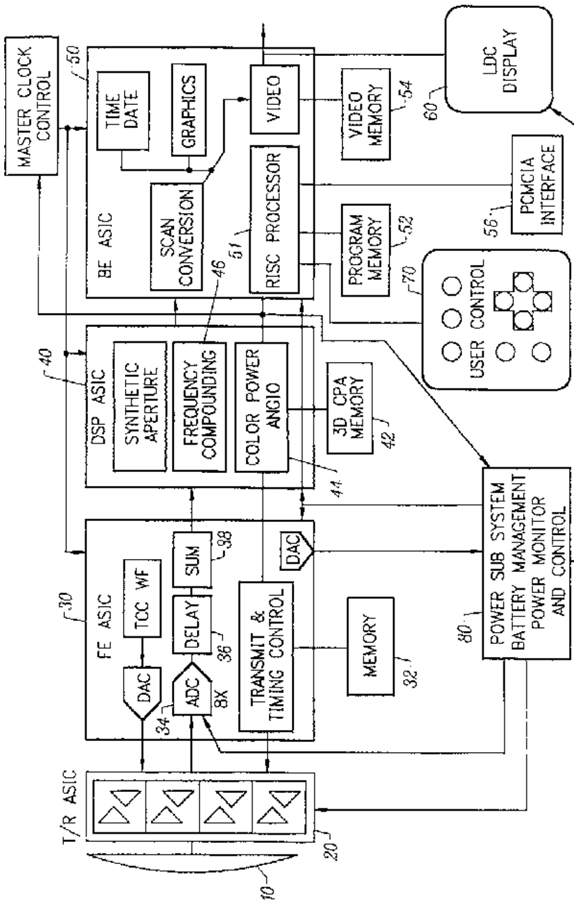
MASTER CLOCK CONTROL
50
BE ASIC
TIME DATE
GRAPHICS
VIDEO
SCAN CONVERSION
46
51
RISC PROCESSOR
VIDEO MEMORY
54
LDC DISPLAY
60
PROGRAM MEMORY
52
PCMCIA INTERFACE
56
USER CONTROL
70
40
DSP ASIC
SYNTHETIC APERTURE
FREQUENCY COMPOUNDING
COLOR POWER ANGIO
3D CPA MEMORY
42
44
POWER SUB SYSTEM BATTERY MANAGEMENT POWER MONITOR AND CONTROL
80
30
FE ASIC
TCC WF
DAC
ADC
8X
34
DELAY
36
SUM
38
DAC
TRANSMIT & TIMING CONTROL
MEMORY
32
T/R ASIC
20
10

FIG. 3

【国際調査報告】

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/12176

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :A61B 8/00
US CL :600/437
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. 73/618, 625, 626, 600/437, 438, 443, 447, 455, 456, 459

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,817,024 A (OGLE et al.) 06 October 1998, col. 3 lines 1-9.	1-26
Y	US 5,865,749 A (DOTEN et al.) 02 February 1999, col. 7 lines 36-59.	1-26

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 21 SEPTEMBER 2000	Date of mailing of the international search report 12 OCT 2000
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer FRANK JAWORSKI Telephone No. (703) 308-3061

Form PCT/ISA/210 (second sheet) (July 1998)★

INTERNATIONAL SEARCH REPORT

In ational application No.
PCT/US00/12176

B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

EAST
Search Terms: Ultra0$, Image$1, imaging, scanning, portable, handheld, battery or batteries, drain$ or prolong$, batiry life, power consumption, standby, mode

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[标]申请(专利权)人(译)	索诺塞特公司		
申请(专利权)人(译)	Sonosaito公司		
[标]发明人	ワンジュインジェット コフリンジャスティンエム ダートデイヴィン ジョーンズジェフリー リトルブレイクダブリュ		
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摘要(译)

便携式超声诊断仪器包括阵列换能器，波束形成器，信号处理和成像电路，以及用于处理的回波信号的显示器，其工作电压不超过25瓦。电路功能可以根据仪器的操作模式选择参加，从而降低功耗。此外，功率监视器和控制可以监视来自电池电源的电流，并且当功耗达到预定水平时，功率监视器和控制进一步改变仪器中的一个或多个功能单元，包括显示操作模式，时钟频率。用于模数转换和信号处理，颜色信号处理和3D信号处理。可以针对两个或更多个预定水平来监视功耗，其中根据已经达到的功耗水平来改变仪器功能单元或操作模式。在具有模拟波束形成器的仪器中，功耗可以被限制为10瓦，而在数字波束形成器中，功耗可以被限制为不超过25瓦。