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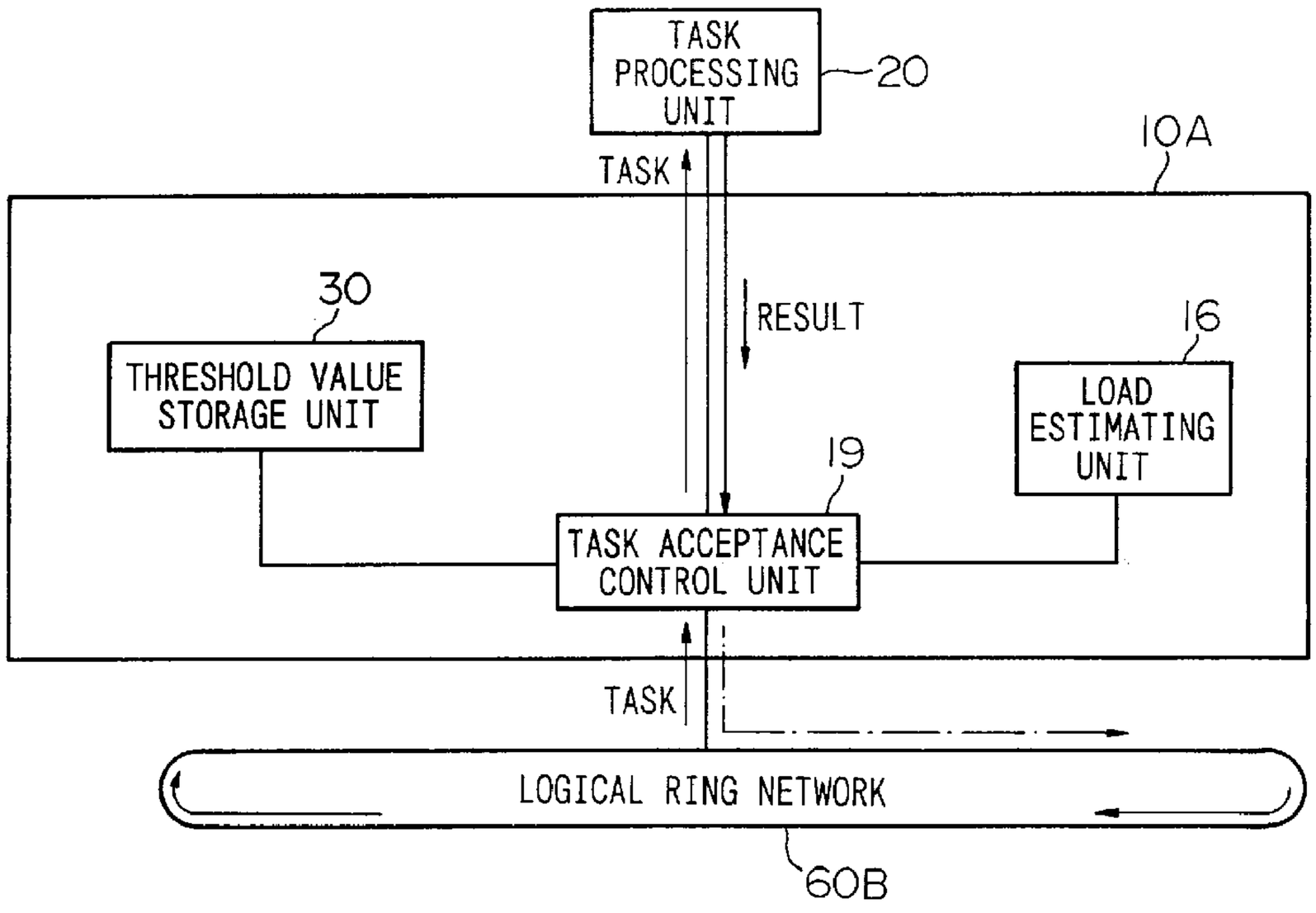
(54) **METHODE ET APPAREIL D'EQUILIBRAGE DE CHARGES**

(54) **LOAD BALANCING METHOD AND APPARATUS**



(57) L'invention est constituée par une méthode et un appareil d'équilibrage de charges qui permettent d'équilibrer, au prix d'un temps-système minime, une vaste gamme de charges de traitement dans toute l'étendue d'un système, tout en réduisant le temps de réponse moyen du système en question. La méthode de l'invention comporte les opérations suivantes : i) évaluation de la charge au noeud du moment d'après le nombre des tâches en cours ou en attente de traitement et détermination de la valeur de charge approximative du noeud; ii) acceptation d'une tâche passant dans un réseau en anneau logique (60B) et, chaque fois qu'une tâche est

(57) A load balancing method and apparatus are provided, by which loads in a wide range of the entire system can be balanced with a small overhead with respect to load balancing processing, and the mean response time of the entire system can be shortened. The method has the steps of (i) estimating a load of the present node based on the number of tasks being or waiting to be processed and determining an estimated load value of the node; (ii) accepting a task passing through a logical ring network (60B), and every time a task is accepted, comparing the estimated load value and a threshold value which is set with respect to the number

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acceptée, comparaison de la valeur de charge évaluée avec un seuil établi par rapport au nombre des tâches au noeud afin de limiter la charge de ce dernier; et iii) prise d'une décision basée sur le résultat de la comparaison précédente quant à savoir si la tâche acceptée doit être transmise à une unité de traitement de tâches (20) ou être retransmise au réseau en anneau logique sans passer par l'unité de traitement de tâches. Le seuil peut être modifié selon les variations du nombre de tâches passant dans le réseau en anneau logique durant une période fixe, ou quand une tâche aller-retour est détectée.

of tasks existing in the node so as to limit the load of the node; and (iii) judging, based on a result of the comparison, whether the accepted task is handed over to a task processing unit (20), or is transmitted to the logical ring network again without handing over the task to the task processing unit. The threshold value may be changed in accordance with a change of the number of tasks passing through the logical ring network during a fixed period, or when a round trip task is detected.

ABSTRACT

A load balancing method and apparatus are provided, by which loads in a wide range of the entire system can be balanced with a small overhead with respect to load balancing processing, and the mean response time of the entire system can be shortened. The method has the steps of (i) estimating a load of the present node based on the number of tasks being or waiting to be processed and determining an estimated load value of the node; (ii) accepting a task passing through a logical ring network (60B), and every time a task is accepted, comparing the estimated load value and a threshold value which is set with respect to the number of tasks existing in the node so as to limit the load of the node; and (iii) judging, based on a result of the comparison, whether the accepted task is handed over to a task processing unit (20), or is transmitted to the logical ring network again without handing over the task to the task processing unit. The threshold value may be changed in accordance with a change of the number of tasks passing through the logical ring network during a fixed period, or when a round trip task is detected.

LOAD BALANCING METHOD AND APPARATUS

The present invention relates to load balancing methods and apparatus used for a computer system in which plural nodes (computers, in practice) are connected with each other via a network and each node processes an input task (message). This application is based on Japanese Patent Application No. Hei 8-200451.

The computer systems in which plural computers (called "nodes", hereinafter) are connected to each other via a network are classified into two types according to the manner in which each task is accepted: one is a centralized arrival system in which all tasks are accepted by a single node (called a "task acceptance node") and the accepted tasks are distributed from the task acceptance node to other nodes; the other type is a distributed arrival system in which a task arrives at any node and the node accepts the task.

There are also two types of load balancing methods: one is a centralized control method in which one node in the system has load balancing processing equipment and only the node (having the load balancing processing equipment) performs load balancing processes; the other type is a distributed control method in which each node in the system has load balancing processing equipment and each node performs load balancing processes.

Regarding a load balancing method, used in such a computer system in which plural computers are connected with each other via a network, for balancing the load of each node by distributing loads of the entire system into each node and for

minimizing a mean response time of the entire system, Japanese Patent Application, First Publication, No. Hei 7-152700 discloses a (performance-function uniform) system in which all nodes in the system are uniform in performance and functions, that is, possible functions to be processed are the same.

In such a performance-function uniform system, the system load can be balanced just by equalizing the number of tasks in each node. However, in a system in which nodes in the system are not uniform in their performance, processing times are different according to performance of each node; thus, the system load cannot be balanced just by equalizing the number of tasks of each node. If a load balancing method used for the performance-function uniform system is applied to such a "performance non-uniform" system, the following problems may occur.

1. Task assignment in accordance with performance of each node is not performed. Therefore, even if there is a node with high performance has reserve ability to process tasks, a task may be assigned to a node having lower performance. That is, if tasks are assigned to nodes with high performance, response times could be shorter and consequently, the mean response time of the system could be minimized. However, the minimization cannot be realized for the above reason.

2. Owing to the order of the nodes in the system arrangement, tasks may be assigned to the nodes starting at a node with lower performance and progressing to a node with higher performance. In this case, nodes with high performance are not sufficiently used, thus the mean response time cannot be minimized.

On the other hand, in a "function non-uniform" system (that is, the number and the kinds of executable tasks are different with respect to each node), the system load cannot be balanced by using the above-mentioned load balancing method used for a performance-function uniform system because the number of steps to be performed is different for each function, and because the number of nodes which can execute a function is different for each function in the system. If applying a load balancing method used for the performance-function uniform system to such a

"performance uniform but function non-uniform" system, the following problems may occur.

1. In the above load balancing method used for the performance-function uniform system, tasks are assigned to each node without distinguishing tasks belonging to functions which many nodes in the system can execute from tasks belonging to functions which fewer nodes can execute. Therefore, even if it is possible to assign a "task belonging to a function which many nodes can execute" to a node which cannot execute a "task belonging to a function which fewer nodes can execute", the task (belonging to a function which many nodes can execute) may be assigned to a node which can execute tasks of both types, and thus a task belonging to the former type (that is, a task belonging to a function which fewer nodes can execute) might circulate in the network while waiting to be processed. In this case, the response time increases.

2. When the number of steps of an executable program to be performed is different for each function, a task having a large number of steps must be processed by the node with the lowest possible load at the time (that is, a node having sufficient resources for processing). However, in the load balancing method used for a function uniform system, tasks are assigned so as to equalize the number of tasks assigned to each node regardless of the number of steps of an executable program; thus, processing of an assigned task having a large total number of steps of an executable program may be delayed in the relevant node. Accordingly, the response time of a task assigned to such a node increases, thus the mean response time of the entire system is not minimized.

On the other hand, in order to balance loads in the distributed arrival system, it is necessary to transfer a task which arrived at any node to another node.

As a conventional transfer algorithm, "sender initiated" and "receiver initiated" algorithms are known. The sender initiated algorithm is effective when the load of the entire system is low. However, if the load of the entire system

becomes high, the mean response time increases and the system becomes unstable. In contrast, the receiver initiated algorithm is effective when the load of the entire system is high. However, when the load of the entire system is low, the mean response time is larger than that of the sender initiated algorithm. In either algorithm, information relating to loads of other nodes is not managed, and after the necessity of task transfer occurs, selection of a source or destination node is started. Therefore, it takes a lot of time before actual task transfer is started, that is, before the load is balanced.

Furthermore, in the distributed control method, information exchange between a node and another node is performed so as to select a source or a destination node; thus, network traffic of the entire system increases. As a result, a time necessary for task transfer increases and the net amount of decrease of the mean response time is small.

That is, in the above-mentioned conventional load balancing methods, there has been a problem in that if the method is applied to a system in which nodes are non-uniform in performance, task assignment in consideration of performance of each node cannot be performed whereby mean response times are not balanced between the nodes and the means response time of the entire system is not minimized.

Also in the above-mentioned conventional load balancing methods, there has been another problem in that if the method is applied to a system in which nodes are non-uniform in the kinds and the number of executable functions, tasks are assigned without consideration of the number of the nodes which can execute each task, a load for each function, and the number of steps in an executable problem for each node; therefore, the response time of a function may be larger and loads of the nodes are not balanced and thus the mean response time of the entire system is not minimized.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide load balancing methods and apparatus by which loads in a wide range (that is, from high to low) of an entire system can be balanced with a small overhead with respect to load balancing processing and the mean response time of the entire system can be shortened.

Another object of the present invention is to provide load balancing methods and apparatus which can effectively be applied to a performance non-uniform system consisting of nodes which are non-uniform in performance so as to balance the mean response times of the nodes and to realize minimization of the mean response time of the entire system.

A further object of the present invention is to provide load balancing methods and apparatus which can effectively be applied to a function non-uniform system in which nodes are uniform in performance but non-uniform in executable functions so as to realize minimization of the mean response time of the entire system and minimization of the mean response time relating to each function.

Therefore, the present invention provides a load balancing method using a computer system in which plural processing nodes, whose performance or executable functions are not uniform, are connected to a logical ring network, wherein when each node processes a task input from a terminal using a task processing unit and returns a result to the terminal, the logical ring network logically transmits tasks in turn and in one direction, said load balancing method equally distributing loads of the entire system into the nodes in the system and comprising the steps of:

(1) estimating a load of a present node based on the number of task being or waiting to be processed and determining an estimated load value of the present node for each executable function of the node;

(2) accepting a task passing through the logical ring network, and every time a task is accepted, comparing the estimated load value and a threshold value which is set with respect to the number of tasks existing in the node, to limit the load of the present node based on the performance or self-executable functions of the present node;

(3) judging, based on a result of the comparison, whether the accepted task is handed over to the task processing unit, or is transmitted to the logical ring network without handing over the task to the task processing unit;

(4) estimating load fluctuation of the entire system; and

(5) updating the threshold value according to the estimated load fluctuation of the entire system and the estimated value of each self-executable function of the present node.

In the above method, the threshold value may be changed in accordance with a change of the number of tasks passing through the logical ring network during a fixed period, or when a round trip task is detected.

In such a case, it is also preferable that:

(1) when organization of the nodes in the computer system is modified by deleting or adding a node, a threshold step as an amount for changing the threshold value is updated based on a value with respect to performance of the node added or deleted; or

(2) all tasks passing through the logical ring network are monitored; a load fluctuation of the entire computer system and a modification of organization of the nodes in the system are estimated in accordance with a change of the number of all passed tasks and with a change of the number of round trip tasks; and the threshold step is updated based on a result of the load fluctuation estimate.

The present invention also provides a load balancing apparatus provided for a computer system similar to the above, said load balancing apparatus, provided between the task processing unit in each node and the logical ring network and equally distributing loads of the entire system into the nodes in the system, the apparatus comprising:

(1) load estimating means for estimating a load of a present node based on the number of task being or waiting to be processed and for determining an estimated load value of the present node for each self-executable function of the present node;

(2) threshold value storage means for holding a threshold value with respect to the number of tasks existing in the node to limit the load of the present node based on the performance or self-executable functions of the present node;

(3) task acceptance control means for accepting a task passing through the logical ring network, and comparing the estimated load value and the threshold value of the node every time the control means accepts a task, and for judging, based on a result of the comparison, whether the accepted task is handed over to the task processing unit, or is transmitted to the logical ring network without handing over the task to the task processing unit; and

(4) threshold value updating means for estimating load fluctuation of the entire system and for updating the threshold value according to the estimated load fluctuation of the entire system and to the estimated load value of each self-executable function of the present node.

In this case, it is preferable to provide threshold step storage means for holding a threshold step which is an amount by which the threshold value is changed by the threshold value setting means, and to further provide:

(1) threshold step updating means which updates the threshold step stored in the threshold step storage means when organization of the nodes in the computer system is modified by deleting or adding a node, based in a value with respect to performance of the node added or deleted; or

(2) threshold step updating means which monitors all task passing through the logical ring network and estimates a load fluctuation of the entire computer system and a modification of organization of the nodes in the system in accordance with a change in the number of all passed tasks and with a change of the number of round trip tasks, and which updates the threshold step (stored in the threshold step storage means) based on a result of the estimate of the load fluctuation of the computer system and the modification or organization of the nodes in the system.

According to the above inventions, the following effects can be obtained:

(1) Task assignment according to the performance and load of each node is performed; thus, tasks are assigned to the nodes on the basis of performance levels in order from highest to lowest. Therefore, the response time of each task is minimized, and thus the mean response time of the entire system is minimized.

(2) Tasks are assigned to the nodes in the order of performance levels thereof regardless of the arrangement order of the nodes; thus, it is possible to make full use of high-performance nodes.

(3) Assignment of (i) tasks belonging to functions which many nodes in the system can execute and (ii) tasks belonging to functions which fewer nodes can execute is optimized by changing the number of tasks, which each node accepts, in accordance with (i) (for each function in the system,) the number of nodes which can execute the function and (ii) the load for each function. In this case, the response time with respect to a task belonging to a function which fewer nodes can execute does not become large; and

(4) The total number of steps in executable programs of each node is balanced by changing the threshold value of each node for each function in accordance with the number of steps of an executable program and load fluctuation of a self-executable function. Therefore, the mean response time of the entire system is minimized.

The present invention also provides a storage medium storing a computer program for making a computer execute the above method.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram showing the configuration of a load balancing apparatus provided for a computer system, as an embodiment of the present invention.

Fig. 2 is a diagram showing the configuration of a load balancing apparatus provided for a computer system, as another embodiment of the present invention.

Fig. 3 is a block diagram showing the configuration of a load balancing apparatus provided for a computer system, as yet another embodiment of the present invention.

Fig. 4 is a diagram showing an example of the arrangement with respect to the apparatuses of Figs. 1-3.

Fig. 5 is also a diagram showing an example of the arrangement with respect to the apparatuses as shown in Figs. 1-3.

Figs. 6A and 6B are flowcharts of general operations of the load balancing apparatus as shown in Fig. 1.

Figs. 7A and 7B are flowcharts of general operations of the load balancing apparatus as shown in Fig. 2.

Figs. 8A and 8B are flowcharts of general operations of the load balancing apparatus as shown in Fig. 3.

Figs. 9A and 9B are flowcharts of the operational example 1 of the load estimating unit.

Figs. 10A-10D are flowcharts of the operational example 2 of the load estimating unit.

Figs. 11A-11D are flowcharts of the operational example 3 of the load estimating unit.

Figs. 12A and 12B are flowcharts of the operational example 1 of the task acceptance control unit.

Figs. 13A and 13B are flowcharts of the operational example 2 of the task acceptance control unit.

Figs. 14A-14D are flowcharts of the operational example 3 of the task acceptance control unit.

Figs. 15A-15D are flowcharts of the operational example 4 of the task acceptance control unit.

Figs. 16A and 16B are flowcharts of the operational example 1 of the threshold value setting unit.

Fig 17 is a flowchart of the operational example 2 of the threshold value setting unit.

Figs. 18A and 18B are flowcharts of the operational example 3 of the threshold value setting unit.

Fig. 19 is a list showing examples for setting the threshold value based on combinations of the load fluctuation of the entire system and the detection situation

of the round trip task.

Fig. 20 is a block diagram showing an example of the centralized management system.

Fig. 21 is a block diagram showing another example of the centralized management system.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinbelow, preferred embodiments of the present invention will be explained in detail with reference to the drawings.

Figs. 1-3 are diagrams showing structures of three examples of the load balancing apparatus 10 (i.e., 10A-10C) according to the present invention, and Figs. 4 and 5 are diagrams showing examples of the arrangement with respect to these apparatuses. That is, the load balancing apparatus 10 is arranged between logical ring network 60B and each node (in the case shown in Fig. 4), or is arranged in each node (in the case shown in Fig. 5).

Load balancing apparatus 10A consists of load estimating unit 16 for estimating the load of the present node, threshold value storage unit 30, and task acceptance control unit 19. In load balancing apparatus 10B, threshold value setting unit 40 is provided in addition to the above elements in apparatus 10A, and in load balancing apparatus 10C, threshold step storage unit 31 for storing a threshold step (value) which is a unit for changing the threshold value and threshold step setting unit 41 are provided in addition to the above elements in apparatus 10B. Here, in the arrangement of load balancing apparatus 10B, a threshold step storage unit may separately be provided outside the threshold value setting unit 40.

The system arrangements as shown in Figs. 1-3 are examples belonging to the centralized arrival system, wherein after a task arrives at an entrance node, the task is input into logical ring network 60B by the entrance node and circulates around

the logical ring network 60B. A task which has not yet made a round of logical ring network 60B after the task is input into the network is called a "normal task (message)", while a task which has made one or more rounds of the logical ring network 60B before being processed by any node is called a "round trip task (message)". When a round trip task is input into the entrance node, the entrance nodes marks it and input the task into logical ring network 60B again so that each node can distinguish between a normal task and a round trip task.

In addition, a distributed arrival system can easily be realized by modifying the centralized arrival system in a manner such that each node performs the task acceptance, the input of tasks into the logical ring network, and the marking of round trip tasks, which are performed by an entrance node in the centralized arrival system.

General operations of load balancing apparatus 10A

Figs. 6A and 6B are flowcharts of general operations of load balancing apparatus 10A as shown in Fig. 1.

Load estimating unit 16 (for estimating the load of the present node) is activated when the estimating unit is informed by task acceptance control unit 19 that the control unit handed over a task of a self-executable function X (which means a function which the present node can execute) to task processing unit 20 or that the control unit received a result of the self-executable function X from task processing unit 20 (see step 3001). The activated load estimating unit 16 updates (or changes) an estimated load value (indicated by reference numeral "21X", hereinafter) of self-executable function X (see step 3002).

On the other hand, task acceptance control unit 19 judges whether or not a task belonging to the self-executable function X has been input from logical ring network 60B to task acceptance control unit 19 (see step 3003). If no task has been input, the task acceptance control unit 19 further judges whether or not a result has been input from task processing unit 20 (see step 3004). If judged "yes", the task

acceptance control unit 19 notifies load estimating unit 16 of the judgment (see step 3008). On the other hand, if a result has also not been input, the processing returns to step 3003.

If it was judged that a task has been input in step 3003, task acceptance control unit 19 reads out a (predetermined) threshold value relating to the self-executable function X (indicated by reference numeral "27X", hereinafter) from threshold value storage unit 30 (see step 3005), then compares the above estimated load value 21X with the threshold value 27X and judges whether the task can be accepted or not in accordance with the size comparison of both values (see step 3006). According to a result of the comparison, task acceptance control unit 19 hands over the task to task processing unit 20 (see step 3007), or inputs the task into logical ring network 60B without handing it over to task processing unit 20 (see step 3009). When task acceptance control unit 19 hands over a task to task processing unit 20 or receives a result from task processing unit 20, the control unit 19 notifies load estimating unit 16 of the event (see step 3008). An alternating long and short dash line in Fig. 1 shows the result from task acceptance control unit 19 and a task which has not been handed over to task processing unit 20.

In the operations described above, the task input control, the update of the estimated load value, and the comparison of the estimated load value and the threshold value are performed for each self-executable function X. However, depending on the form of an application system, each node may have a single estimated load value and a single threshold value (that is, not for each self-executable function) for observing and controlling all tasks, or both methods may be used together in a system.

General operations of load balancing apparatus 10B

Figs. 7A and 7B are flowcharts of general operations of load balancing apparatus 10B as shown in Fig. 2.

Load estimating unit 16 (for estimating the load of the present node) is activated when the estimating unit is informed by task acceptance control unit 19 that the control unit handed over a task of self-executable function X to task processing unit 20 or the control unit received a result of the self-executable function X from task processing unit 20 (see step 2001). The activated load estimating unit 16 updates an estimated load value 21X of self-executable function X (see step 2002).

On the other hand, task acceptance control unit 19 judges whether or not a task belonging to the self-executable function X has been input from logical ring network 60B to task acceptance control unit 19 (see step 2003). If no task has been input, the task acceptance control unit 19 further judges whether or not a result has been input from task processing unit 20 (see step 2004). If judged "yes", the task acceptance control unit 19 notifies load estimating unit 16 of the judgment (see step 2008). On the other hand, if a result has also not been input, the processing returns to step 2003.

If it was judged that a task has been input in step 2003, task acceptance control unit 19 notifies threshold value setting unit 40 of the judgment. The threshold value setting unit 40 estimates a load fluctuation of the entire system by monitoring tasks passing through the logical ring network 60B according to the notification from task acceptance control unit 19, and updates total threshold value 27 of the present node according to the estimated load fluctuation. The task acceptance control unit 19 also estimates a load fluctuation with respect to self-executable functions, and updates threshold value 27X for each self-executable function according to the estimated load fluctuation (see step 2005).

If an input task belongs to the function X, the task acceptance control unit 19 compares the above estimated load value 21X with the threshold value 27X, and judges whether the task can be accepted or not in accordance with the size comparison of both values (see step 2006). According to a result of the comparison, task acceptance control unit 19 hands over the task to task processing unit 20 (see

step 2007), or inputs the task into logical ring network 60B without handing it over to task processing unit 20 (see step 2009). When task acceptance control unit 19 hands over a task to task processing unit 20 or receives a result from task processing unit 20, the control unit 9 notifies load estimating unit 16 of the event (see step 2008). An alternating long and short dash line in Fig. 2 shows the result from task acceptance control unit 19 and a task which has not been handed over to task processing unit 20.

When the load balancing apparatus operating as explained above is applied to a function non-uniform system in which the number and the kinds of executable tasks are different with respect to each node, the logical ring network is used as a common buffer for each node; the load relating to the self-executable function X of each node is estimated by the load estimating unit of the node; the threshold value of the entire system and the threshold value of self-executable function X are updated by the threshold value setting unit according to load fluctuation of the entire system and load fluctuation of the self-executable function; the estimated load value of self-executable function X and the threshold value of self-executable function X are compared by the task acceptance control unit; and task acceptance control is performed in accordance with the size comparison of both values. Therefore:

(1) Assignment of (i) tasks belonging to functions which many nodes in the system and (ii) tasks belonging to functions which fewer nodes can execute is optimized by changing the number of tasks, which each node accepts, in accordance with (i) (for each function in the system,) the number of nodes which can execute the function and (ii) the load for each function. In this case, the response time with respect to a task belonging to a function which fewer nodes can execute does not become large; and

(2) The total number of steps in executable programs of each node is balanced by changing the threshold value of each node for each function in accordance with the number of steps of an executable program and load fluctuation of a self-executable

function. Therefore, the mean response time of the entire system is minimized.

General operations of load balancing apparatus 10C

Figs. 8A and 8B are flowcharts of general operations of load balancing apparatus 10C as shown in Fig. 3.

Load estimating unit 16 (for estimating the load of the present node) is activated when the estimating unit is informed by task acceptance control unit 19 that the control unit handed over a task to task processing unit 20 or the control unit received a result of processing of the task from task processing unit 20 (see step 1011). The activated load estimating unit 16 updates an estimated load value (indicated by reference numeral "21", hereinafter) of the node (see step 1012).

On the other hand, task acceptance control unit 19 judges whether or not a task has been input from logical ring network 60B to task acceptance control unit 19 (see step 1013). If no task has been input, the task acceptance control unit 19 further judges whether or not a result has been input from task processing unit 20 (see step 1014). If judged "yes", the task acceptance control unit 19 notifies load estimating unit 16 of the judgment (see step 1018). On the other hand, if a result has also not been input, the processing returns to step 1013.

If it was judged that a task has been input in step 1013, task acceptance control unit 19 notifies threshold value setting unit 40 of the judgment. The threshold value setting unit 40 estimates a load fluctuation of the entire system by monitoring tasks passing through the logical ring network 60B according to the notification from task acceptance control unit 19, and updates threshold value 27 of the present node. Threshold step setting unit 41 updates a threshold step (indicated by reference numeral "28", hereinafter) as a unit for changing the threshold value, by estimating performance of the entire system and performance of the present node at each time (see step 1015), or by receiving information relating to the performance of the entire system and the performance of the present node from an

external unit.

The task acceptance control unit 19 compares the above estimated load value 21 with the threshold value 27, and judges whether the task can be accepted or not in accordance with the size comparison of both values (see step 1016). According to a result of the comparison, task acceptance control unit 19 hands over the task to task processing unit 20 (see step 1017), or inputs the task into logical ring network 60B without handing it over to task processing unit 20 (see step 1019). When task acceptance control unit 19 hands over a task to task processing unit 20 or receives a result from task processing unit 20, the control unit 9 notifies load estimating unit 16 of the event (see step 1018). An alternating long and short dash line in Fig. 3 shows the result from task acceptance control unit 19 and a task which has not been handed over to task processing unit 20.

When the load balancing apparatus operating as explained above is applied to a performance non-uniform system in which the performance with respect to each node is different, the logical ring network is used as a common buffer for each node; the load of each node is estimated by the load estimating unit of the node; the threshold value of the present node is updated by the threshold value setting unit according to load fluctuation of the entire system; the threshold step is set according to the performance of the entire system and the performance of the present node by the threshold step setting unit, and when the performance of the entire system is changed, the threshold value is updated according to the change; the estimated load value and the threshold value of the node are compared by the task acceptance control unit; and task acceptance control is performed in accordance with the size comparison of both values. Therefore:

(1) Task assignment according to the performance and load of each node is performed; thus, tasks are assigned to the nodes on the basis of performance levels in order from highest to lowest. Therefore, the response time of each task is minimized, and thus the mean response time of the entire system is minimized.

(2) Tasks are assigned to the nodes in the order of performance levels thereof regardless of the arrangement order of the nodes; thus, it is possible to make full use of high-performance nodes.

In the operations described above, the control (not for each function) using a single estimated load value and a single threshold value of the present node is performed. However, depending on the form of an application system, the task input control, the updating of the estimated load value, and the comparison of the estimated load value and the threshold value may be performed for each self-executable function X, or both methods may be used together in a system.

Next, plural operational examples of load estimating unit 16 will be explained. The following examples may be applied to any of the load balancing apparatuses 10A-10C.

Operational example 1 of load estimating unit

Fig. 9A is a flowchart of the operational example 1 which uses a task counter.

When a task relating to function X is handed over from task acceptance control unit 19 to task processing unit 20, load estimating unit 16 (for the present node) increases a task counter for function X by "1" (see steps 2101 and 2102), while when a result of the task for function X is informed from task processing unit 20 to task acceptance control unit 19, load estimating unit 16 decreases the task counter by "1" (see steps 2103 and 2104). The load estimating unit 16 then sets estimated load value 21X of self-executable function X to be the counter value as a result of the increasing or decreasing operation, and informs task acceptance control unit 19 of the set value.

When estimated load value 21 (that is, not for each function) is set, similar operations are used and a flowchart for such a case is shown in Fig. 9B.

Operational example 2 of load estimating unit

Figs. 10A and 10B are flowcharts of the operational example 2 which uses a response time.

When a task of function X is handed over from task acceptance control unit 19 to task processing unit 20, load estimating unit 16 (for the present node) records the (present) time T_r (see steps 2401 and 2402), while when a relevant result of the task for function X is informed from task processing unit 20 to task acceptance control unit 19, load estimating unit 16 records the (present) time T_s (see steps 2403 and 2404). The load estimating unit 16 then calculates response time "$RT_x = T_s - T_r$" (see step 2405) and divides the response time RT_x by response time RT_{x0} which is used for such a case in which a task of self-executable function X is exclusively processed in a node which has no tasks in the waiting queue at that time. The fractions of the quotient are then rounded up so as to make an integer, and estimated load value 21X of self-executable function X is set to be this integer (see step 2406).

When estimated load value 21 (not for each function) is set, similar operations are used and a flowchart for such a case is shown in Figs. 10C and 10D.

Operational example 3 of load estimating unit

Figs. 11A and 11B are flowcharts of the operational example 3 which uses an average of the response time.

Regarding n tasks (n being a fixed number) of self-executable function X, when each task is handed over from task acceptance control unit 19 to task processing unit 20, load estimating unit 16 (for the present node) records the (present) time T_{ri} (i=1, 2, $\cdots$, n) (see steps 2501 and 2502), while when a result of each task of function X is informed from task processing unit 20 to task acceptance control unit 19, load estimating unit 16 records the (present) time T_{si}. The load

estimating unit 16 then measures each response time "$RT_{xi} = T_{si}-T_{ri}$" (i=1, 2, ···, n) (see steps 2503-2508) and calculates an average of the response times (i.e., the mean response time) RT_{xmean} by the following formula (see step 2509):

$$RT_{xmean} = (\Sigma\ RT_{xi})/n$$

This mean response time RT_{xmean} is divided by response time RT_{x0} used for such a case in that a task of self-executable function X is exclusively processed. The fractions of the quotient is then rounded up so as to make an integer, and estimated load value 21X of self-executable function X is set to be this integer (see step 2510).

Here, mean response time RT_{xmean} may be calculated by measuring an entire response time RT_{xi} with respect to tasks processed in a fixed time.

When estimated load value 21 (not for each function) is set, similar operations are used and a flowchart for such a case is shown in Figs. 11C and 11D.

Next, plural operational examples of task acceptance control unit 19 will be explained. The following examples may also be applied to any of the load balancing apparatuses 10A-10C.

Operational example 1 of task acceptance control unit

Fig. 12A is a flowchart of the operational example 1, which is an example using a result of comparison between estimated load value 21X and threshold value 27X of self-executable function X.

Task acceptance control unit 19 compares estimated load value 21X of self-executable function X with threshold value 27X of the function X for each arrival of a task relating to function X (see steps 2301 and 2302). If estimated load value 21X of

self-executable function X is smaller than threshold value 27X of the function X, the task acceptance control unit 19 hands over the task to task processing unit 20 regardless of the kind of task (that is, in either the case of a round trip task or a normal task) (see step 2303). In the other cases, that is, if estimated load value 21X of self-executable function X is equal to or greater than threshold value 27X of the function X, the task acceptance control unit 19 hands over the task if the task is a round trip task and the condition "threshold value 27X > estimated load value 21X" would be realized by increasing the threshold value 27X (see steps 2304, 2305, and 2303). If the task is not a round trip task in step 2304, the task is input into logical ring network 60B (see step 2306).

When task acceptance control is performed by using a result of comparison between estimated load value 21 and threshold value 27 (that is, not for each function), similar operations are used and a flowchart for such a case is shown in Fig. 12B.

Operational example 2 of task acceptance control unit

Fig. 13A is a flowchart of the operational example 2, which is another example using a result of comparison between estimated load value 21X and threshold value 27X of self-executable function X. Judgment performed in this example is simpler.

Task acceptance control unit 19 compares estimated load value 21X of self-executable function X with threshold value 27X of the function X for each arrival of a task relating to function X (see steps 2701 and 2702). If estimated load value 21X of self-executable function X is smaller than threshold value 27X of the function X, the task acceptance control unit 19 hands over the task to task processing unit 20 (see step 2703), while if estimated load value 21X of self-executable function X is equal to or greater than threshold value 27X of the function X, the task acceptance control

unit 19 inputs the task into logical ring network 60B (see step 2704).

When task acceptance control is performed by using a result of comparison between estimated load value 21 and threshold value 27 (not for each function), similar operations are used and a flowchart for such a case is shown in Fig. 13B.

Operational example 3 of task acceptance control unit

Figs. 14A and 14B are flowcharts of the operational example 3, which is an example using a task acceptance control flag in addition to a result of comparison between estimated load value 21X and threshold value 27X of self-executable function X.

Task acceptance control unit 19 periodically compares estimated load value 21X of self-executable function X with threshold value 27X of the function X for each fixed period (see steps 2801 and 2802). If estimated load value 21X of self-executable function X is smaller than threshold value 27X of the function X, the task acceptance control unit 19 sets task acceptance control flag 29X to be in an "on" state (see step 2803). In the other cases, that is, if estimated load value 21X of self-executable function X is equal to or greater than threshold value 27X of the function X, the task acceptance control unit 19 sets the task acceptance control flag 29X to be in an "on" state if the task is a round trip task and the condition "threshold value 27X > estimated load value 21X" would be realized by increasing the threshold value 27X (see steps 2804, 2805, and 2803). If the task is not a round trip task in step 2804, the task acceptance control flag 29X is set to be in an "off" state (see steps 2804 and 2806).

When a task relating to function X arrives, the task acceptance control unit 19 examines the state of task acceptance control flag 29X (see steps 2807 and 2808), and if the flag is "on", the task is handed over to task processing unit 20 (see step 2809), while if the flag is "off", the task is input into logical ring network 60B (see

step 2810).

Here, comparison in step 2802 may be performed with a change of threshold value 27X of self-executable function X for the present node or a change of estimated load value 21X (of self-executable function X) as a trigger.

When task acceptance control is performed by using a result of comparison between estimated load value 21 and threshold value 27 and task acceptance control flag 29 (that is, not for each function), similar operations are used and a flowchart for such a case is shown in Figs. 14C and 14D.

Operational example 4 of task acceptance control unit

Figs. 15A and 15B are flowcharts of the operational example 4, which is the second example using a task acceptance control flag.

Task acceptance control unit 19 periodically compares estimated load value 21X of self-executable function X with threshold value 27X of the function X for each fixed period (see steps 2901 and 2902). If estimated load value 21X is smaller than threshold value 27X of the function X, the task acceptance control unit 19 sets task acceptance control flag 29X to be in an "on" state (see step 2903). If estimated load value 21X is equal to or greater than threshold value 27X, the task acceptance control unit 19 sets the task acceptance control flag 29X to be in an "off" state (see step 2904).

When a task relating to function X arrives, the task acceptance control unit 19 examines the state of task acceptance control flag 29X (see steps 2905 and 2906), and if the flag is "on", the task is handed over to task processing unit 20 (see steps 2906 and 2907). If the flag is "off", the task is a round trip task, and the condition "threshold value 27X $>$ estimated load value 21X" would be realized by increasing the threshold value 27X, then the task is also handed over to task processing unit 20 (see steps 2908, 2909 and 2907). On the other hand, if task acceptance control flag

29X is "off" and the task is not a round trip task, the task is input into logical ring network 60B (see step 2910).

Here, comparison in step 2902 may be performed with a change of threshold value 27X of self-executable function X for the present node or a change of estimated load value 21X (of self-executable function X) as a trigger.

When task acceptance control is performed by using a result of comparison between estimated load value 21 and threshold value 27 and task acceptance control flag 29 (not for each function), similar operations are used and a flowchart for such a case is shown in Figs. 15C and 15D.

Next, plural operational examples of threshold value setting unit 40 will be explained. The following examples may be applied to either of the load balancing apparatuses 10B and 10C.

Operational example 1 of threshold value setting unit

Fig. 16A is a flowchart of the operational example 1 of threshold value setting unit 40. In this example, the threshold value is updated when a round trip task is detected.

Threshold value setting unit 40 monitors, via task acceptance control unit 19, all tasks passing through logical ring network 60B. When the threshold value setting unit 40 detects a round trip task relating to a self-executable function X, the unit records the time of the detection (see steps 2201 and 2202).

Next, if:

(1) an amount obtained by subtracting the preceding detection time from the present detection time with respect to the round trip task is greater than a predetermined "round trip" time (see step 2203);

(2) estimated load value 21X of self-executable function X compared with threshold value 27X of the function X is equal to or greater than the threshold value

27X (see step 2204);

(3) a value obtained by adding a predetermined threshold step with respect to the function X (the threshold value will be called "1 unit" hereinafter, and the value of the "1 unit" is independently determined for each function) to the threshold value 27X is smaller than an upper limit threshold value $27X_{L1}$ which is predetermined with respect to the function X (see step 2205); and

(4) the total value of (i) the sum of threshold values $27X_i$ of each self-executable function X_i (i.e., the sum of threshold values $27X_1+27X_2+\cdots$) of the present node and (ii) the threshold step (value) of the above (specified) function X does not exceed the overall threshold value 27 of the present node (see step 2206);

then the threshold value setting unit 40 increases threshold value 27X by "1 unit" (see step 2207).

While if a round trip task is not detected, if:

(1) the difference between the present time and the preceding detection time with respect to the round trip task is greater than the round trip time of the task; and

(2) threshold value 27X would not be smaller than a lower limit threshold value $27X_{L2}$ (which is also predetermined with respect to the function X) even if the threshold value 27X is decreased by "1 unit", the threshold value setting unit 40 decreases threshold value 27X by "1 unit" (see steps 2208-2210).

When the threshold value is updated by using a result of comparison between estimated load value 21 and threshold value 27 (that is, not for each function), similar operations are used but the process corresponding to the above step 2206 is unnecessary in this case. A flowchart for such a case is shown in Fig. 16B.

Operational example 2 of threshold value setting unit

Fig. 17 is a flowchart of the operational example 2 of threshold value setting

unit 40. In this example, an estimated value for load fluctuation (i.e., estimated load fluctuation) is calculated.

Threshold value setting unit 40 counts, via task acceptance control unit 19, the number of all tasks which have passed through logical ring network 60B during a fixed measurement period (see steps 2601-2606) and calculates a ratio of the counted value to the preceding counted value (measured similarly) of all tasks which passed through the network during the preceding measurement period. An estimated value of load fluctuation of the entire system is determined as the ratio (see step 2607).

The threshold value setting unit 40 continues to monitor all tasks passing through logical ring network 60B and to calculate the estimated value of load fluctuation. In a case in which the estimated value of load fluctuation of the entire system has increased, if estimated load value 21 of the present node is equal to or greater than threshold value 27, the threshold value 27 is increased by a predetermined amount unless the threshold value 27 exceeds a predetermined upper limit 27_{L1} for the threshold value (see steps 2608-2611). In the opposite case in which the estimated value of load fluctuation of the entire system has decreased, the threshold value 27 is decreased by a predetermined amount unless the threshold value 27 falls below a predetermined lower limit 27_{L2} for the threshold value (see steps 2612-2614). Here, symbols α and β indicate any reasonable values greater than 0 and smaller than 1.

In addition, if the estimated value of load fluctuation of the entire system is very small, no change of the overall threshold value 27 of the present node may be better. Therefore, the update of the threshold value is performed when the estimated value of load fluctuation is greater than a predetermined level.

Operational example 3 of threshold value setting unit

Figs. 18A and 18B are flowcharts of the operational example 3 of threshold value setting unit 40. In this example, an estimated value for load fluctuation with respect to self-executable function X is calculated.

Threshold value setting unit 40 counts, via task acceptance control unit 19, the number of all tasks relating to function X, which have passed through logical ring network 60B during a fixed measurement period (see steps 2615-2620) and calculates a ratio of the counted value to the preceding counted value of passed tasks of function X during the preceding measurement period. An estimated value of load fluctuation of the function X is determined as the ratio (see step 2621).

The threshold value setting unit 40 continues to monitor all tasks relating to function X passing through logical ring network 60B and to calculate the estimated value of load fluctuation for each function.

(1) In a case in which the estimated value of load fluctuation of the function X is greater than 1, if:

(i) estimated load value 21X of self-executable function X is equal to or greater than threshold value 27X of the function X;

(ii) the updated threshold value 27X does not exceed upper limit $27X_{L1}$ of the threshold value 27X; and

(iii) the total value of (i) the sum of threshold values $27X_i$ of each self-executable function X_i (i.e., the sum of threshold values $27X_1+27X_2+\cdots$) of the present node and (iv) the threshold step (value) of the above (specified) function X does not exceed the overall threshold value 27 of the present node;

then threshold value 27X is increased according to the amount of the estimated value of load fluctuation of self-executable function X (see steps 2622-2626).

(2) In a case in which the estimated value of load fluctuation of the function X is smaller than 1, if:

(i) estimated load value 21X of self-executable function X is smaller than

threshold value 27X of the function X; and

(ii) the updated threshold value 27X is greater than or equal to lower limit $27X_{L2}$ of the threshold value 27X;

then threshold value 27X is decreased (see steps 2627-2630). Here, symbols α and β indicate any reasonable values greater than 0 and smaller than 1.

In addition, if the estimated value of load fluctuation of self-executable function X is very small, no change of the threshold value 27X of the function X may be better. Therefore, the update of the threshold value is performed when the estimated value of load fluctuation is greater than a predetermined level.

In load balancing apparatus 10C having threshold step setting unit 41, threshold step can be updated (or changed).

The threshold step setting unit 41 holds a value with respect to performance of the entire system (that is, the total performance of all nodes in the system) and a value with respect to performance of the present node, as known information, and sets an initial value of threshold step 28 to be a value obtained by dividing the value of the performance of the present node by the value of the performance of the entire system (normally, the initial value is provided from an external unit before the system operation is started). When a node is deleted from the system or a node is added to the system, the threshold step setting unit 41 updates the threshold step 28 based on a value with respect to performance of the node which has been deleted or added.

That is, the initial value of threshold step is set to be in an suitable value such as 0.1, 0.5, or 1. The threshold step setting unit 41 presumes that a node is deleted from the system or that a node is newly added to the system, based on a fluctuation manner of the flow rate of tasks passing through logical ring network 60B and a detection situation of round trip tasks, and updates threshold step 28 when

deletion or addition of a node is presumed. Examples based on combinations of the fluctuation manner of the flow rate of tasks passing through logical ring network 60B (called "load fluctuation of the entire system") and the detection situation of the round trip task is shown in the list in Fig. 19.

Example of arrangement of centralized management system

In the above-explained load balancing apparatuses 10B and 10C, threshold value setting unit 40 and threshold step setting unit 41 are provided for each node, that is, the units corresponding to the number of the nodes in the system are provided. However, threshold value setting unit 40C and threshold step setting unit 41C which perform centralized controls of updating the threshold value and the threshold step of each node may be provided. Exemplary arrangements of such a control are shown in Figs. 20 and 21.

Fig. 20 shows an arrangement of a combination of load balancing apparatus 10D, which is an example of a centralized management system relating to load balancing apparatus 10B as shown in Fig. 2, and threshold value setting unit 40C. Here, threshold value setting unit 40C is provided in a node in the system or are independently provided, and performs threshold value setting processes of each node via logical ring network 60B and task acceptance control unit 19 of each node. The operations of the processes are similar to each relevant above-mentioned operation examples.

Fig. 21 shows an arrangement of a combination of load balancing apparatus 10E, which is an example of a centralized management system relating to load balancing apparatus 10C as shown in Fig. 3; and threshold value setting unit 40C; and threshold step setting unit 41C. Here, threshold value setting unit 40C and threshold step setting unit 41C are provided in a node in the system or are independently provided, and performs threshold value and threshold step setting processes of each node via logical ring network 60B and task acceptance control unit

19 of each node. The operations of the processes are similar to each relevant above-mentioned operation examples.

In each operational example explained, tasks are processed in turn from one which is earlier handed over to task processing unit 20, and results of processing are output in the same order of processing of the tasks, where one result for each task is returned. However, in another case in which results are output in another order different from the order of inputting tasks, the system can easily be operated by establishing correspondence between tasks and their results using identifiers and the like.

In yet another case in which plural results are returned for one task, the system can easily be operated by identifying the last result.

In addition, when load balancing apparatus is separately provided outside each node, as shown in Fig. 4, load balancing processing can be performed without imposing an extra burden on (computer) processing in each node; thus, the mean response time can much further be shortened, even at high load levels, in comparison with conventional systems. Furthermore, by making an LSI of the load balancing apparatus for making the apparatus independently operate, greater high-speed processing and contraction of the mean response time are realized.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A load balancing method for a computer system in which plural processing nodes, whose performance or executable functions are not uniform, are connected to a logical ring network, wherein when each node processes a task input from a terminal using a task processing unit and returns a result to the terminal, the logical ring network logically transmits tasks in turn and in one direction, said load balancing method equally distributing loads of the entire system into the nodes in the system and comprising the steps of:

estimating a load of a present node based on the number of tasks being or waiting to be processed and determining an estimated load value of the present node for each self-executable function of the node;

accepting a task passing through the logical ring network, and every time a task is accepted, comparing the estimated load value and a threshold value, which is set with respect to the number of tasks existing in the node, to limit the load of the present node based on the performance or self-executable functions of the present node;

judging, based on a result of the comparison, whether the accepted task is handed over to the task processing unit, or is transmitted to the logical ring network without handing over the task to the task processing unit;

estimating load fluctuation of the entire system; and

updating the threshold value according to the estimated load fluctuation of the entire system and the estimated value of each self-executable function of the present node.

2. The load balancing method as claimed in claim 1, further comprising the step of updating a threshold step as an amount for changing the threshold value.

3. The load balancing method as claimed in claim 2, wherein the step of updating the threshold step includes performing centralized management with respect to the threshold steps of plural processing nodes and updating the threshold step for each node.

4. The load balancing method as claimed in claim 2, wherein when organization of the nodes in the computer system is modified by deleting or adding a node, the threshold step is updated based on a value with respect to performance of the node added or deleted.

5. The load balancing method as claimed in claim 2, wherein the step of updating the threshold step includes:

monitoring all tasks passing through the logical ring network;

estimating a load fluctuation of the entire system and a modification of organization of the nodes in the system in accordance with a change of the number of all passed tasks and with a change of the number of round trip tasks;

and

updating the threshold step based on a result of the load fluctuation estimate.

6. The load balancing method as claimed in claim 5, wherein the step of updating the threshold value includes:

monitoring all tasks passing through the logical ring network; and

updating the threshold value when a round trip task is detected.

7. The load balancing method as claimed in claim 6, wherein the step of determining the estimated load value includes:

increasing the task counter by 1 when a task is handed over to the task processing unit, and decreasing the task counter by 1 when a result is returned from the task processing unit; and

determining the estimated load value as the value of the task counter.

8. The load balancing method as claimed in any one of claims 1 to 7, wherein the step of updating the threshold value includes performing centralized management with respect to the threshold values of plural processing nodes and updating the threshold value for each node.

9. The load balancing method as claimed in any one of claims 1 to 8, wherein a predetermined value greater than 0 is provided as the threshold value before the load balancing processing is started.

10. The load balancing method as claimed in claim 1, wherein a value acquired by dividing a value with respect to performance of the present node by a value relating to total performance of the entire system which is a sum of performance values of all nodes in the system is provided as a threshold step as an amount for changing the threshold value, before the load balancing processing is started.

11. The load balancing method as claimed in any one of claims 1 to 10, wherein the step of determining the estimated load value includes:

increasing a task counter by 1 when a task is handed over to the task processing unit, and decreasing the task counter by 1 when a result is returned from the task processing unit; and

determining the estimated load value as the value of the task counter.

12. The load balancing method as claimed in any one of claims 1 to 6 and 8 to 10, wherein the step of determining the estimated load value includes calculating a response time of a task according to a time when the task is handed over to the task processing unit and a time when a result relating to the task is returned from the task processing unit, and determining the estimated load value based on the response time.

13. The load balancing method as claimed in claim 12, wherein the estimated load value is defined to be a ratio of said response time to a response time of a case wherein a task is exclusively processed.

14. The load balancing method as claimed in any one of claims 1 to 10, wherein the step of determining the estimated load value includes calculating, for a fixed number of tasks or tasks processed in a fixed time, a response time of each task according to a time when the task is handed over to the task processing unit and a time when a result relating to the task is returned from the task processing unit, and determining the estimated load value based on an average of the response times.

15. The load balancing method as claimed in claim 14, wherein the estimated load value is defined to be a ratio of said average of the response time to a response time of a case wherein a task is exclusively processed.

16. The load balancing method as claimed in any one of claims 1 to 15, wherein the step of judging whether or not the accepted task is handed over to the task processing unit includes:

comparing the estimated load value of the present node with the threshold value at every arrival of a task;

if the estimated load value is smaller than the threshold value, handing over the task to the task processing unit;

if the estimated load value is equal to or greater than the threshold value, the task is a round trip task and the estimated load value would be smaller than the threshold value if the threshold value was increased, handing over the task to the task processing unit;

if the estimated load value is equal to or greater than the threshold value and the task is a normal task, inputting the task into the logical ring network.

17. The load balancing method as claimed in any one of claims 1 to 15, wherein the step of judging whether or not the accepted task is handed over to the task processing unit includes:

comparing the estimated load value of the present node with the threshold value at every arrival of a task;

if the estimated load value is smaller than the threshold value, handing over the task to the task processing unit; and

if the estimated load value is equal to or greater than the threshold value, inputting the task into the logical ring network.

18. The load balancing method as claimed in any one of claims 1 to 15, wherein the step of judging whether or not the accepted task is handed over to the task processing unit includes:

comparing the estimated load value of the present node with the threshold value at every arrival of a task, periodically, or when the threshold value or the estimated load value is updated; and storing a result of the comparison;

when a task arrives, handing over the task to the task processing unit if the stored result of the comparison indicates that the estimated load value is smaller than the threshold value;

if the stored result of comparison indicates that the estimated load value is equal to or greater than the threshold value and the task is a normal task, inputting the task into the logical ring network; and

if the stored result of comparison indicates that the estimated load value is equal to or greater than the threshold value, the task is a round trip and the estimated load value would be smaller than the threshold value if the threshold value was increased, handing over the task to the task processing unit.

19. The load balancing method as claimed in any one of claims 1 to 15, wherein the step of judging whether or not the accepted task is handed over to the task processing unit includes:

comparing the estimated load value of the present node with the threshold value at every arrival of a task, periodically, or when the threshold value or the estimated load value is updated; and

if the estimated load value is smaller than the threshold value, setting a task acceptance control flag to be in an on state;

if the estimated load value is equal to or greater than the threshold value, the task is a round trip task and the estimated load value can be smaller than the threshold value if the threshold value was increased, setting a task acceptance control flag to be in an on state;"

if the estimated load value is equal to or greater than the threshold value and the task is a normal task, setting the task acceptance control flag to be in an off state; and

when a task newly arrives, handing over the task to the task processing unit if the task acceptance control flag is in the on state, while if the task acceptance control flag is in the off state, inputting the task into the logical ring network.

20. The load balancing method as claimed in any one of claims 1 to 15, wherein the step of judging whether or not the accepted task is handed over to the task processing unit includes:

comparing the estimated load value of the present node with the threshold value at every arrival of a task, periodically with a fixed period, or with an update of the threshold value or estimated load value as a trigger, and

if the estimated load value is smaller than the threshold value, setting a task acceptance control flag to be in an on state;

if the estimated load value is equal to or greater than the threshold value and the task is a normal task, setting the task acceptance control flag to be in an off state;

when a task newly arrives, if the task acceptance control flag is in the on state, handing over the task to the task processing unit;

when a task newly arrives, if the task acceptance control flag is in the off state, the task is a round trip task and the estimated load value would be smaller than the threshold value if the threshold value was increased, handing over the task to the task processing unit; and

when a task newly arrives, if the task acceptance control flag is in the off state and the task is a normal task, inputting the task into the logical ring network.

21. The load balancing method as claimed in any one of claims 16 to 20, wherein the comparison of the estimated load value and the threshold value is performed for each self-executable function of the present node.

22. The load balancing method as claimed in any one of claims 1 to 21, wherein the updating of the threshold value is performed in accordance with a change of the number of tasks passing through the logical ring network during a fixed period.

23. The load balancing method as claimed in any one of claims 1 to 21, wherein the step of updating the threshold value includes:

monitoring all tasks passing through the logical ring network; and

updating the threshold value when a round trip task is detected.

24. The load balancing method as claimed in claim 22, wherein the step of updating the threshold value includes:

determining an estimated load fluctuation of the entire system as a ratio of the number of tasks that have passed through the logical ring network during a fixed measurement period to the number of tasks that passed through the logical ring network during a preceding measurement period; and

increasing the threshold value by a predetermined threshold step if the estimated load fluctuation is greater than a predetermined value, while if the estimated load fluctuation is smaller than a predetermined value, decreasing the threshold value by the threshold step.

25. The load balancing method as claimed in claim 23, wherein the step of updating the threshold value includes increasing the threshold value by a predetermined threshold step if a round trip task is detected and the estimated load value is equal to or greater than the threshold value.

26. A load balancing apparatus provided for a computer system in which plural processing nodes, whose performance or executable functions are not uniform, are connected to a logical ring network, wherein when each node processes a task input from a terminal by using a task processing unit and returns a result to the terminal, the logical ring network logically transmits tasks in turn and in one direction, said load balancing apparatus, provided between the task processing unit in each node and the logical ring network and equally distributing loads of the entire system into the nodes in the system, the apparatus comprising:

load estimating means for estimating a load of a present node based on the number of tasks being or waiting to be processed and for determining an estimated load value of the present node for each self-executable function of the present node;

threshold value storage means for holding a threshold value with respect to the number of tasks existing in the node to limit the load of the present node based on the performance or self-executable functions of the present node;

task acceptance control means for accepting a task passing through the logical ring network, and comparing the estimated load value and the threshold value of the node every time the control means accepts a task, and for judging, based on a result of the comparison, whether the accepted task is handed over to the task processing unit, or is transmitted to the logical ring network without handing over the task to the task processing unit; and

threshold value updating means for estimating load fluctuation of the entire system and for updating the threshold value according to the estimated load fluctuation of the entire system and to the estimated load value of each self-executable function of the present node.

27. The load balancing apparatus as claimed in claim 26, further comprising threshold step storage means for holding a threshold step which is an amount by which the threshold value is changed by the threshold value updating means.

28. The load balancing apparatus as claimed in claim 27, wherein the threshold step storage means is provided with a value acquired by dividing a value with respect to performance of the present node by a value relating to total performance of the entire system which is a sum of performance values of all nodes in the system, as the threshold step, before the load balancing processing is started.

29. The load balancing apparatus as claimed in claim 27 or 28, further comprising threshold step updating means for updating the threshold step stored in the threshold step storage means.

30. The load balancing apparatus as claimed in claim 29, wherein the threshold step updating means performs centralized management with respect to the threshold steps of plural processing nodes and updates the threshold step stored in the threshold step storage means in each node.

31. The load balancing apparatus as claimed in claim 30, wherein the threshold step updating means is provided in any one of the processing nodes.

32. The load balancing apparatus as claimed in claim 30, wherein the computer system further includes a control node for managing and controlling the system, and the threshold step updating means is provided in the control node.

33. The load balancing apparatus as claimed in claim 29, wherein the threshold step updating means is provided in each processing node, and updates the threshold step stored in the threshold step storage means of the present node.

34. The load balancing apparatus as claimed in any one of claims 26 to 33, wherein the load balancing apparatus is disposed in each processing node.

35. The load balancing apparatus as claimed in any one of claims 26 to 33, wherein the load balancing apparatus is disposed outside each processing node.

36. The load balancing apparatus as claimed in any one of claims 26 to 35, wherein the threshold value updating means performs centralized management with respect to the threshold values of plural processing nodes and updates the threshold value stored in the threshold value storage means in each node.

37. The load balancing apparatus as claimed in claim 36, wherein the threshold value updating means is provided in any one of the processing nodes.

38. The load balancing apparatus as claimed in claim 36, wherein the computer system further includes a control node for managing and controlling the system, and the threshold value updating means is provided in the control node.

39. The load balancing apparatus as claimed in any one of claims 26 to 35, wherein the threshold value updating means is provided in each processing node, and updates the threshold value stored in the threshold value storage means of the present node.

40. The load balancing apparatus as claimed in any one of claims 26 to 39, wherein the threshold value storage means is provided with a predetermined value greater than 0 as the threshold value before the load balancing processing is started.

41. The load balancing apparatus as claimed in any one of claims 26 to 40, wherein:

the load estimating means has a task counter, and when a task is handed over to the task processing unit, the load estimating means increases the task counter by 1, while when a result is returned from the task processing unit, the load estimating means decreases the task counter by 1; and

the load estimating means informs the task acceptance control means of the value of the task counter as the estimated load value.

42. The load balancing apparatus as claimed in any one of claims 26 to 40, wherein the load estimating means calculates a response time of a task according to a time when the task is handed over to the task processing unit and a time when a result

relating to the task is returned from the task processing unit, and determines the estimated load value based on the response time.

43. The load balancing apparatus as claimed in claim 42, wherein the estimated load value is defined to be a ratio of said response time to a response time of a case wherein a task is exclusively processed.

44. The load balancing apparatus as claimed in any one of claims 26 to 40, wherein the load estimating means calculates, for a fixed number of tasks or tasks processed in a fixed time, a response time of each task according to a time when the task is handed over to the task processing unit and a time when a result relating to the task is returned from the task processing unit, and determines the estimated load value based on an average of the response times.

45. The load balancing apparatus as claimed in claim 44, wherein the estimated load value is defined to be a ratio of said average of the response time to a response time of a case wherein a task is exclusively processed.

46. The load balancing apparatus as claimed in any one of claims 26 to 45, wherein the task acceptance control means compares the estimated load value of the present node with the threshold value at every arrival of a task;

hands over the task to the task processing unit if the estimated load value is smaller than the threshold value; and

if the estimated load value is equal to or greater than the threshold value, the task is a round trip task and the estimated load value would be smaller than the threshold value if the threshold value was increased, the task acceptance control means hands over the task to the task processing unit; and

if the estimated load value is equal to or greater than the threshold value and the task is a normal task, the task acceptance control means inputs the task into the logical ring network.

47. The load balancing apparatus as claimed in any one of claims 26 to 45, wherein the task acceptance control means compares the estimated load value of the present node with the threshold value at every arrival of a task;

hands over the task to the task processing unit if the estimated load value is smaller than the threshold value; and

in another case in which the estimated load value is equal to or greater than the threshold value, the task acceptance control means inputs the task into the logical ring network.

48. The load balancing apparatus as claimed in any one of claims 26 to 45, wherein:

the task acceptance control means compares the estimated load value of the present node with the threshold value at every arrival of a task, periodically, or when the threshold value or the estimated load value is updated; and the task acceptance control means stores a result of the comparison, and

when a task arrives, the task acceptance control means hands over the task to the task processing unit if a result of the comparison indicating that the estimated load value is smaller than the threshold value is stored;

if the stored result of comparison indicates that the estimated load value is equal to or greater than the threshold value and the task is a normal task, the task acceptance control means inputs the task into the logical ring network; and

if the stored result of comparison indicates that the estimated load value is equal to or greater than the threshold value, the task is a round trip task and the estimated load value would be smaller than the threshold value if the threshold value was increased, the task acceptance control means hands over the task to the task processing unit.

49. The load balancing apparatus as claimed in any one of claims 26 to 45, wherein:

the task acceptance control means compares the estimated load value of the present node with the threshold value at every arrival of a task, periodically, or when the threshold value or the estimated load value is updated, and

if the estimated load value is smaller than the threshold value, the task acceptance control means sets a task acceptance control flag to be in an on state;

if the estimated load value is equal to or greater than the threshold value, the task is a round trip task and the estimated load value would be smaller than the threshold value if the threshold value was increased, the task acceptance control means sets a task acceptance control flag to be in an on state;

if the estimated load value is equal to or greater than the threshold value and the task is a normal task, the task acceptance control means sets the task acceptance control flag to be in an off state; and

when a task newly arrives, if the task acceptance control flag is in the on state, the task acceptance control means hands over the task to the task processing unit, while if the task acceptance control flag is in the off state, the task acceptance control means inputs the task into the logical ring network.

50. The load balancing apparatus as claimed in any one of claims 25 to 45, wherein:

the task acceptance control means compares the estimated load value of the present node with the threshold value at every arrival of a task, periodically with a fixed period, or with an update of the threshold value or the estimated load value as a trigger, and

if the estimated load value is smaller than the threshold value, the task acceptance control means sets a task acceptance control flag to be in an on state;

if the estimated load value is equal to or greater than the threshold value, the task

acceptance control means sets the task acceptance control flag to be in an off state;

when a task newly arrives, if the task acceptance control flag is in the on state, the task acceptance control means hands over the task to the task processing unit;

when a task newly arrives, if the task acceptance control flag is in the off state, the task is a round trip task and the estimated load value would be smaller than the threshold value if the threshold value was increased, the task acceptance control means hands over the task to the task processing unit; and

when a task newly arrives, if the task acceptance control flag is in the off state and the task is a normal task, the task acceptance control means inputs the task into the logical ring network.

51. The load balancing apparatus as claimed in any one of claims 46 to 50, wherein the task acceptance control means performs the comparison of the estimated load value and the threshold value for each self-executable function of the present node.

52. The load balancing apparatus as claimed in any one of claims 26 to 51, wherein the threshold value updating means updates the threshold value in accordance with a change in the number of tasks passing through the logical ring network during a fixed period.

53. The load balancing apparatus as claimed in any one of claims 26 to 51, wherein the threshold value updating means monitors all tasks passing through the logical ring network, and updates the threshold value when a round trip task is detected.

54. The load balancing apparatus as claimed in claim 52, wherein the threshold value updating means determines an estimated load fluctuation of the entire system as a ratio of the number of tasks that have passed through the logical ring

network during a fixed measurement period to the number of tasks that passed through the logical ring network during the preceding measurement period; and

if the estimated load fluctuation is greater than a predetermined value, the threshold value updating means increases the threshold value by a predetermined threshold step, while if the estimated load fluctuation is smaller than a predetermined value, the threshold value updating means decreases the threshold value by the threshold step.

55. The load balancing apparatus as claimed in claim 52, further comprising threshold step storage means for holding a threshold step which is a unit for changing the threshold value by the threshold value updating means, wherein:

the threshold value updating means determines an estimated load fluctuation of the entire system as a ratio of the number of tasks that have passed through the logical ring network during a fixed measurement period to the number of tasks that passed through the logical ring network during the preceding measurement period; and

if the estimated load fluctuation is greater than a predetermined value, the threshold value updating means increases the threshold value by the threshold step stored in the threshold step storage means, while if the estimated load fluctuation is smaller than a predetermined value, the threshold value updating means decreases the threshold value by the threshold step.

56. The load balancing apparatus as claimed in claim 53, wherein the threshold value updating means increases the threshold value by a predetermined threshold step if a round trip task is detected and the estimated load value is equal to or greater than the threshold value.

57. The load balancing apparatus as claimed in claim 53, further comprising threshold step storage means for holding a threshold step which is a unit for changing the threshold value by the threshold value updating means, wherein:

the threshold value updating means increases the threshold value by the predetermined threshold step stored in the threshold step storage means if a round trip task is detected and the estimated load value is equal to or greater than the threshold value.

58. The load balancing apparatus as claimed in claim 29, wherein when organization of the nodes in the computer system is modified by deleting or adding a node, the threshold step updating means updates the threshold step based on a value with respect to performance of the node added or deleted.

59. The load balancing apparatus as claimed in claim 29, wherein the threshold step updating means monitors all tasks passing through the logical ring network, and estimates a load fluctuation of the entire computer system and a modification of organization of the nodes in the system in accordance with a change in the number of all passed tasks and with a change of the number of round trip tasks, and the threshold step updating means updates the threshold step based on a result of the estimate of the load fluctuation of the computer system and the modification or organization of the nodes in the system.

60. The load balancing apparatus as claimed in claim 59, wherein the threshold value updating means monitors all tasks passing through the logical ring network, and updates the threshold value when a round trip task is detected.

61. The load balancing apparatus as claimed in claim 60, wherein:

the load estimating means has a task counter, and when a task is handed over to the task processing unit, the load estimating means increases the task counter by 1, while when a result is returned from the task processing unit, the load estimating means decreases the task counter by 1; and

the load estimating means informs the task acceptance control means of the value of the task counter as the estimated load value.

62. A computer-readable storage medium storing a computer program for making a computer execute any one of the methods claimed in any one of claims 1 to 25.

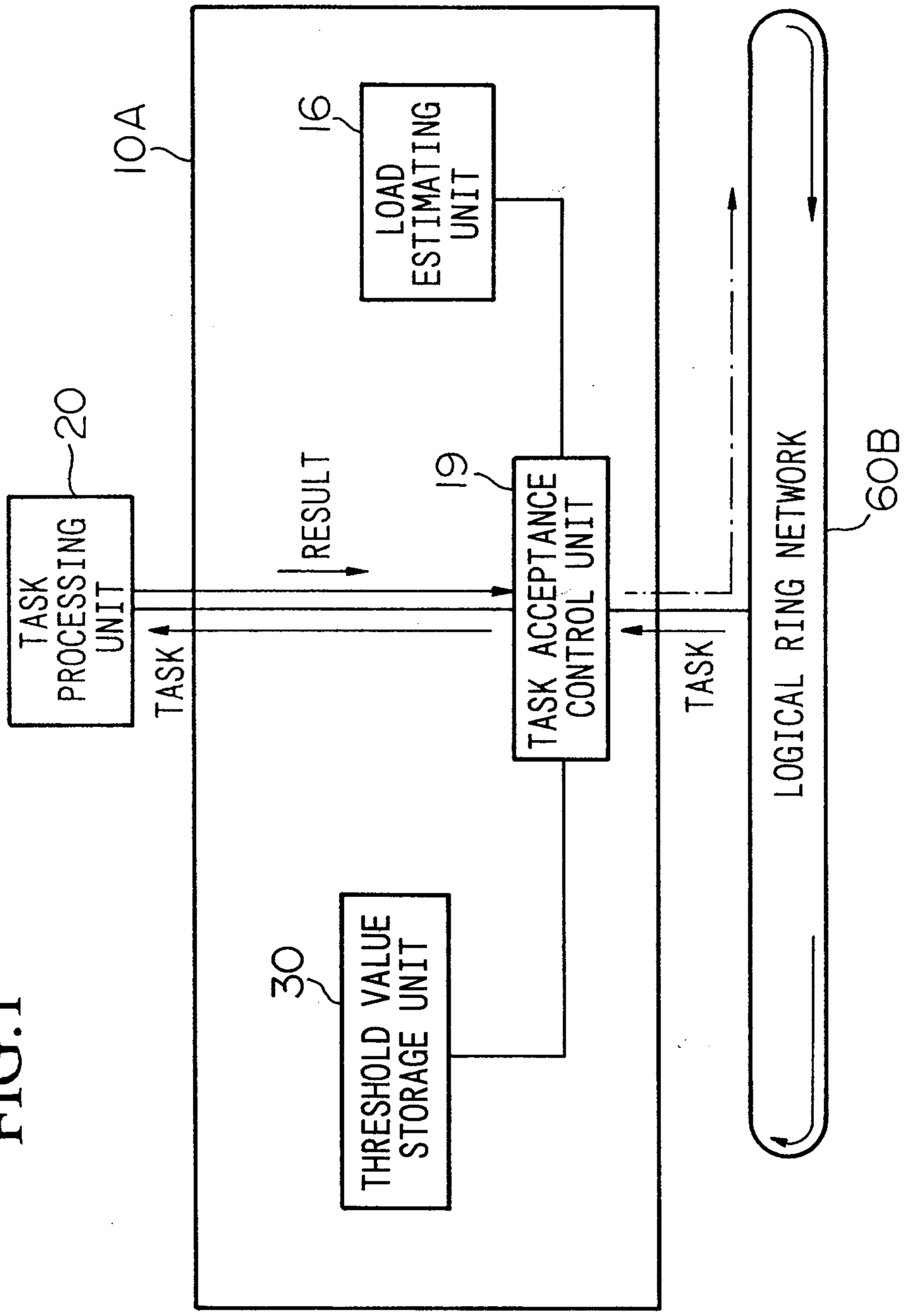

10A
16
LOAD ESTIMATING UNIT
19
TASK ACCEPTANCE CONTROL UNIT
20
TASK PROCESSING UNIT
RESULT
TASK
30
THRESHOLD VALUE STORAGE UNIT
NETWORK
60B
LOGICAL RING NETWORK
TASK

FIG.1

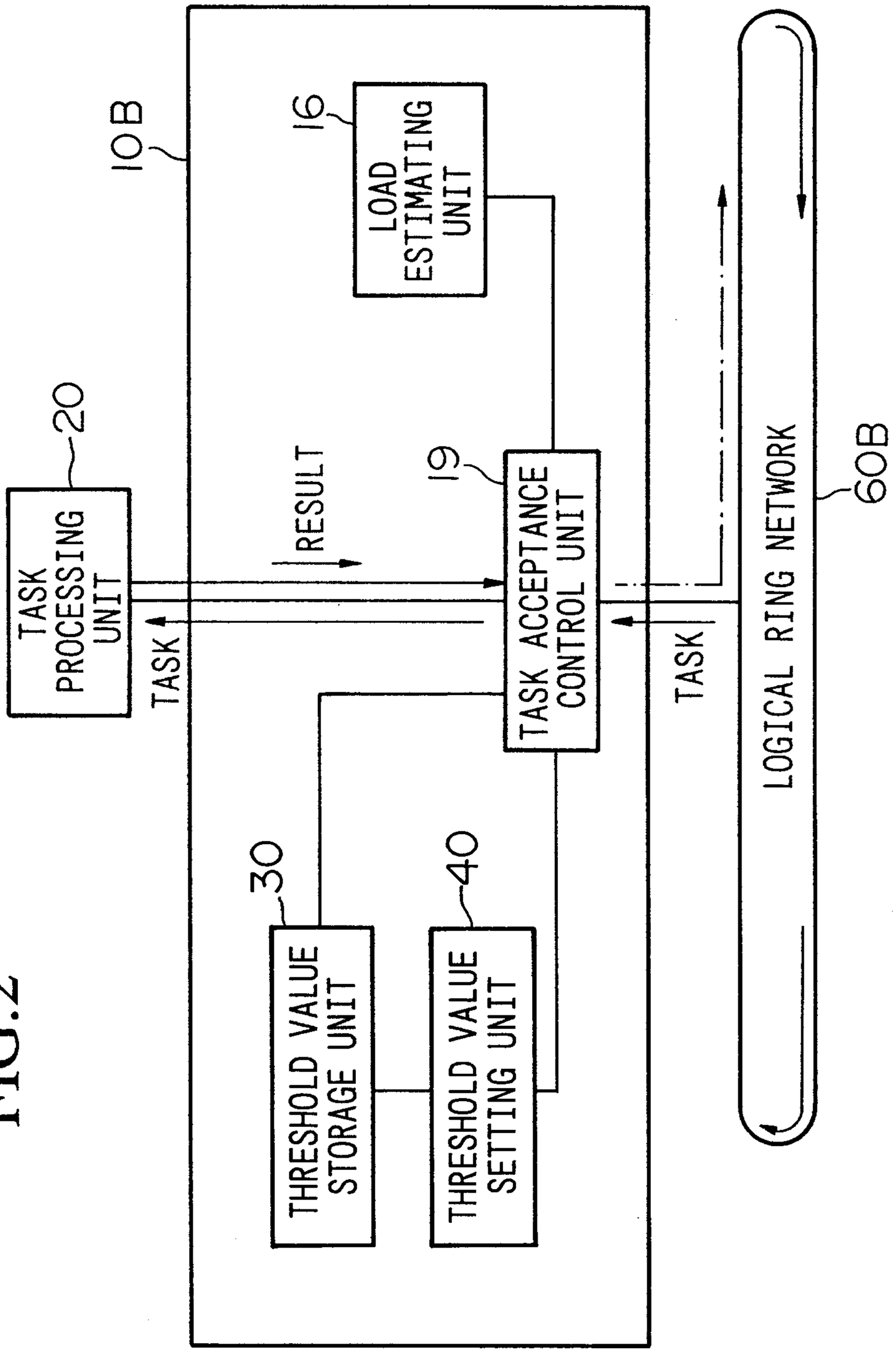

10B
16
LOAD ESTIMATING UNIT
20
TASK PROCESSING UNIT
RESULT
19
ACCEPTANCE CONTROL UNIT
60B
LOGICAL RING NETWORK
TASK
TASK
30
THRESHOLD VALUE STORAGE UNIT
40
THRESHOLD VALUE SETTING UNIT
TASK ACCEPTANCE CONTROL

FIG.2

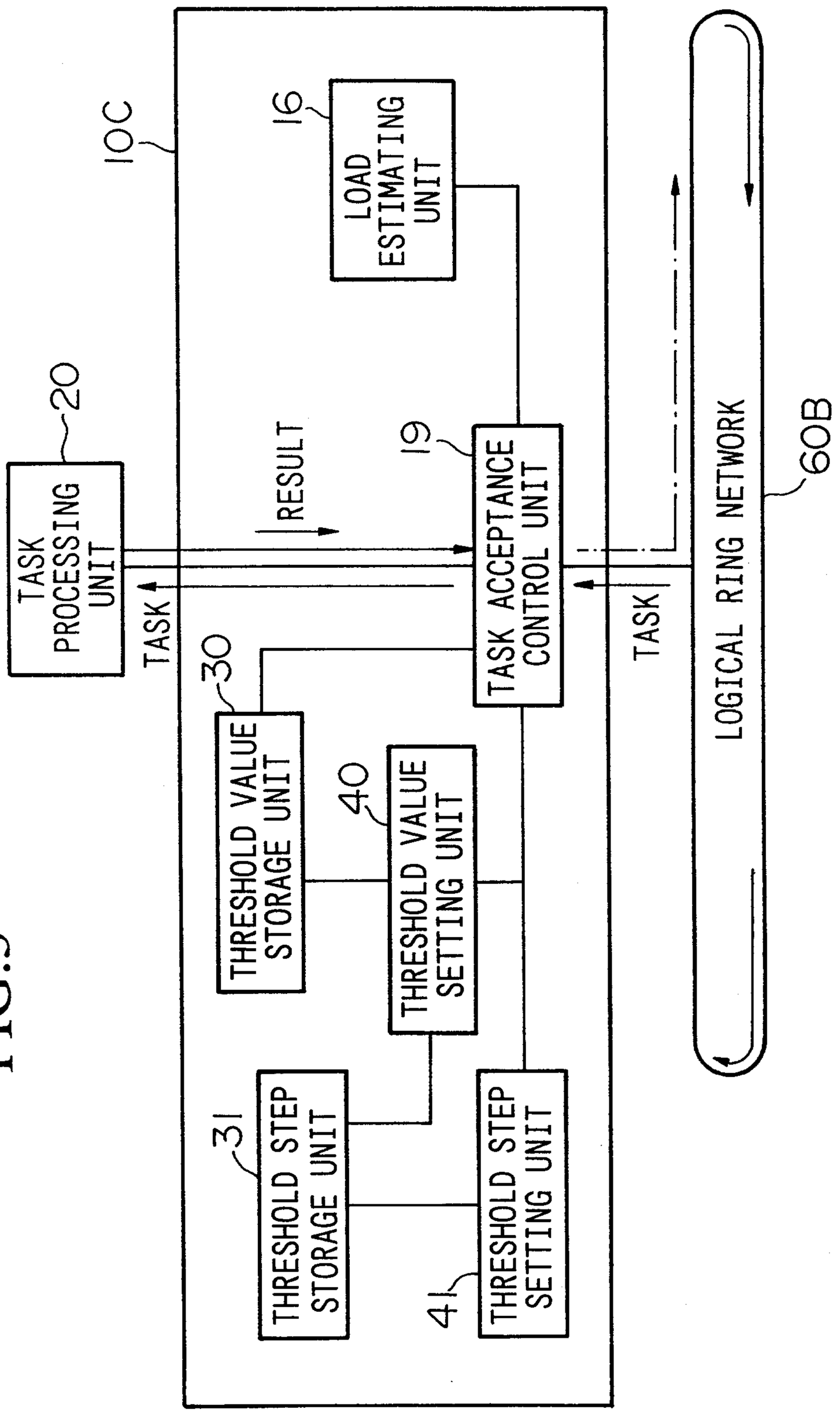

10C
16
LOAD ESTIMATING UNIT
20
TASK PROCESSING UNIT
RESULT
19
TASK ACCEPTANCE CONTROL UNIT
TASK
TASK
60B
LOGICAL RING NETWORK
30
THRESHOLD VALUE STORAGE UNIT
40
THRESHOLD VALUE SETTING UNIT
31
THRESHOLD STEP STORAGE UNIT
41
THRESHOLD STEP SETTING UNIT

FIG.3

FIG.4

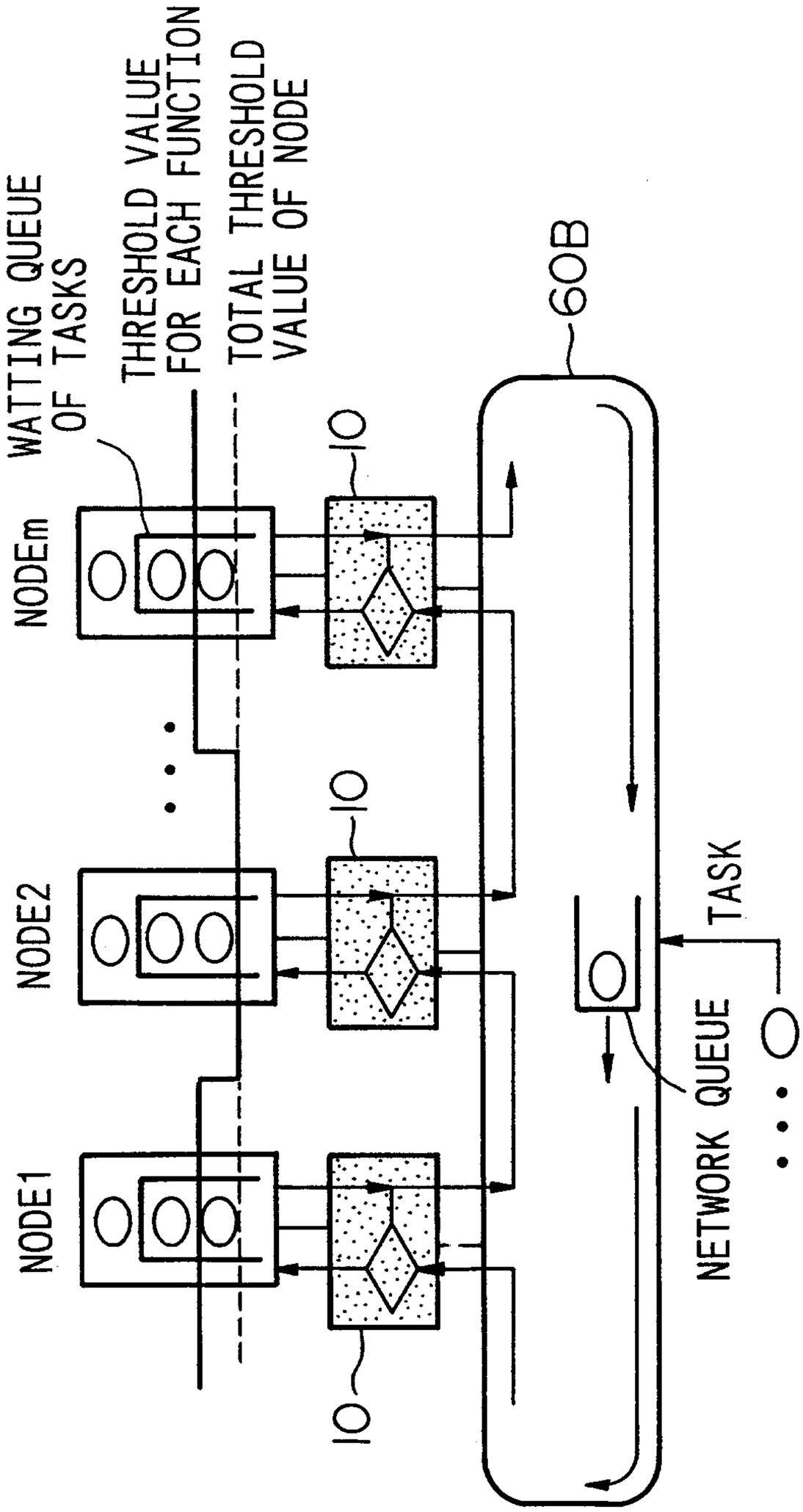
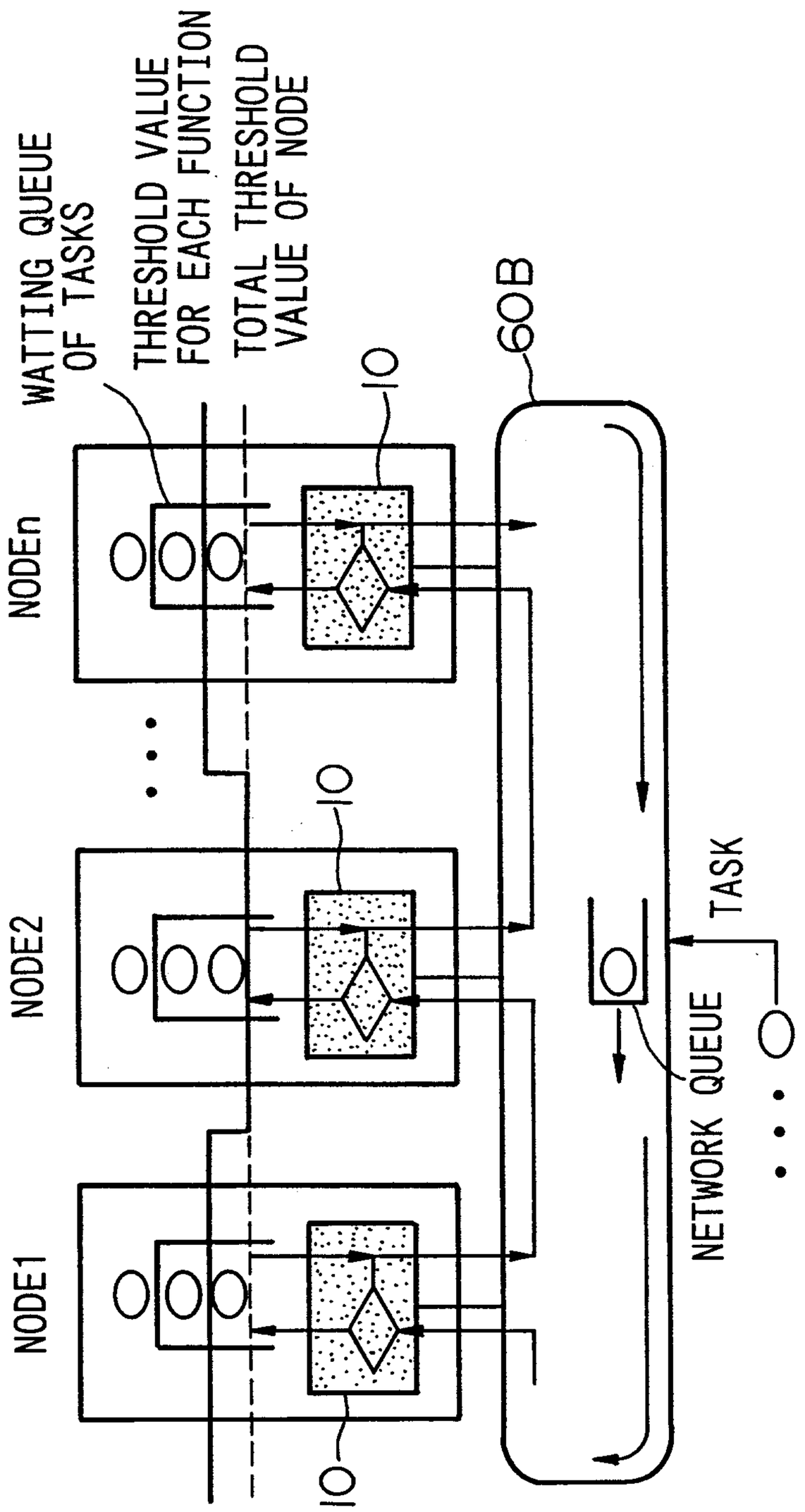

NODEm
NODE2
NODE1
WATTING QUEUE OF TASKS
THRESHOLD VALUE FOR EACH FUNCTIO
TOTAL THRESHOLD VALUE OF NODE
10
60B
NETWORK QUEUE
TASK

FIG.5


NODEn
WATTING QUEUE OF TASKS
THRESHOLD VALUE FOR EACH FUNCTIO
TOTAL THRESHOLD VALUE OF NODE
10
60B
NODE2
10
NODE1
NETWORK QUEUE
TASK

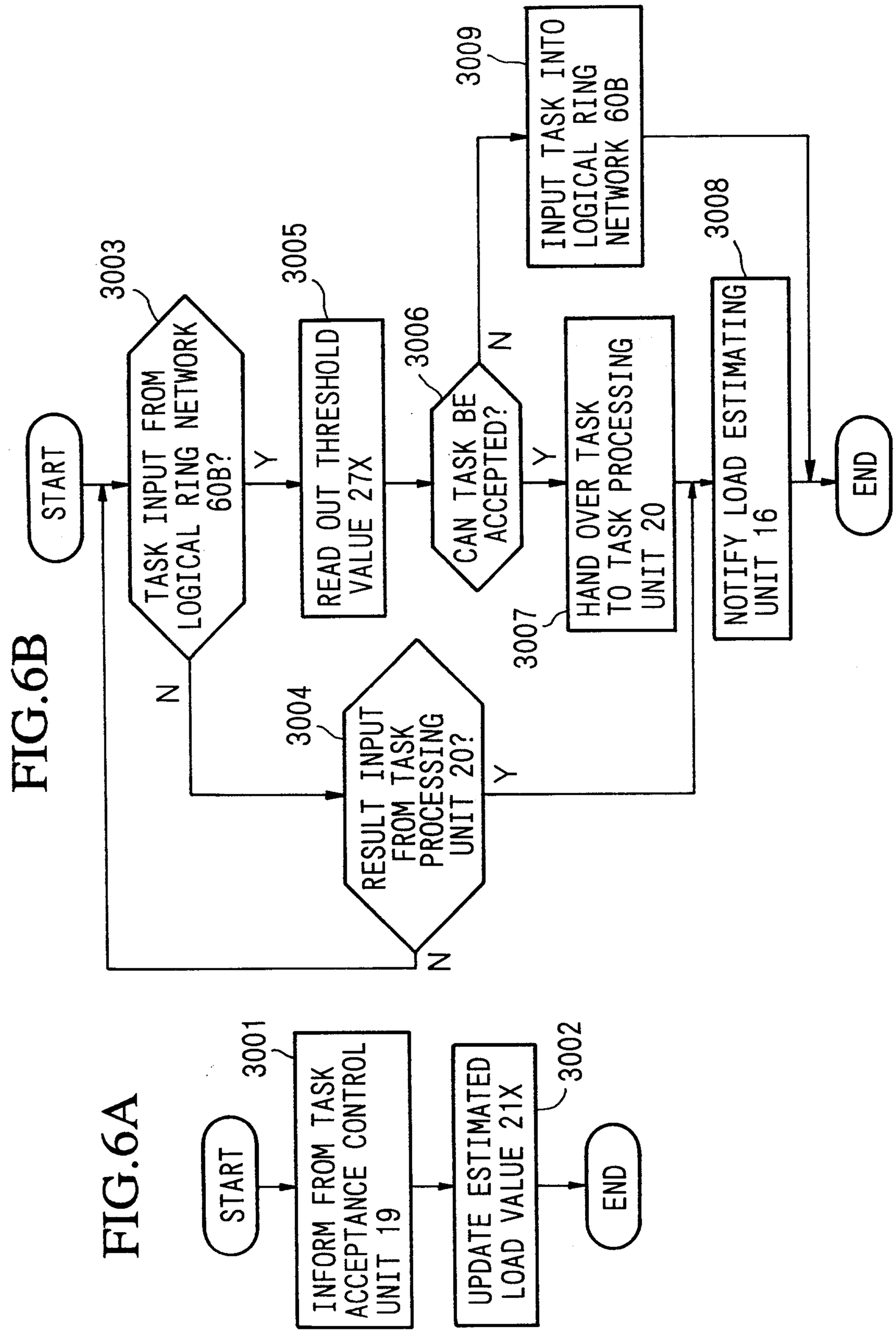

START
3001
INFORM FROM TASK ACCEPTANCE CONTROL UNIT 19
3002
UPDATE ESTIMATED LOAD VALUE 21X
END

FIG.6A

START
3003
TASK INPUT FROM LOGICAL RING NETWORK 60B?
Y
3005
READ OUT THRESHOLD VALUE 27X
3006
CAN TASK BE ACCEPTED?
N
INPUT TAS
LOGICAL R
NETWORK 6
Y
3007
HAND OVER TASK TO TASK PROCESSING UNIT 20
3008
NOTIFY LOAD ESTIMATING UNIT 16
END
N
3004
RESULT INPUT FROM TASK PROCESSING UNIT 20?
Y
N
3009

FIG.6B

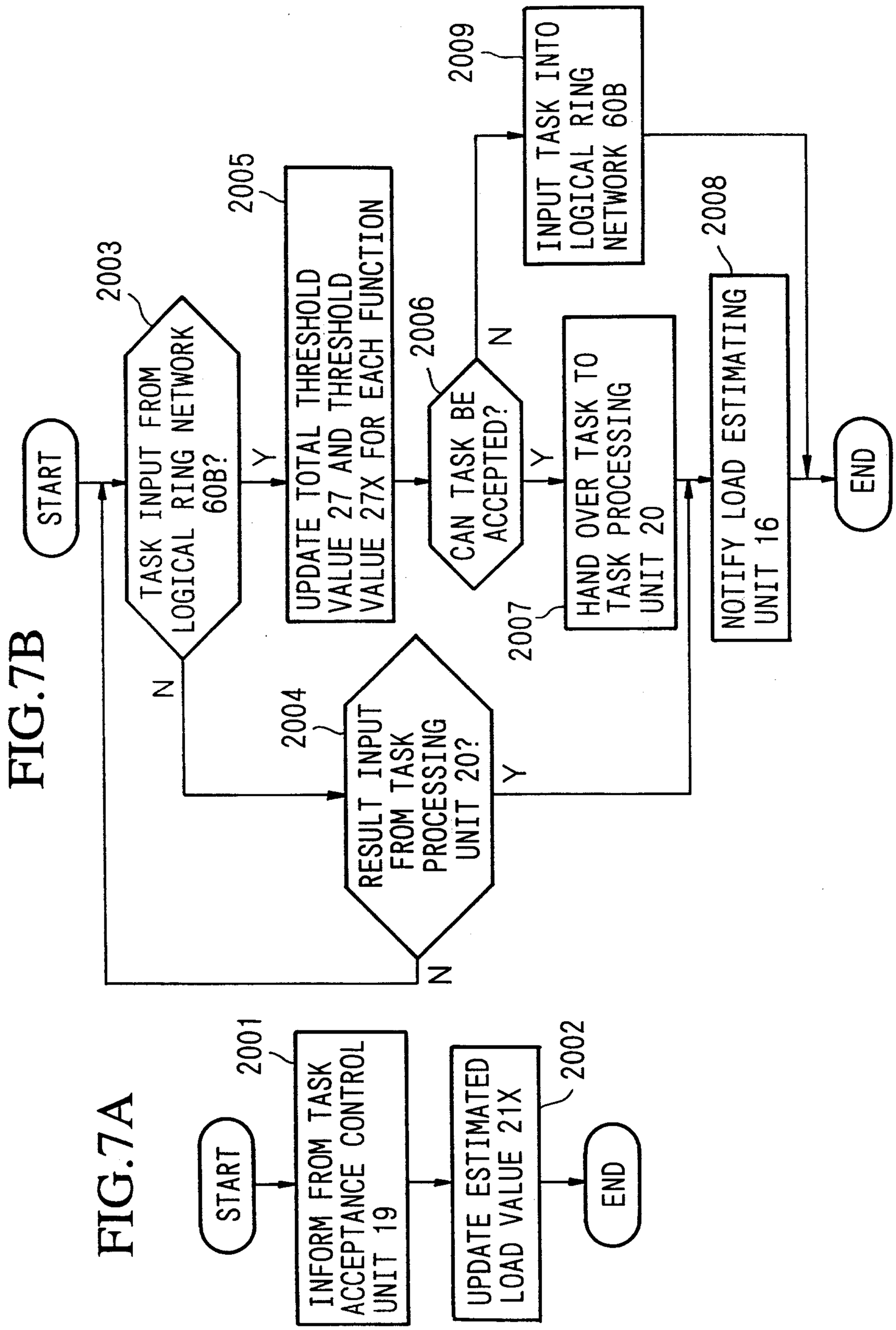

START
2001
INFORM FROM TASK ACCEPTANCE CONTROL UNIT 19
2002
UPDATE ESTIMATED LOAD VALUE 21X
END
START
2003
TASK INPUT FROM LOGICAL RING NETWORK 60B?
Y
2005
UPDATE TOTAL THRESHOLD VALUE 27 AND THRESHOLD VALUE 27X FOR EACH FUNCTION
2006
CAN TASK BE ACCEPTED?
N
INPUT TAS
LOGICAL R
NETWORK 6
Y
2007
HAND OVER TASK TO TASK PROCESSING UNIT 20
2008
NOTIFY LOAD ESTIMATING UNIT 16
END
N
2004
RESULT INPUT FROM TASK PROCESSING UNIT 20?
Y
N
2009

FIG.7A

FIG.7B

FIG.8A

START
1011
INFORM FROM TASK ACCEPTANCE CONTROL UNIT 19
UPDATE ESTIMATED LOAD VALUE 21X
1012
END

FIG.8B

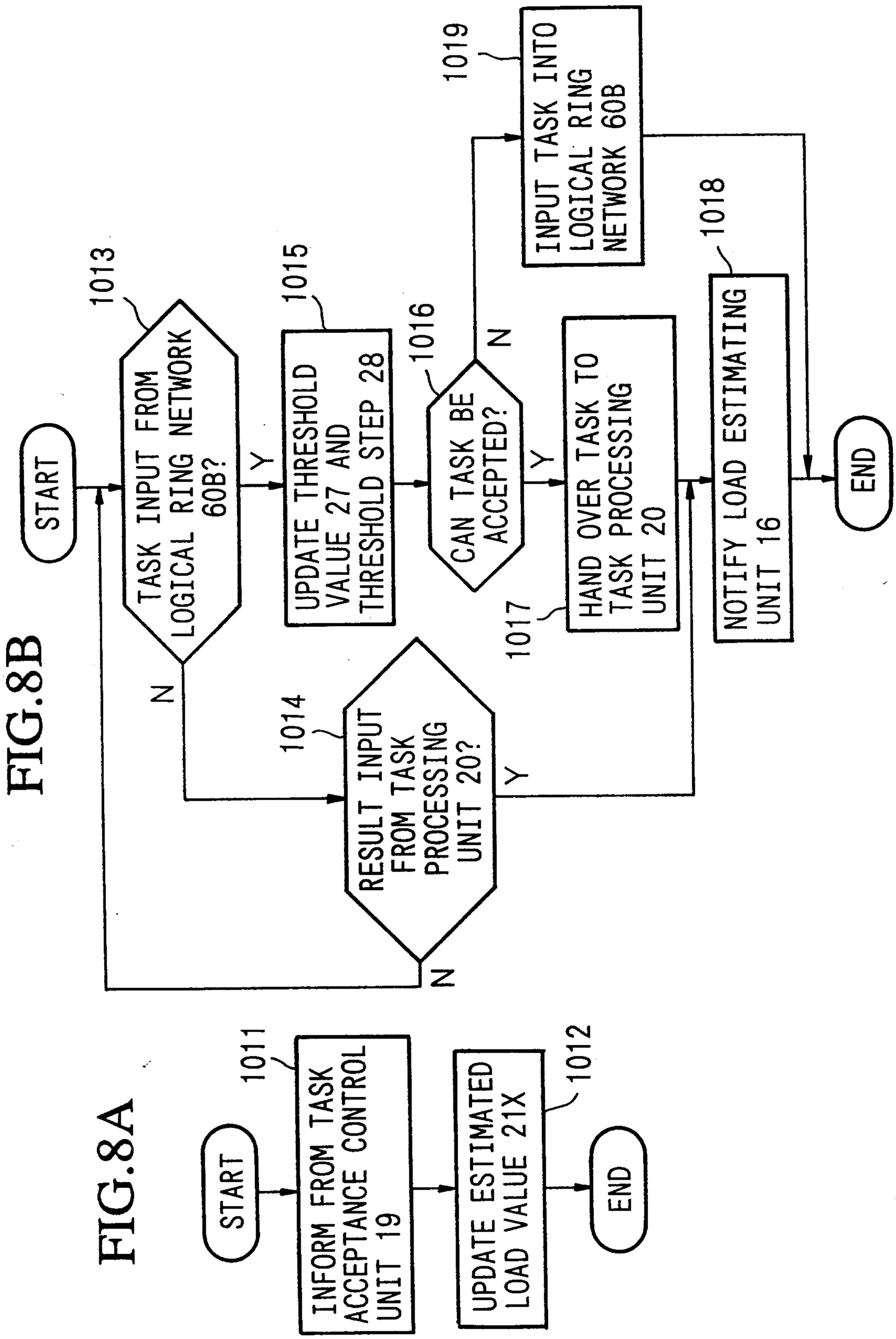

START
1013
TASK INPUT FROM LOGICAL RING NETWORK 60B?
Y
N
1014
RESULT INPUT FROM TASK PROCESSING UNIT 20?
Y
N
1015
UPDATE THRESHOLD VALUE 27 AND THRESHOLD STEP 28
1016
CAN TASK BE ACCEPTED?
Y
N
1017
HAND OVER TASK TO TASK PROCESSING UNIT 20
INPUT TAS
LOGICAL R
NETWORK 6
1018
NOTIFY LOAD ESTIMATING UNIT 16
END

FIG.9A

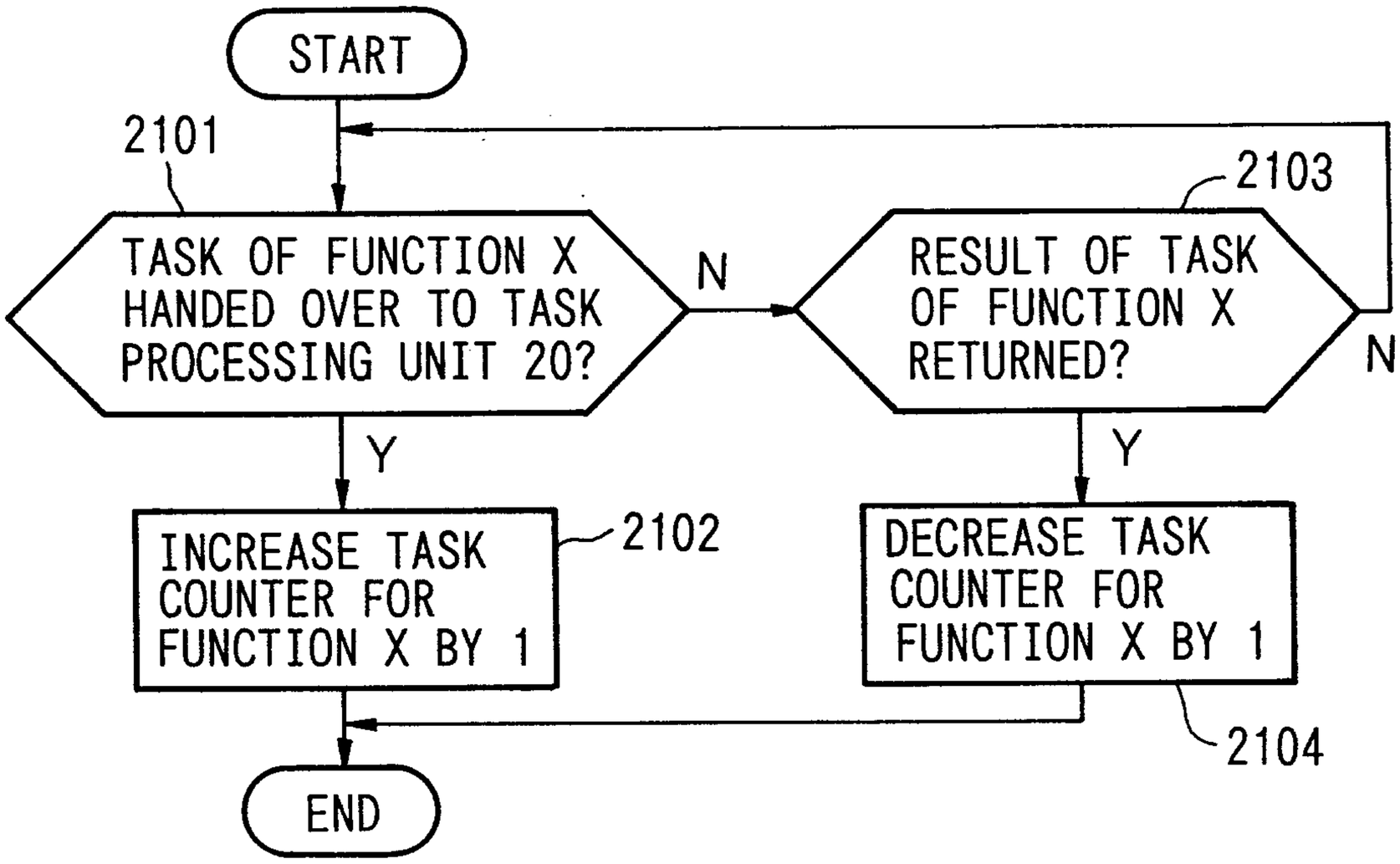

START
2101
TASK OF FUNCTION X HANDED OVER TO TASK PROCESSING UNIT 20?
N
2103
RESULT OF TASK OF FUNCTION X RETURNED?
N
Y
Y
INCREASE TASK COUNTER FOR FUNCTION X BY 1
2102
DECREASE TASK COUNTER FOR FUNCTION X BY 1
2104
END

FIG.9B

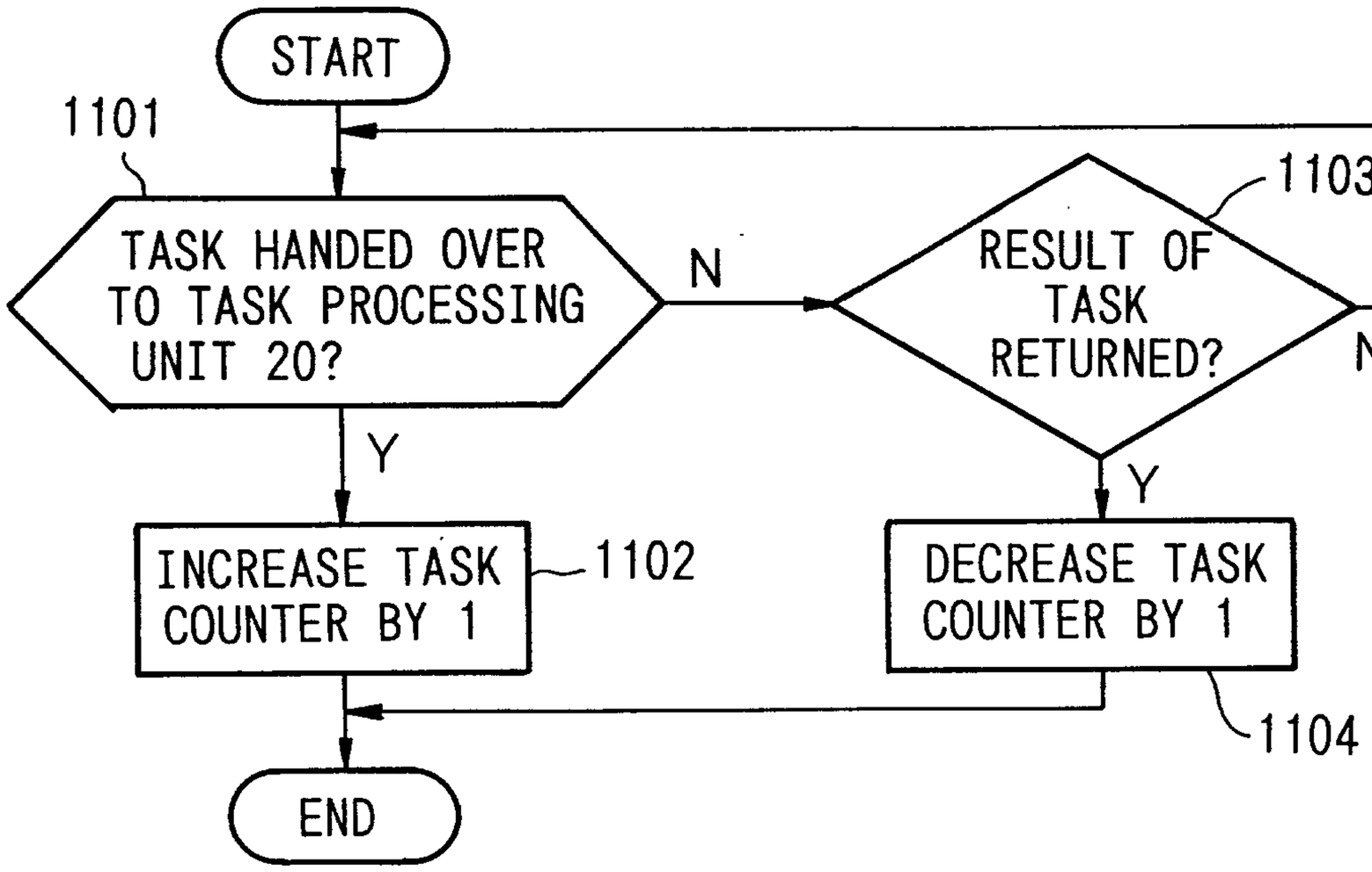

START
1101
TASK HANDED OVER TO TASK PROCESSING UNIT 20?
N
1103
RESULT OF TASK RETURNED?
N
Y
Y
INCREASE TASK COUNTER BY 1
1102
DECREASE TASK COUNTER BY 1
1104
END

FIG.10A

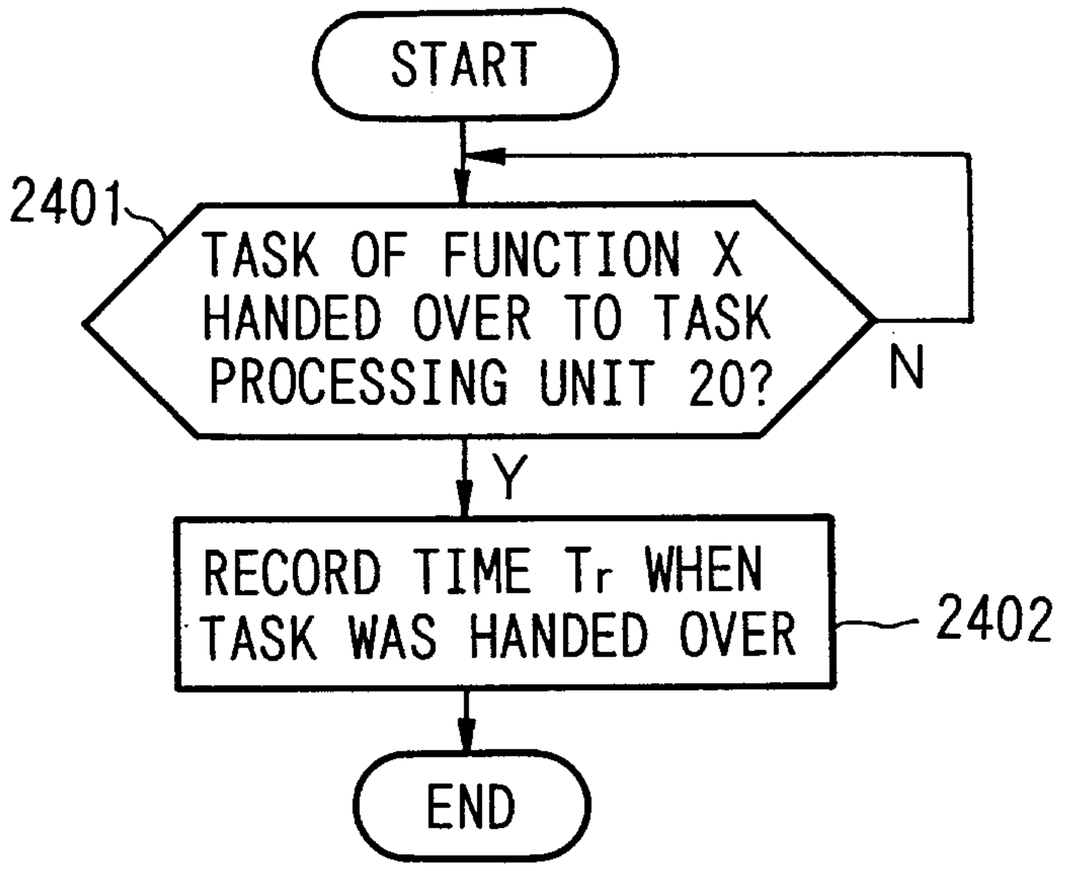


FIG.10B

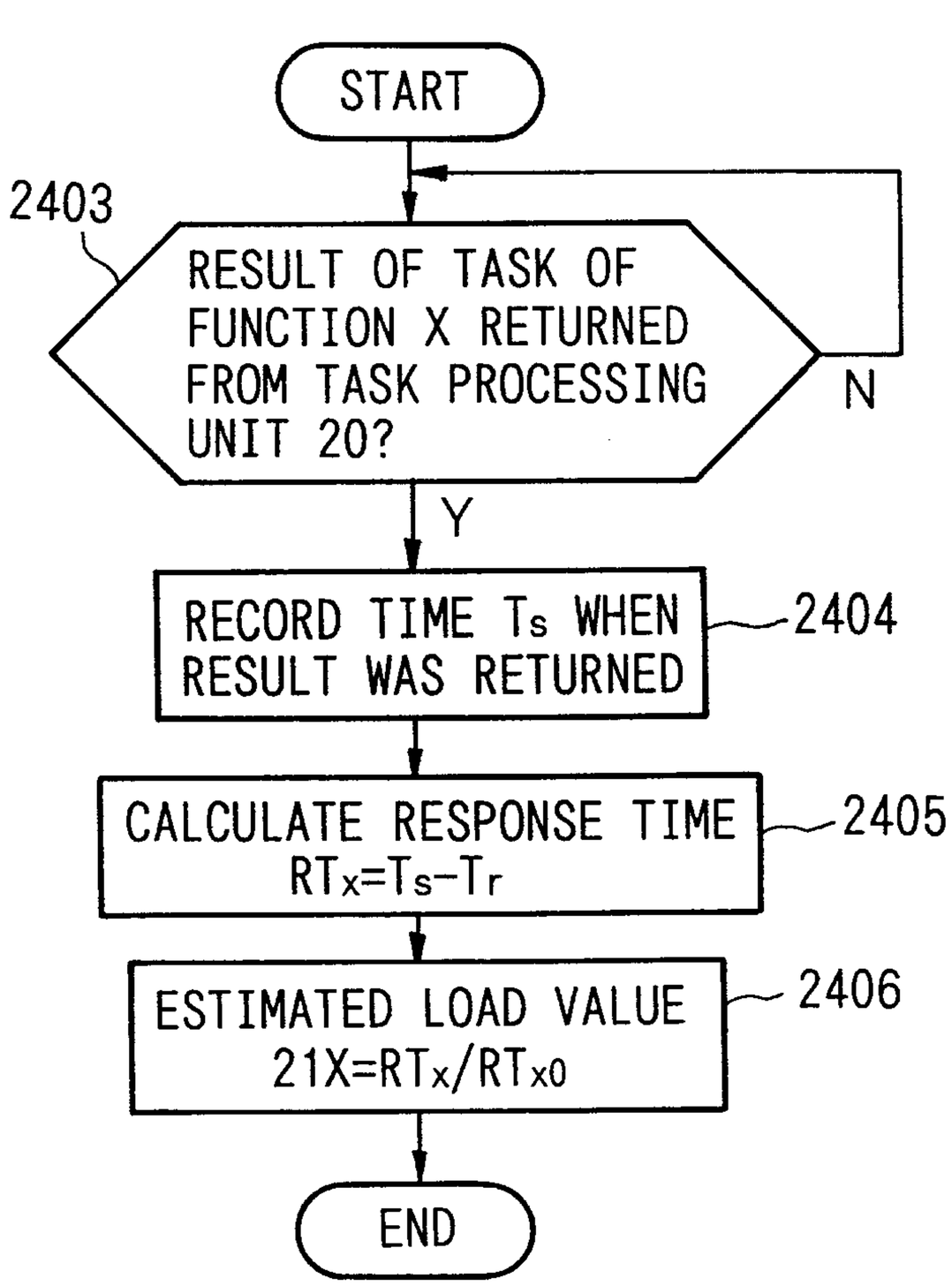


FIG.10C

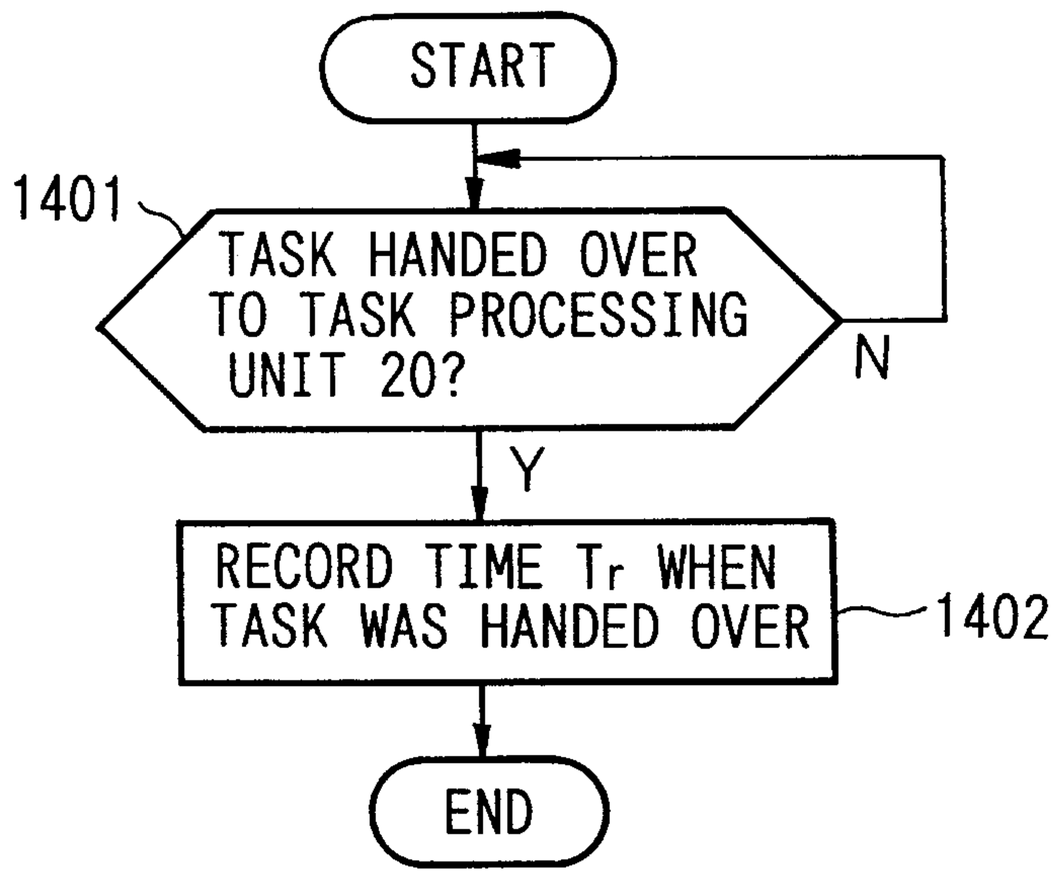


FIG.10D

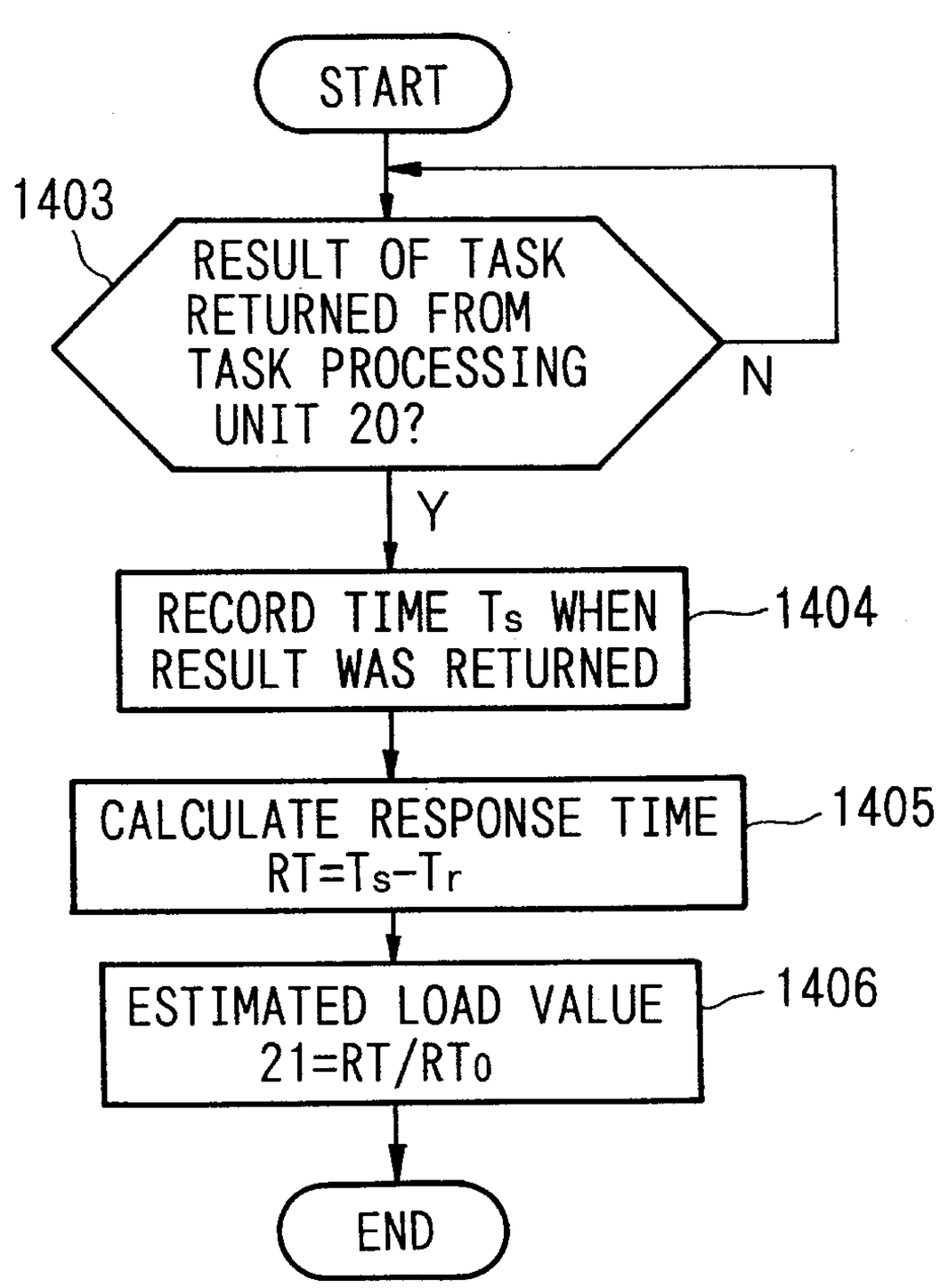


FIG.11A

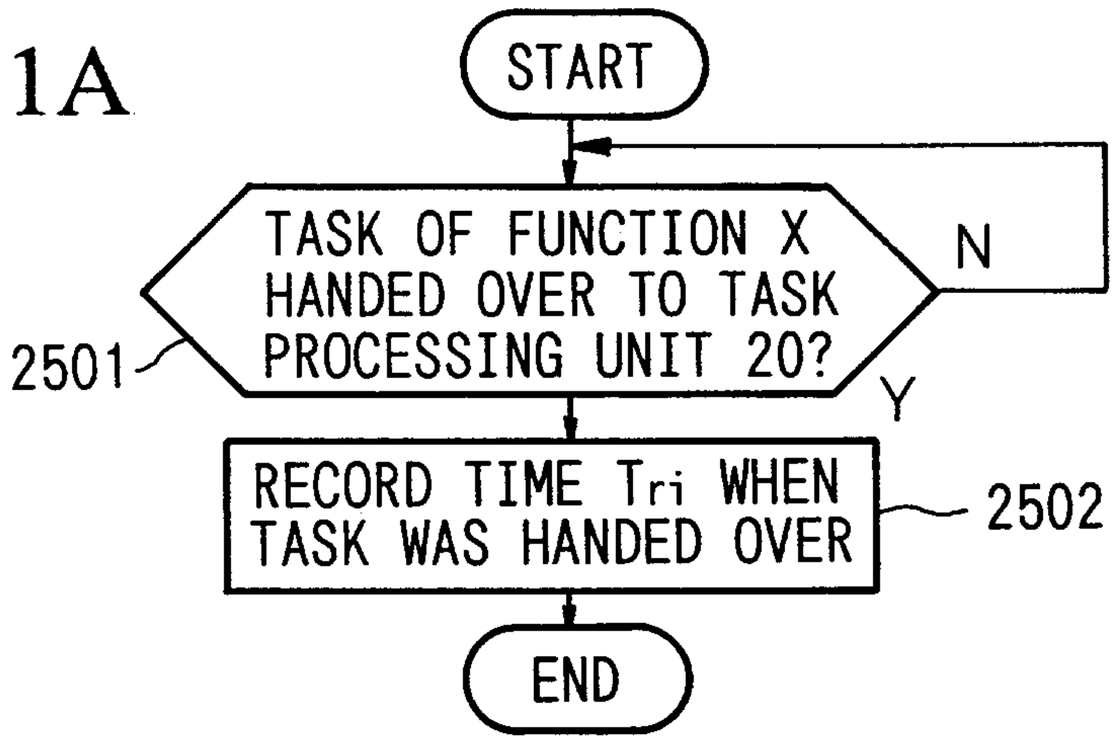


FIG.11B

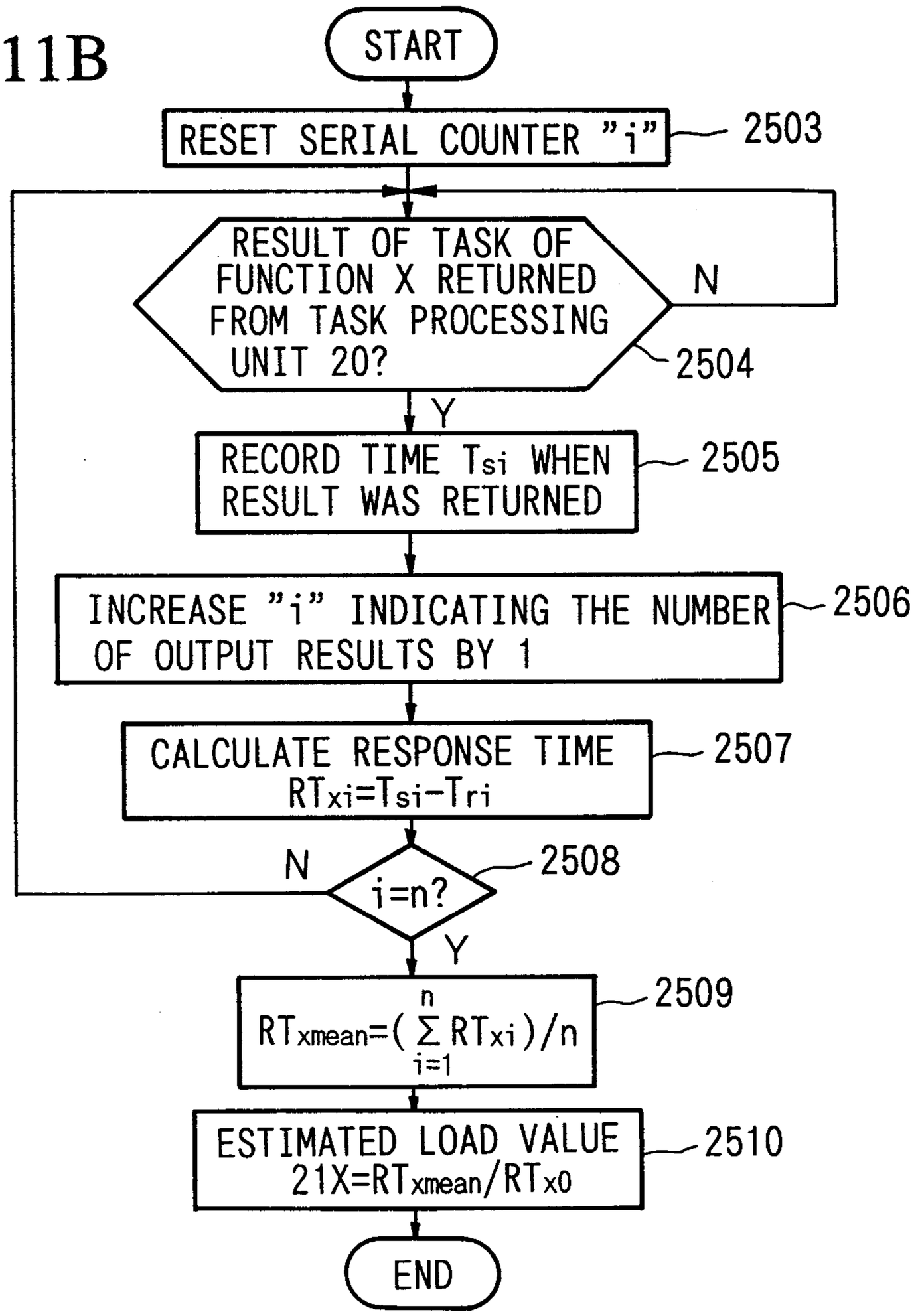


FIG.11C

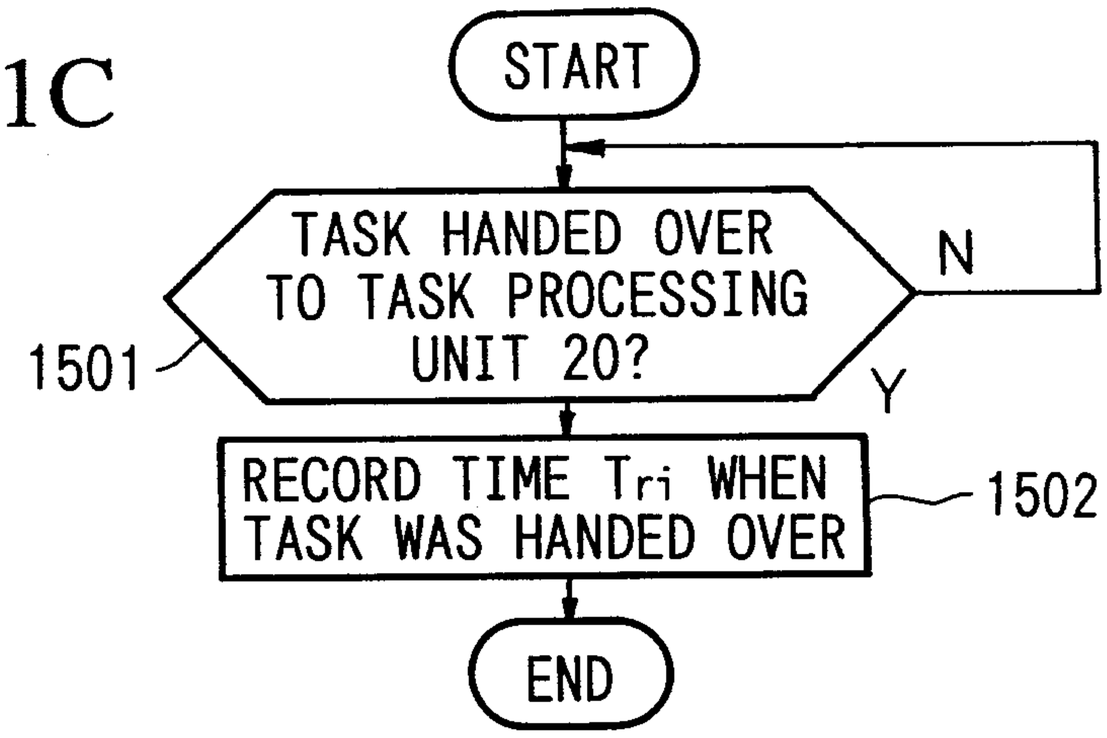
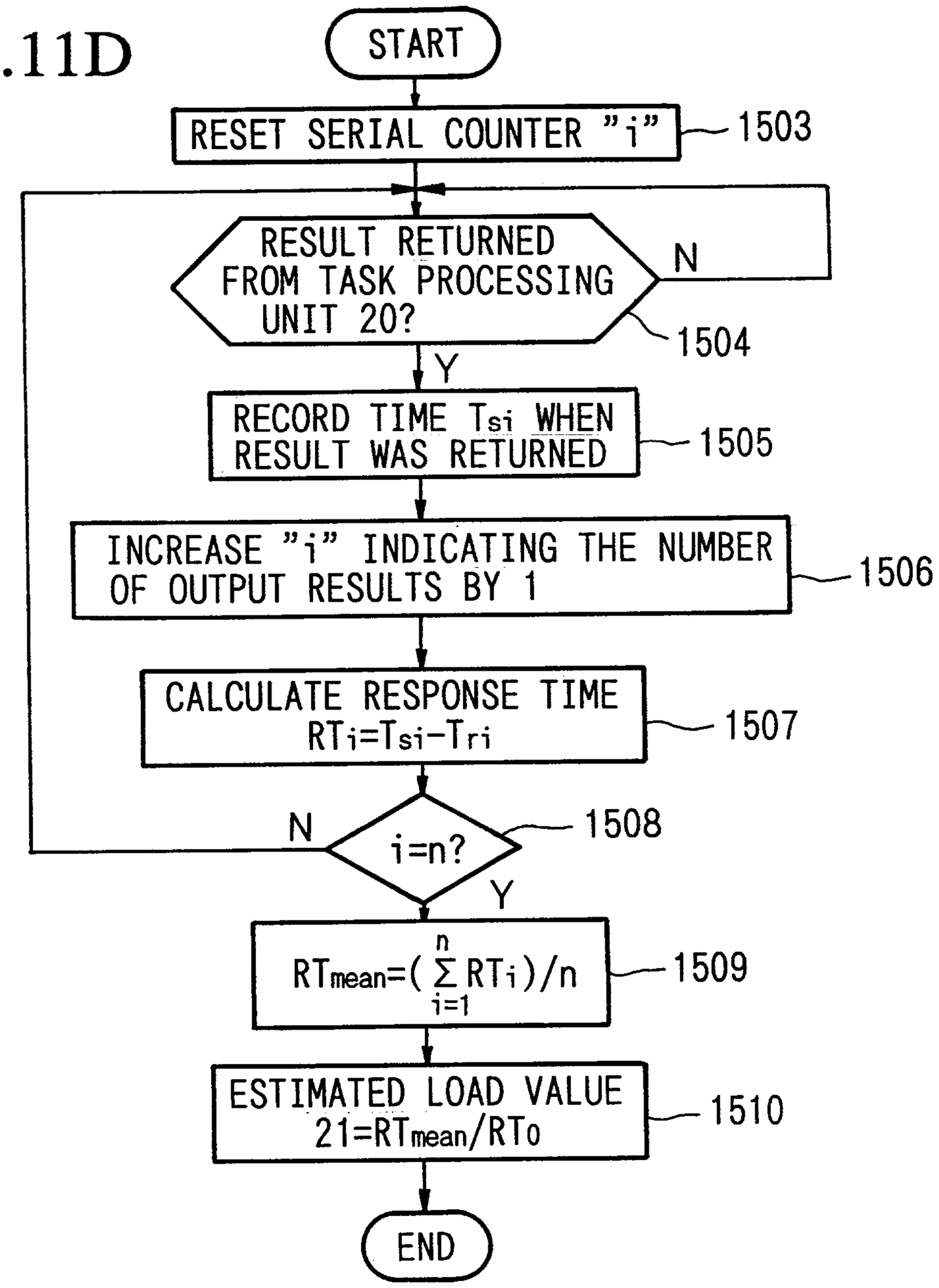


FIG.11D



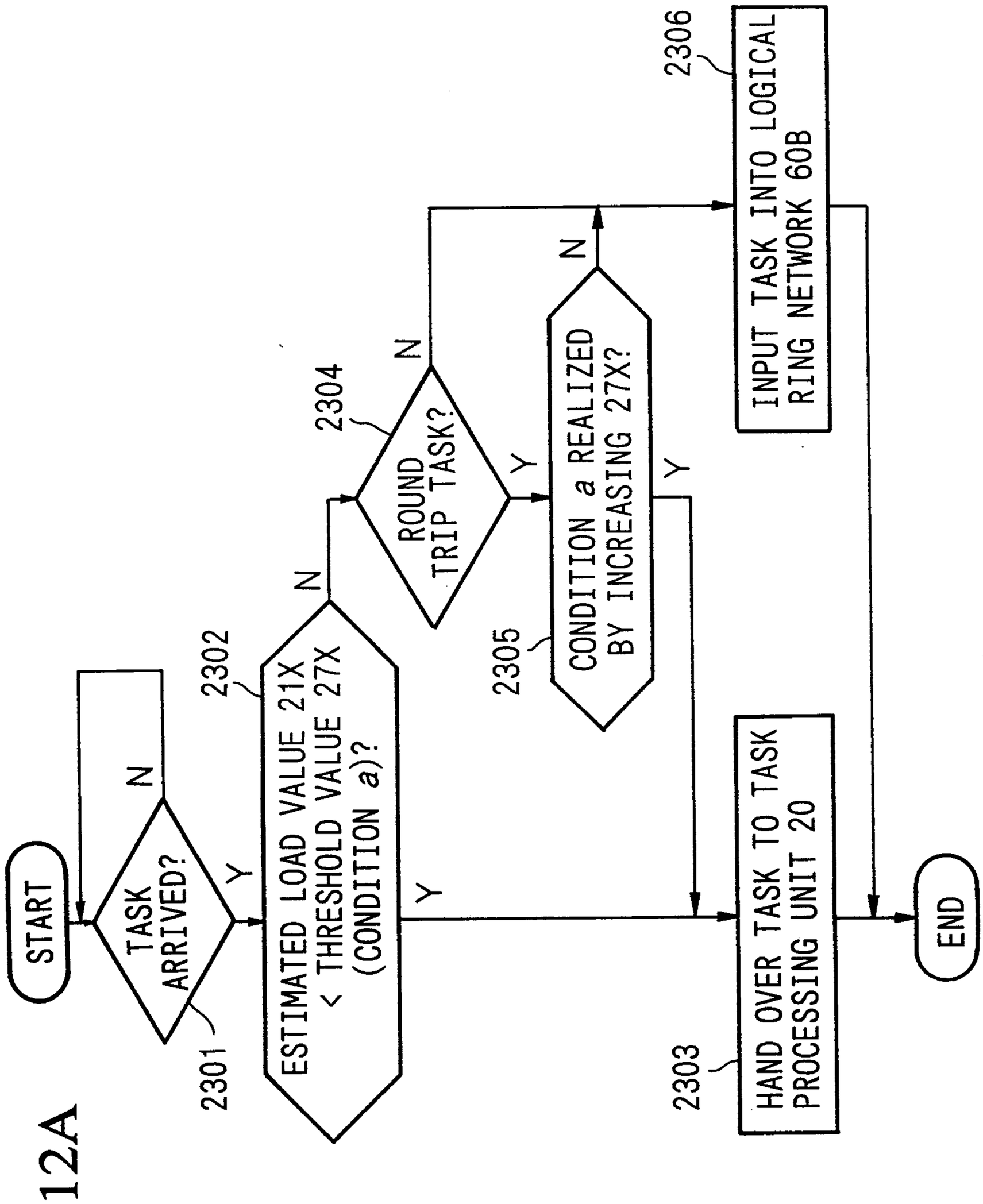

START
TASK ARRIVED?
Y
N
2301
ESTIMATED LOAD VALUE 21X < THRESHOLD VALUE 27X (CONDITION a)?
2302
Y
N
ROUND TRIP TASK?
2304
Y
N
CONDITION a REALIZED BY INCREASING 27X?
2305
Y
N
INPUT TASK INTO LOGICAL RING NETWORK 60B
2306
HAND OVER TASK TO TASK PROCESSING UNIT 20
2303
END

FIG.12A

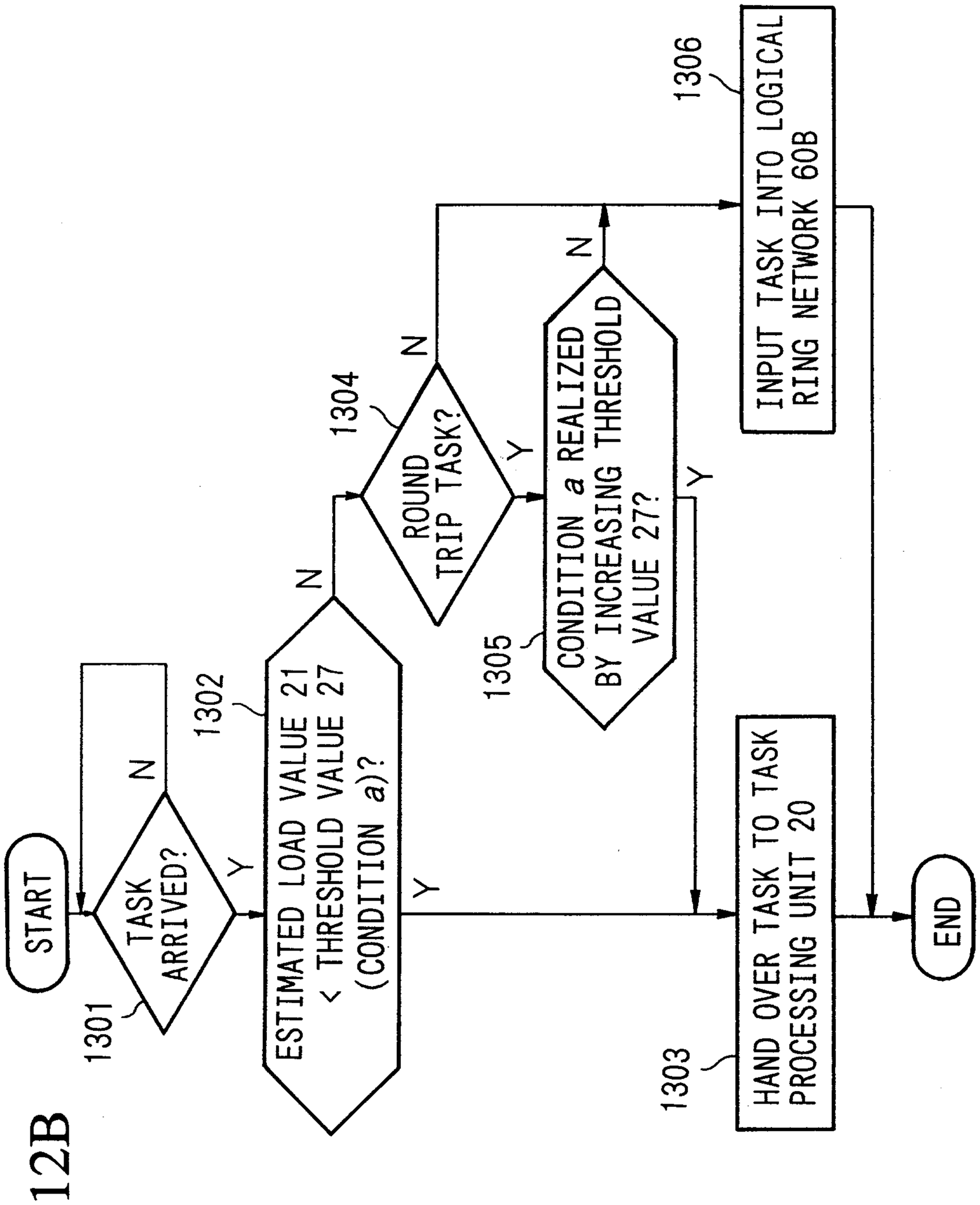

START
TASK ARRIVED?
1301
N
Y
ESTIMATED LOAD VALUE 21 < THRESHOLD VALUE 27 (CONDITION a)?
1302
Y
ROUND TRIP TASK?
1304
N
Y
CONDITION a REALIZED BY INCREASING THRESHOLD VALUE 27?
1305
N
Y
INPUT TASK INTO LOOP RING NETWORK 60B
1306
HAND OVER TASK TO TASK PROCESSING UNIT 20
1303
END

FIG.12B

FIG.13A

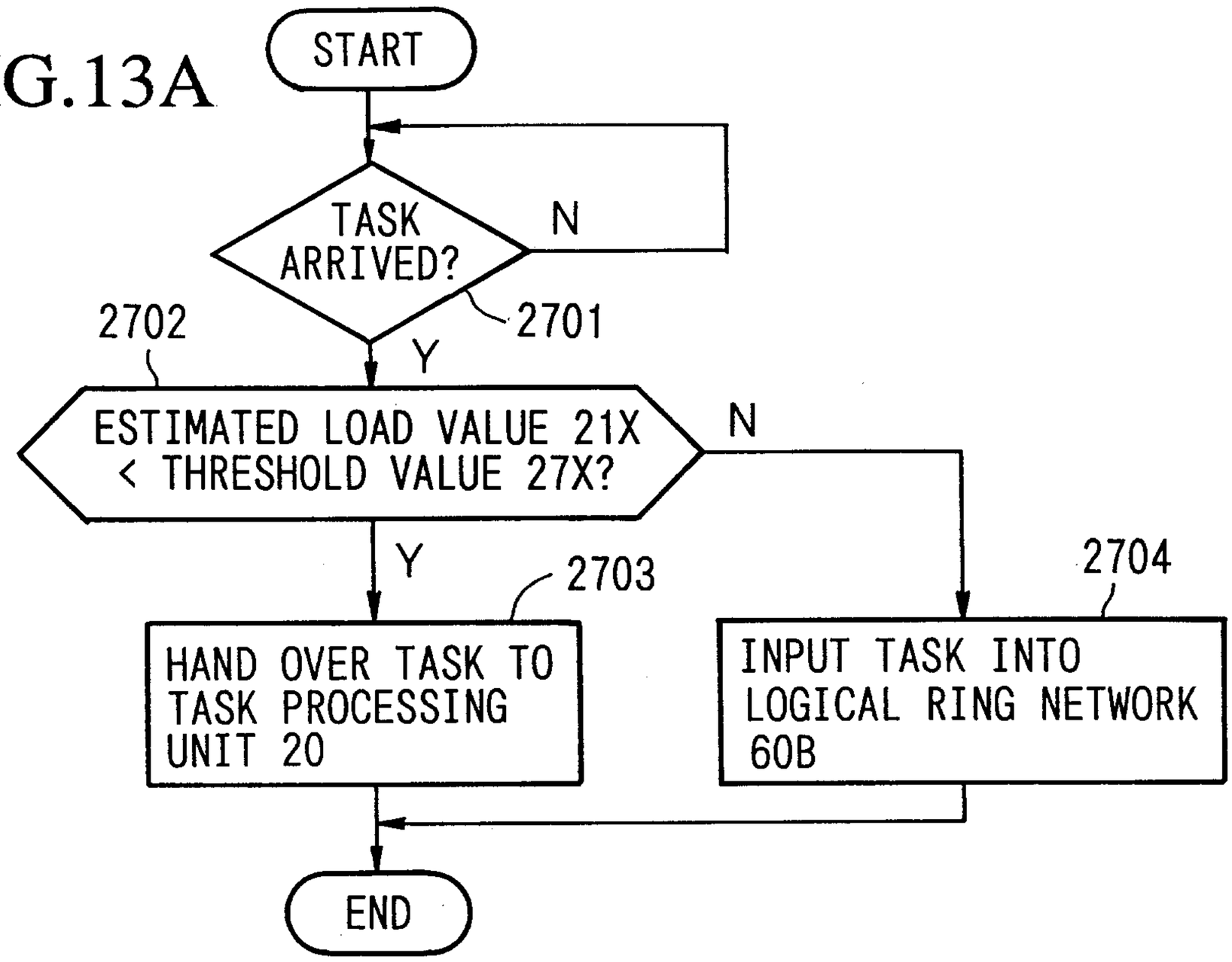


FIG.13B

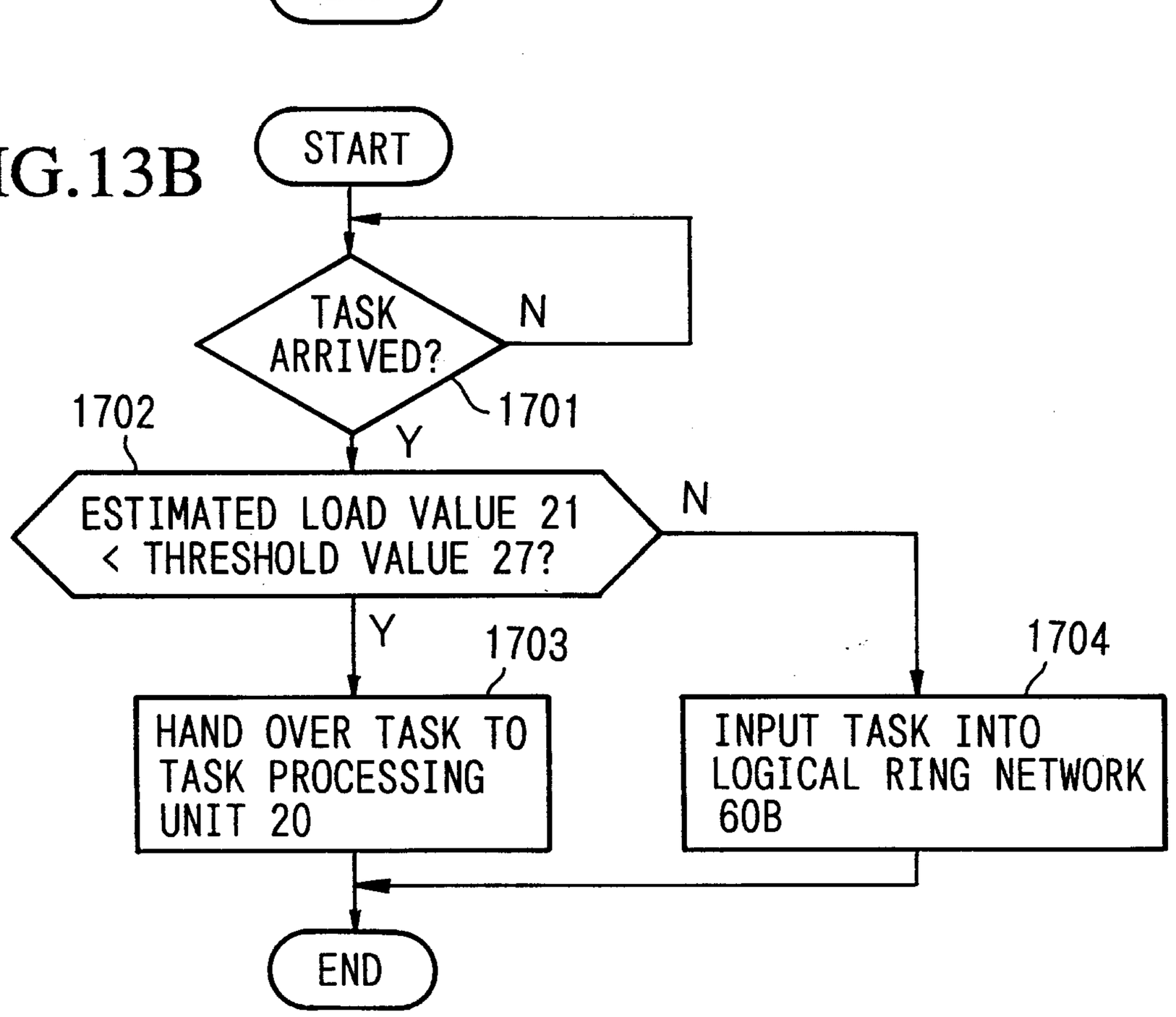


FIG.14A

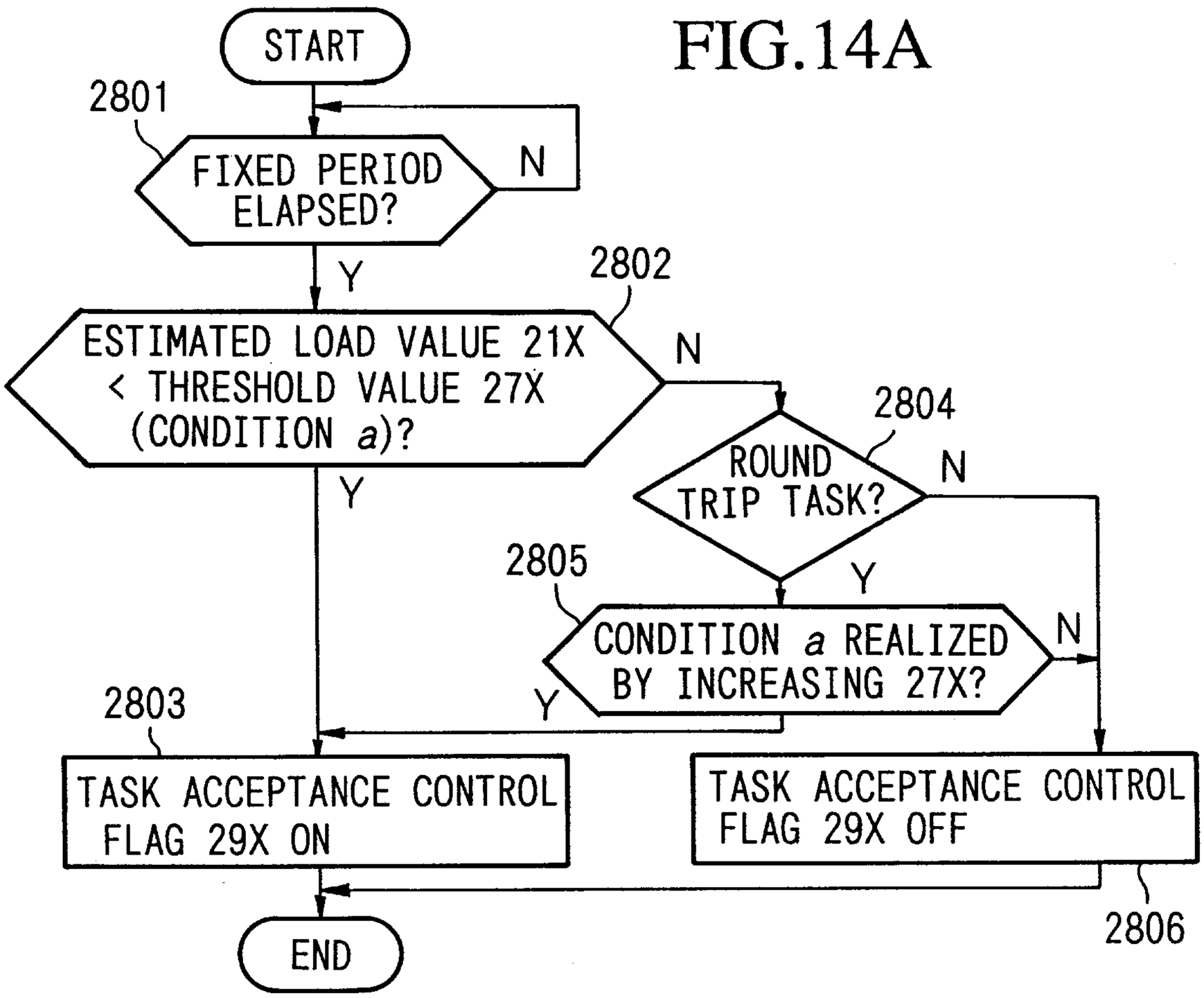


FIG.14B

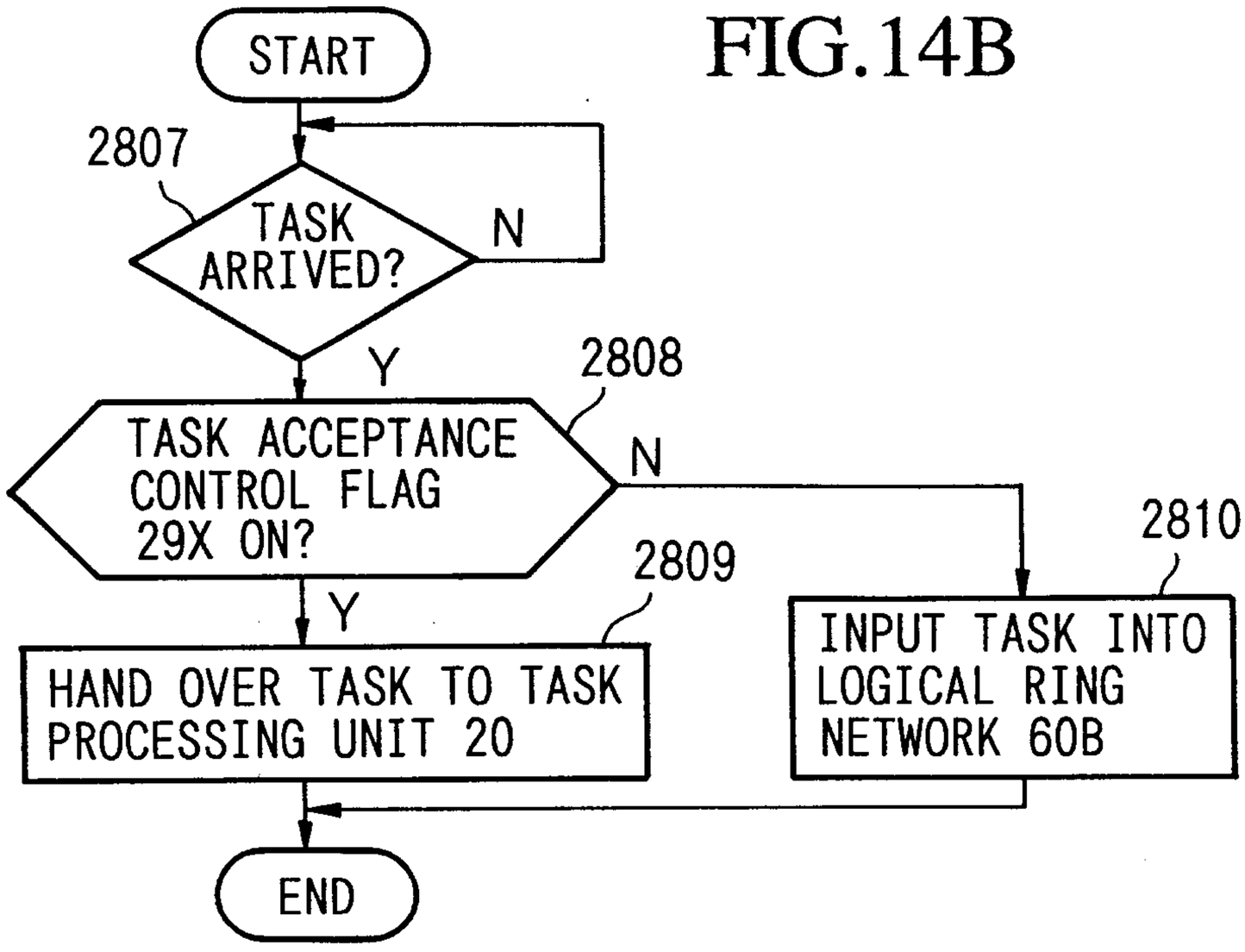


FIG.14C

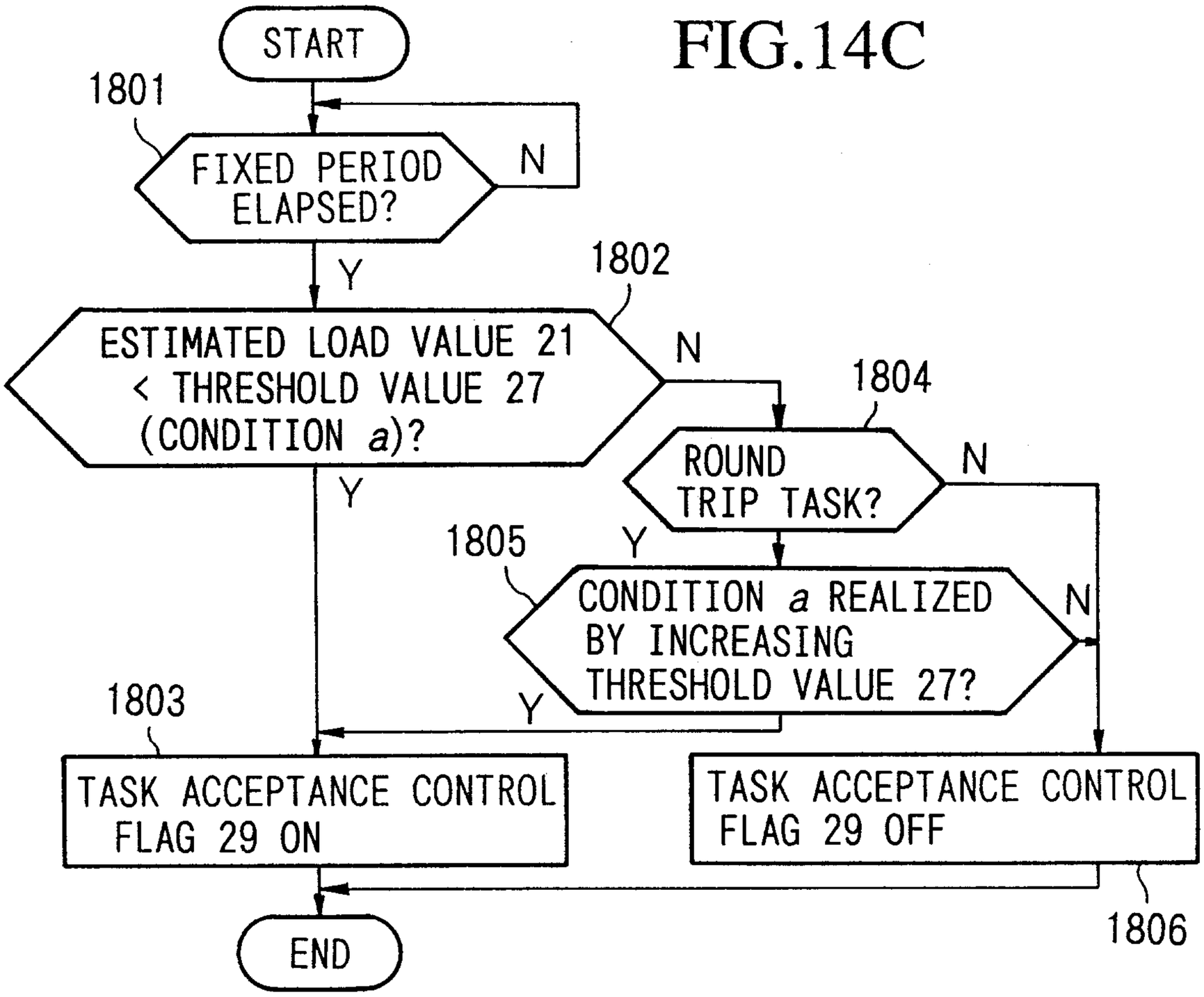


FIG.14D

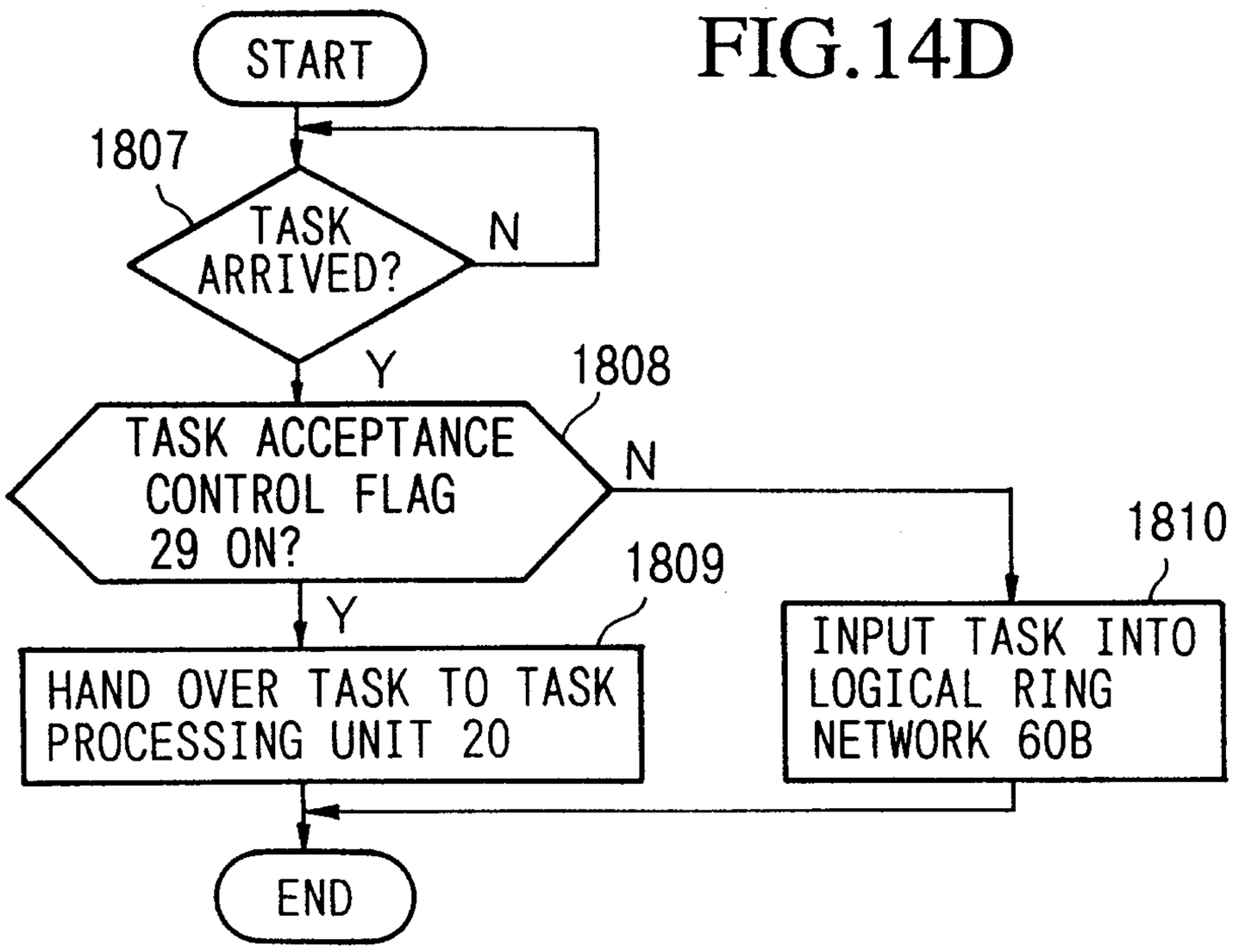


FIG.15A

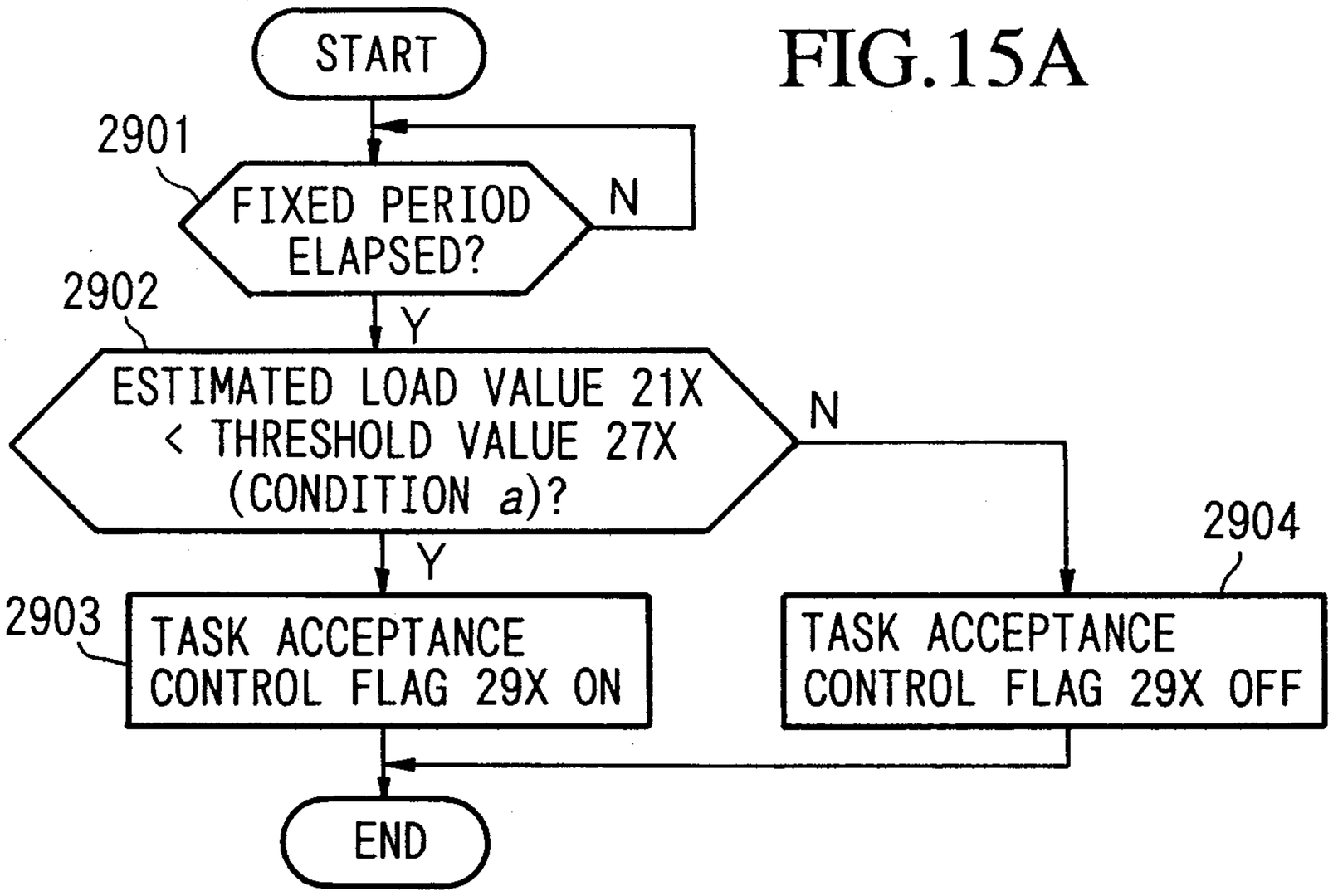


FIG.15B

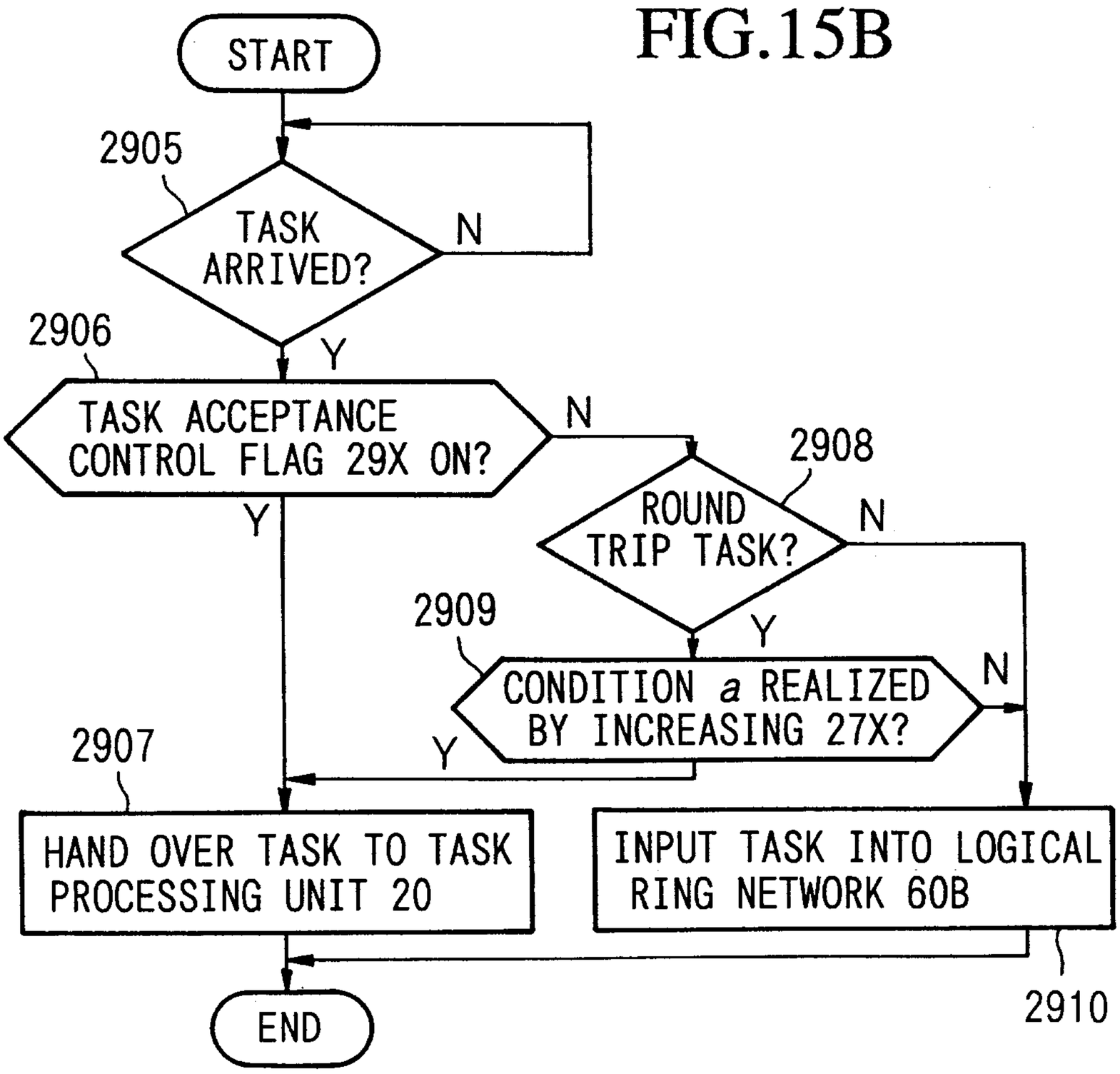


FIG.15C

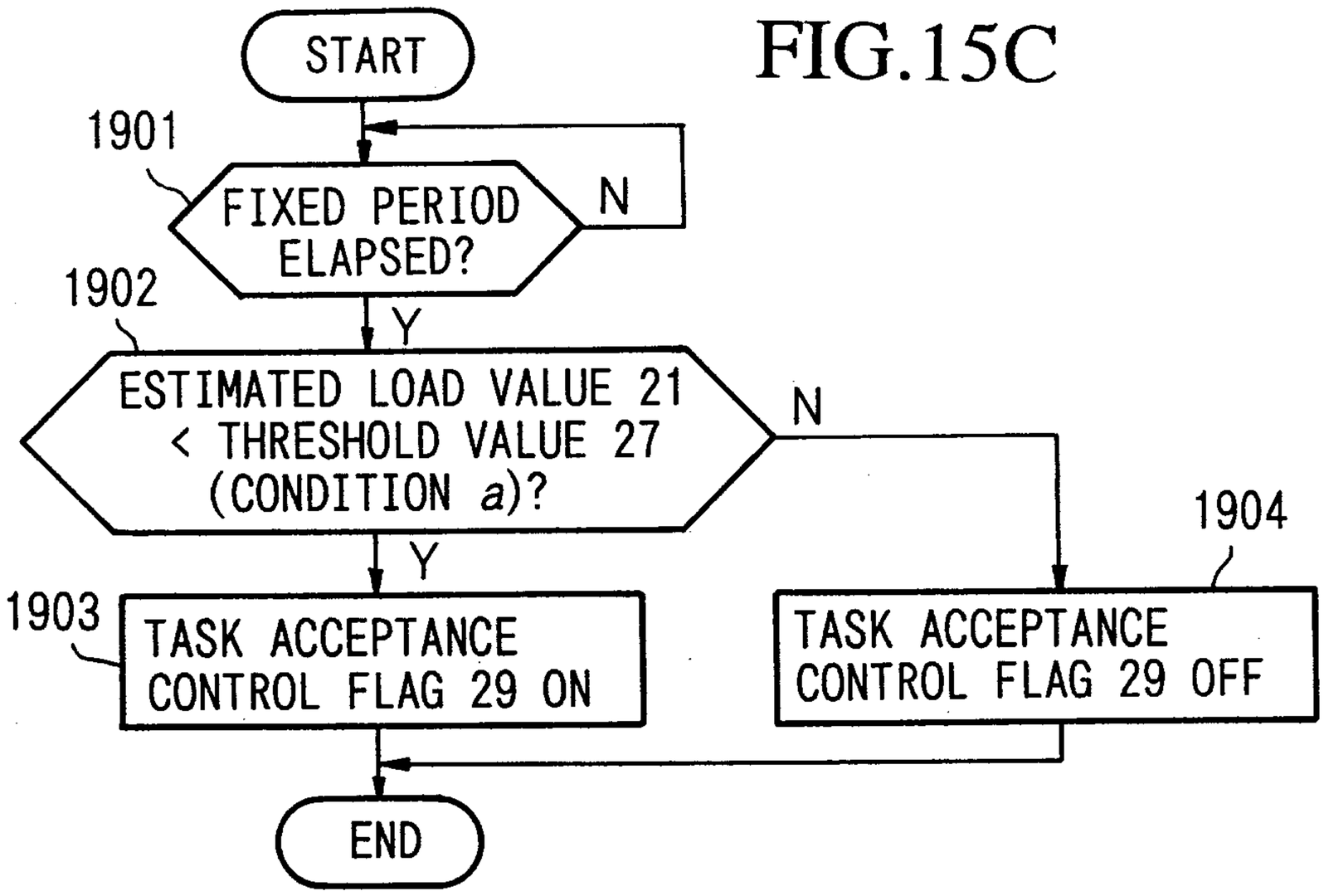


FIG.15D

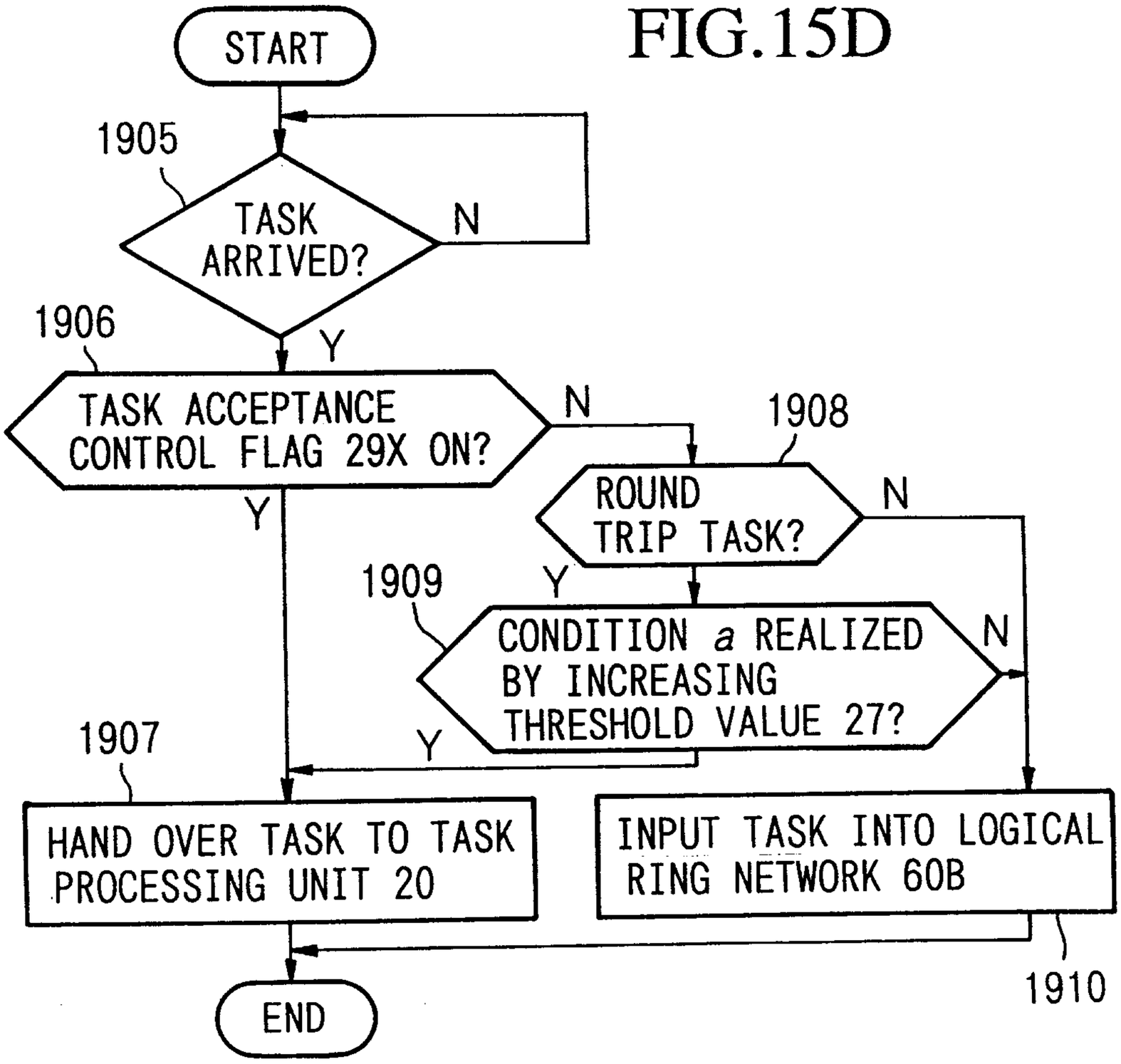


FIG.16A

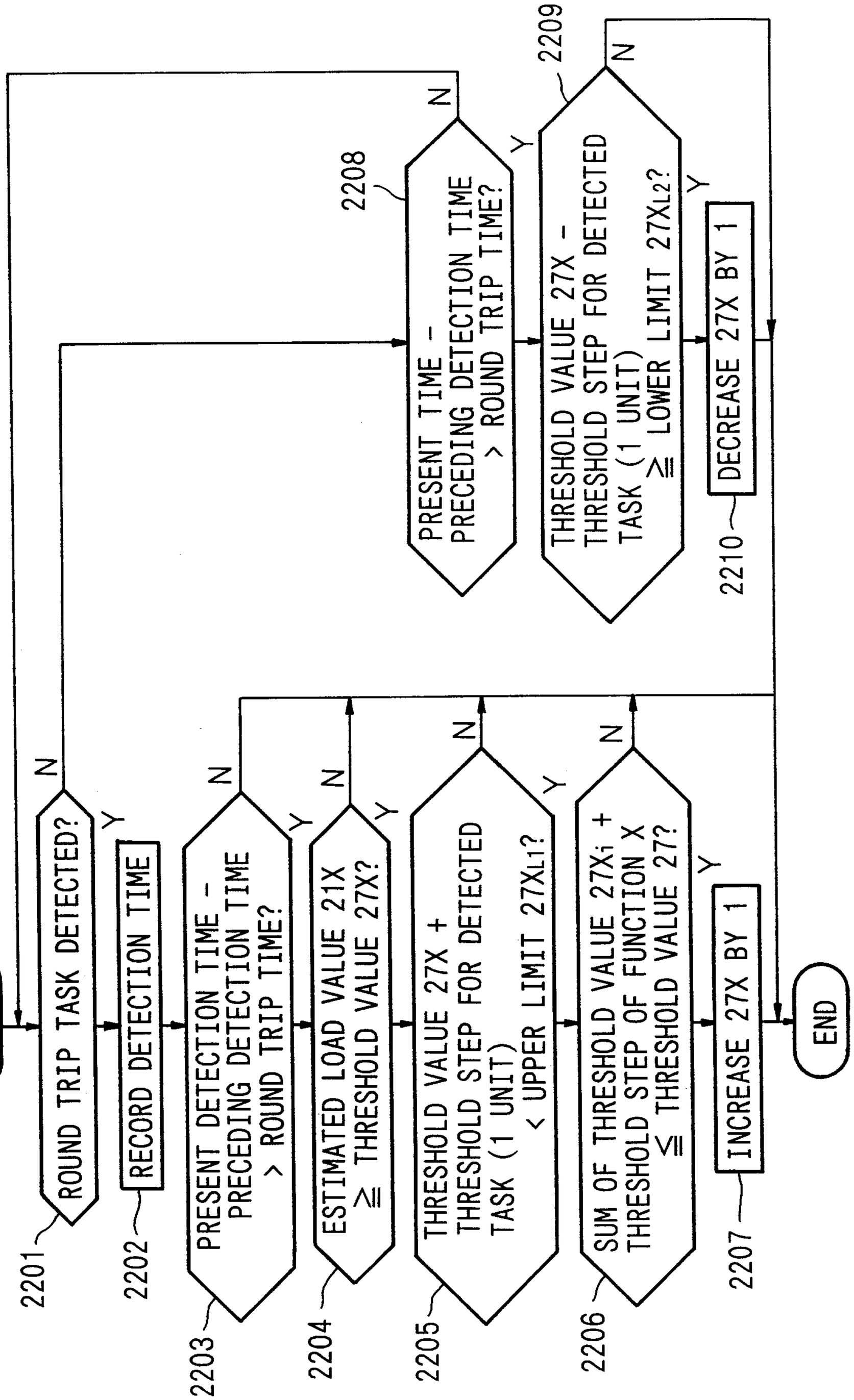
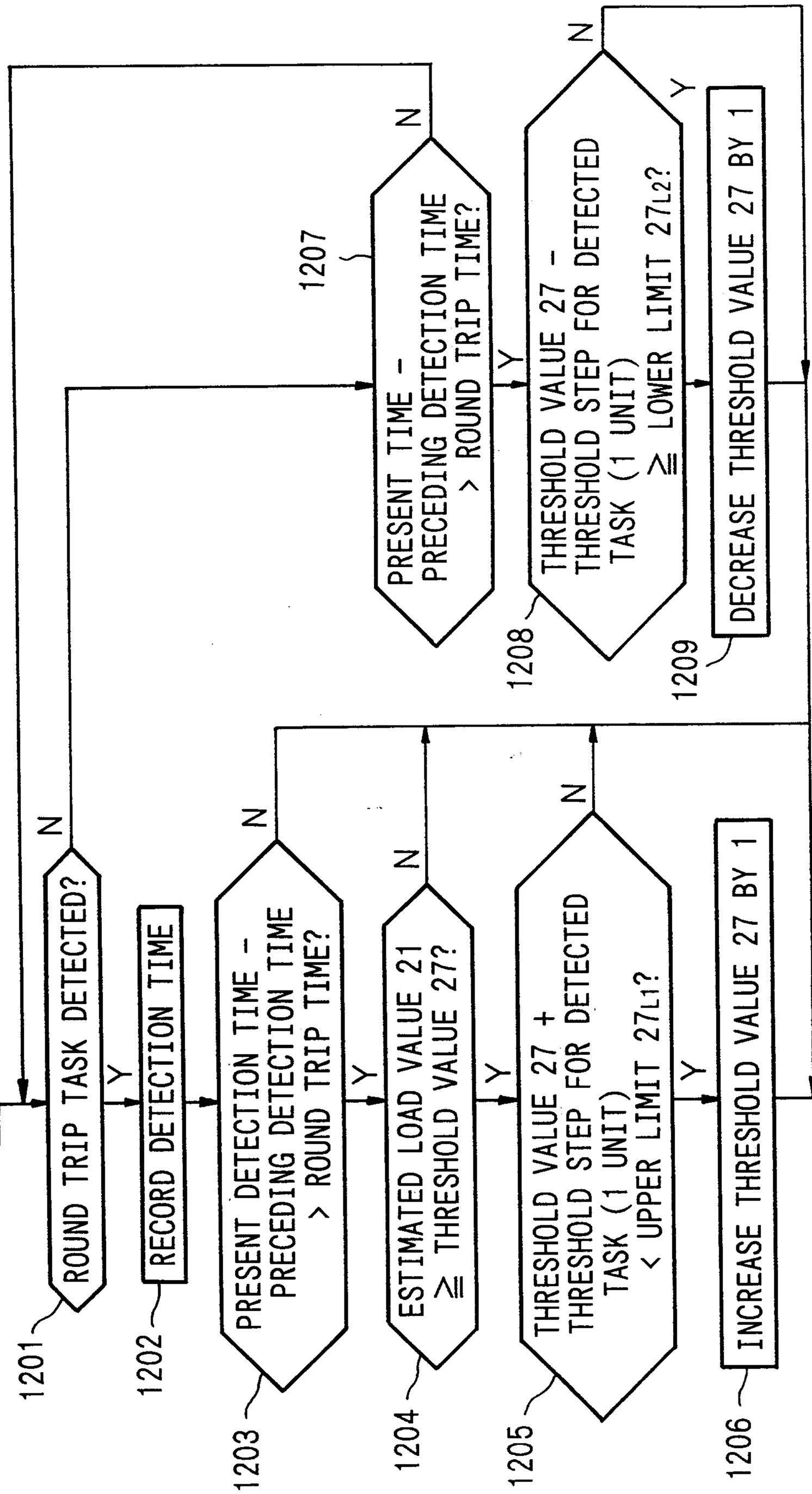

START
2201 ROUND TRIP TASK DETECTED?
N
Y
2202 RECORD DETECTION TIME
2203 PRESENT DETECTION TIME - PRECEDING DETECTION TIME > ROUND TRIP TIME?
N
Y
2204 ESTIMATED LOAD VALUE 21X ≧ THRESHOLD VALUE 27X?
N
Y
2205 THRESHOLD VALUE 27X + THRESHOLD STEP FOR DETECTED TASK (1 UNIT) < UPPER LIMIT 27XL1?
N
Y
2206 SUM OF THRESHOLD VALUE 27Xi + THRESHOLD STEP OF FUNCTION X ≦ THRESHOLD VALUE 27?
N
Y
2207 INCREASE 27X BY 1
2208 PRESENT TIME - PRECEDING DETECTION TIME > ROUND TRIP TIME?
N
Y
2209 THRESHOLD VALUE 27X - THRESHOLD STEP FOR DETECTED TASK (1 UNIT) ≧ LOWER LIMIT 27XL2?
N
Y
2210 DECREASE 27X BY 1
END

FIG.16B



Marks & Clerk

FIG.17

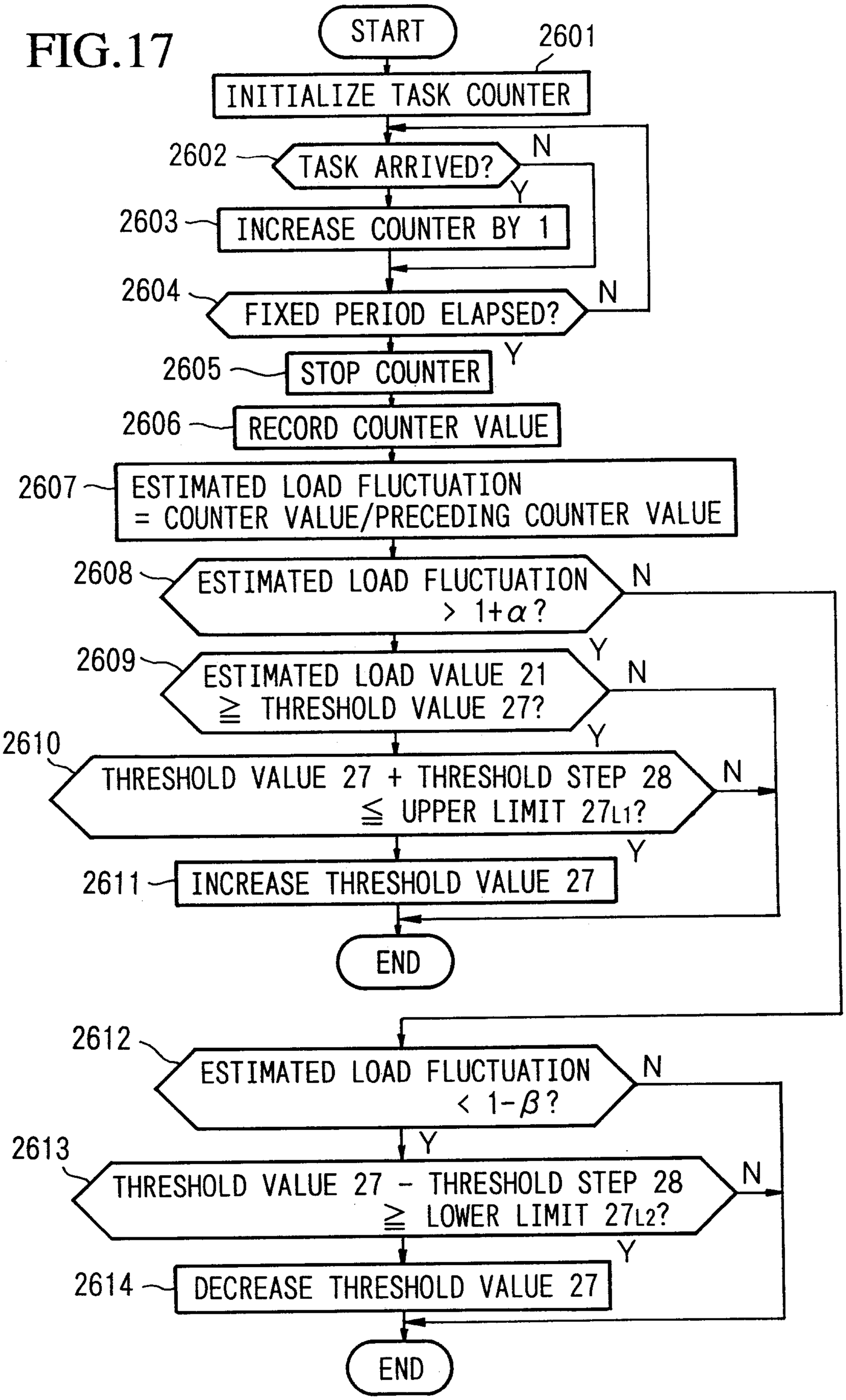

START
2601
INITIALIZE TASK COUNTER
2602
TASK ARRIVED?
N
Y
2603
INCREASE COUNTER BY 1
2604
FIXED PERIOD ELAPSED?
N
Y
2605
STOP COUNTER
2606
RECORD COUNTER VALUE
2607
ESTIMATED LOAD FLUCTUATION
= COUNTER VALUE/PRECEDING COUNTER VALUE
2608
ESTIMATED LOAD FLUCTUATION
> 1+α?
N
Y
2609
ESTIMATED LOAD VALUE 21
≧ THRESHOLD VALUE 27?
N
Y
2610
THRESHOLD VALUE 27 + THRESHOLD STEP 28
≦ UPPER LIMIT 27L1?
N
Y
2611
INCREASE THRESHOLD VALUE 27
END
2612
ESTIMATED LOAD FLUCTUATION
< 1-β?
N
Y
2613
THRESHOLD VALUE 27 - THRESHOLD STEP 28
≧ LOWER LIMIT 27L2?
N
Y
2614
DECREASE THRESHOLD VALUE 27
END

FIG.18A

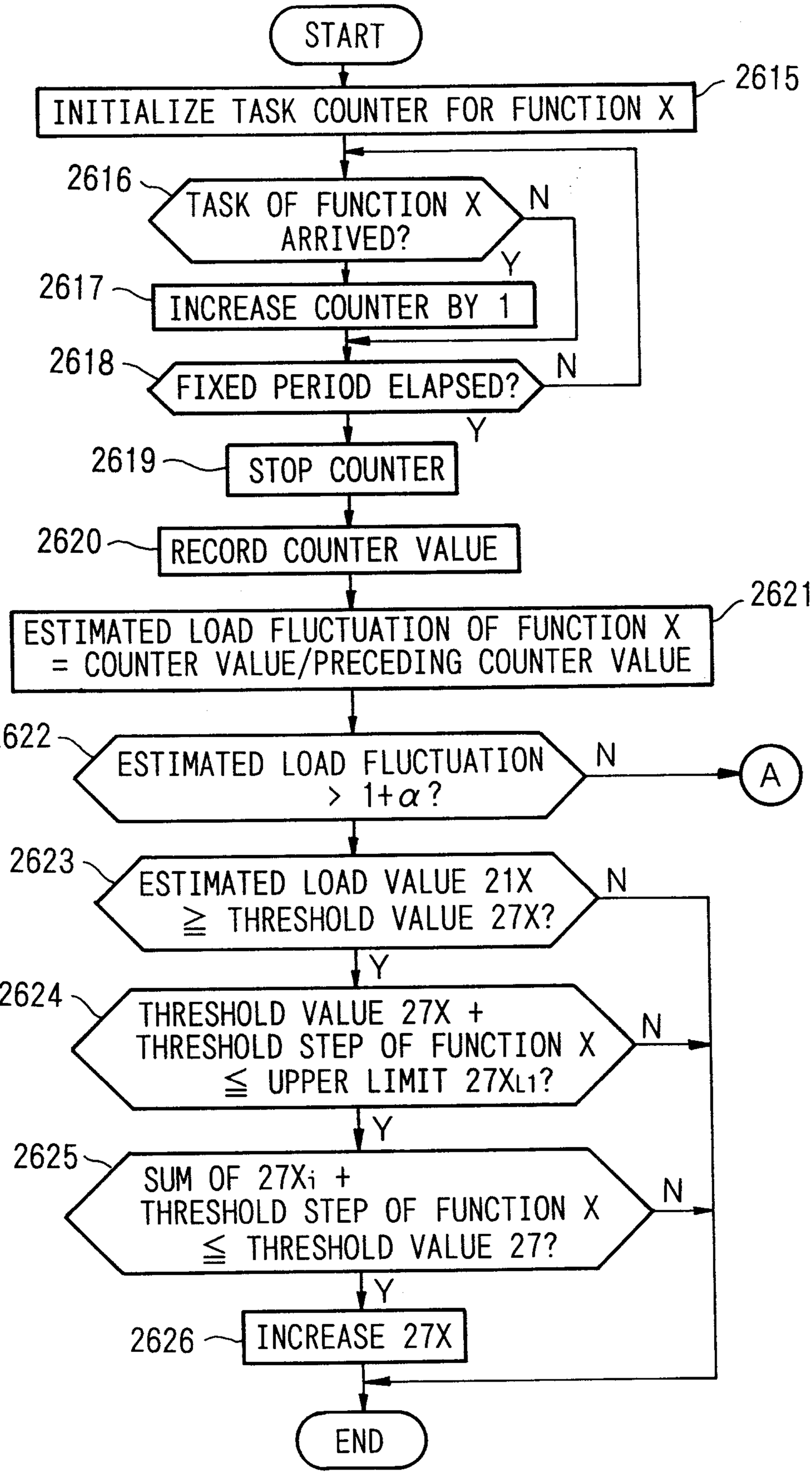

START
INITIALIZE TASK COUNTER FOR FUNCTION X
2615
2616
TASK OF FUNCTION X ARRIVED?
N
Y
2617
INCREASE COUNTER BY 1
2618
FIXED PERIOD ELAPSED?
N
Y
2619
STOP COUNTER
2620
RECORD COUNTER VALUE
2621
ESTIMATED LOAD FLUCTUATION OF FUNCTION X = COUNTER VALUE/PRECEDING COUNTER VALUE
2622
ESTIMATED LOAD FLUCTUATION > 1+α?
N
A
2623
ESTIMATED LOAD VALUE 21X ≧ THRESHOLD VALUE 27X?
N
Y
2624
THRESHOLD VALUE 27X + THRESHOLD STEP OF FUNCTION X ≦ UPPER LIMIT 27XL1?
N
Y
2625
SUM OF 27Xi + THRESHOLD STEP OF FUNCTION X ≦ THRESHOLD VALUE 27?
N
Y
2626
INCREASE 27X
END

FIG.18B

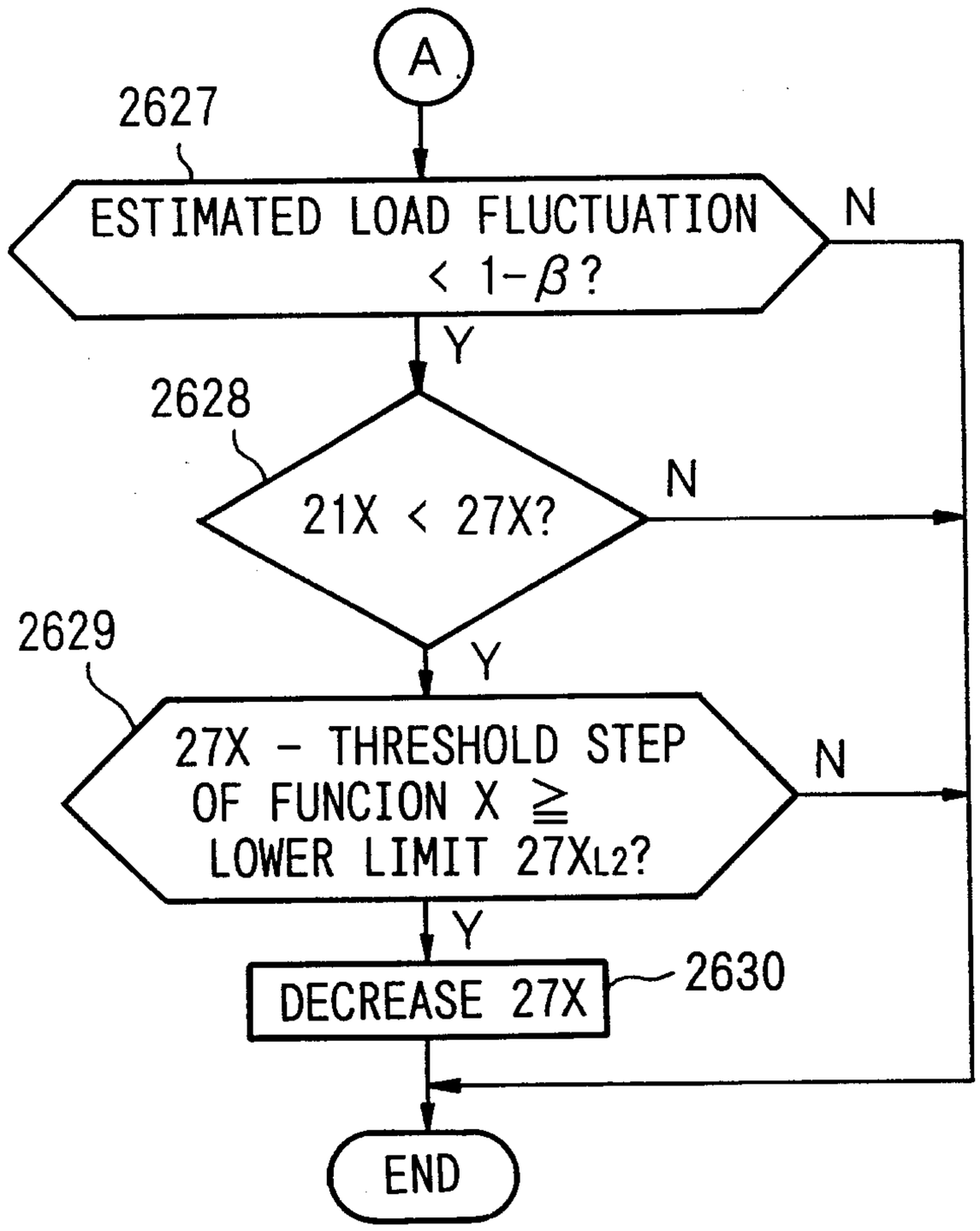

A
2627
ESTIMATED LOAD FLUCTUATION < 1-β?
N
Y
2628
21X < 27X?
N
Y
2629
27X - THRESHOLD STEP OF FUNCION X ≧ LOWER LIMIT 27XL2?
N
Y
DECREASE 27X
2630
END

FIG.19

LOAD FLUCTUATION OF ENTIRE SYSTEM (DEC=DECREASE, INC=INCREASE)	THE NUMBER OF ROUND TRIP TASKS	ESTIMATED PERFORMANCE LEVEL OF ENTIRE SYSTEM	CHANGE OF THRESHOLD STEP
DEC→INC	INCREASE	CONSTANT	NONE
DEC→INC	CONSTANT	INCREASE	DECREASE
DEC→INC	DECREASE	INCREASE	DECREASE
DEC→RAPID INC	INCREASE	CONSTANT	NONE
DEC→RAPID INC	CONSTANT	INCREASE	DECREASE
DEC→RAPID INC	DECREASE	INCREASE	DECREASE
INC→DEC	INCREASE	DECREASE	INCREASE
INC→DEC	CONSTANT	DECREASE	INCREASE
INC→DEC	DECREASE	CONSTANT	NONE
INC→RAPID DEC	INCREASE	DECREASE	INCREASE
INC→RAPID DEC	CONSTANT	DECREASE	INCREASE
INC→RAPID DEC	DECREASE	CONSTANT	NONE
RAPID DEC→GRADUAL DEC	INCREASE	CONSTANT	NONE
RAPID DEC→GRADUAL DEC	CONSTANT	INCREASE	DECREASE
RAPID DEC→GRADUAL DEC	DECREASE	INCREASE	DECREASE
GRADUAL DEC→RAPID DEC	INCREASE	DECREASE	INCREASE
GRADUAL DEC→RAPID DEC	CONSTANT	DECREASE	INCREASE
GRADUAL DEC→RAPID DEC	DECREASE	CONSTANT	NONE
RAPID INC→GRADUAL INC	INCREASE	CONSTANT	NONE
RAPID INC→GRADUAL INC	CONSTANT	CONSTANT	NONE
RAPID INC→GRADUAL INC	DECREASE	INCREASE	DECREASE
GRADUAL INC→RAPID INC	INCREASE	DECREASE	INCREASE
GRADUAL INC→RAPID INC	CONSTANT	CONSTANT	NONE
GRADUAL INC→RAPID INC	DECREASE	CONSTANT	NONE

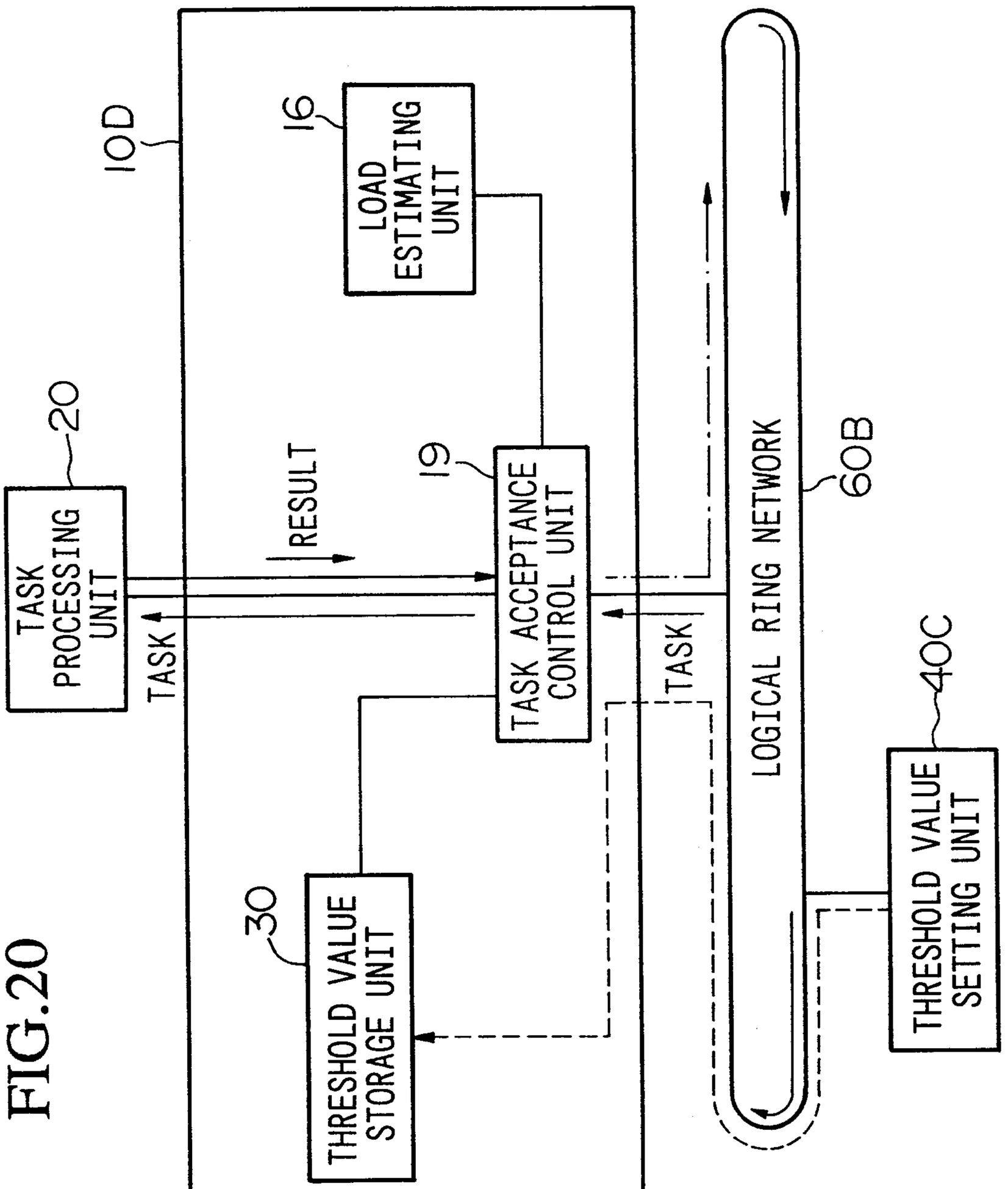

10D
16
LOAD ESTIMATING UNIT
19
TASK ACCEPTANCE CONTROL UNIT
20
TASK PROCESSING UNIT
RESULT
TASK
30
THRESHOLD VALUE STORAGE UNIT
TASK
LOGICAL RING NETWORK
60B
40C
THRESHOLD VALUE SETTING UNIT

FIG.20

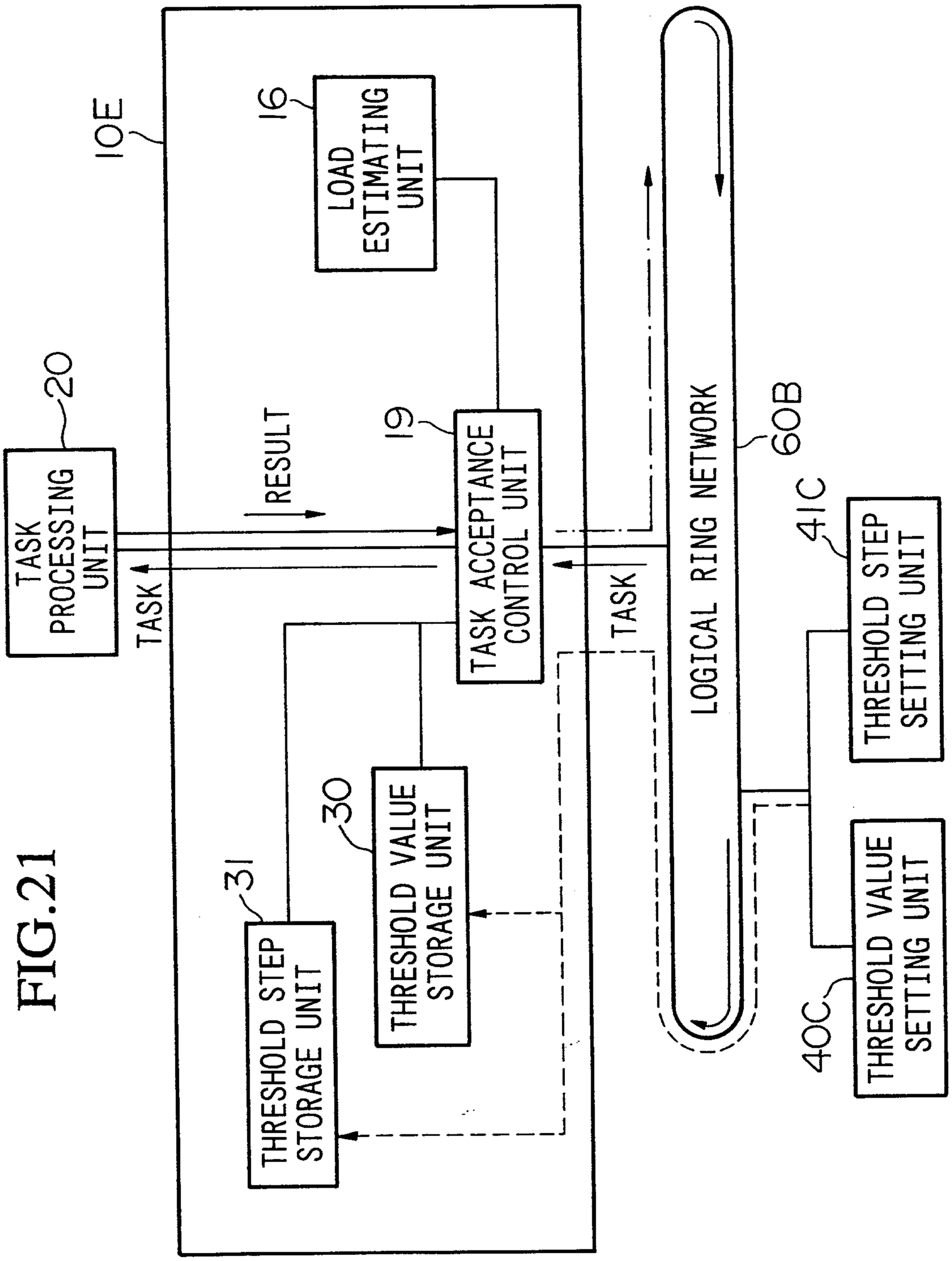
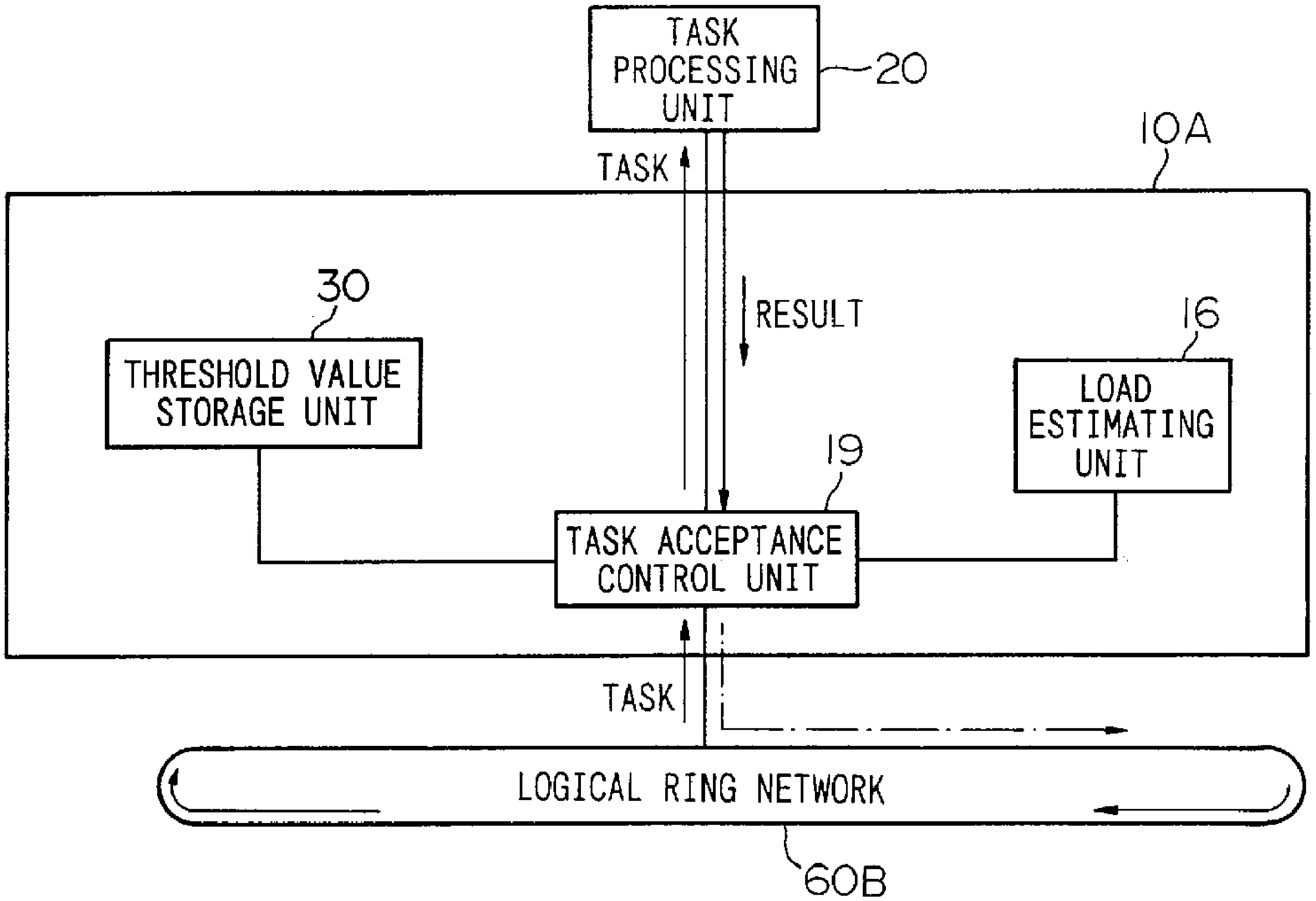

10E
16
LOAD ESTIMATING UNIT
19
TASK ACCEPTANCE CONTROL UNIT
20
TASK PROCESSING UNIT
RESULT
TASK
TASK
30
THRESHOLD VALUE STORAGE UNIT
31
THRESHOLD STEP STORAGE UNIT
LOGICAL RING NETWORK
60B
40C
THRESHOLD VALUE SETTING UNIT
41C
THRESHOLD STEP SETTING UNIT

FIG.21


TASK PROCESSING UNIT
20
10A
TASK
RESULT
30
THRESHOLD VALUE STORAGE UNIT
16
LOAD ESTIMATING UNIT
19
TASK ACCEPTANCE CONTROL UNIT
TASK
LOGICAL RING NETWORK
60B