Using MUSIC Devices and RCPs for IP Flow Recognition

INTRODUCTION

Much has been said regarding Layer 3 switching (routing) of IP (Internet Protocol) packets, but little has been said about how to identify types of traffic in order to assign a Class of Service (CoS) or Quality of Service (QoS) to these packets. Avoiding CoS or QoS by using tremendous amounts of bandwidth is costly and inefficient, particularly for WANs. A better solution is to assign priority based on the Layer 3 IP address and the Layer 4 TCP or UDP port numbers.

The solution proposed in this document is to identify not individual packets, but traffic "flows." For example, a Voice Over IP (VOIP) application would carry a telephone conversation between two host terminals, connected by a combination of Local Area Networks (LANs) and Wide Area Networks (WANs). Although voice traffic is not a high bandwidth application, it is sensitive to delay and jitter (variation in delay). To properly control the undesirable effects of bursty network traffic, each network node (switch or router) must identify this unique traffic flow, and prioritize this flow in such a way as to control delay and jitter. On the otherhand, data traffic, such as large file transfers are high bandwidth traffic but are not sensitive to delay and jitter. Data traffic would be assigned a lower, or at least different priority within the network node.

If the network node must identify and prioritize traffic on a packet by packet basis, the workload from even a small amount of traffic could completely consume the node's processing resources. The key to making prioritization of traffic work is to identify and assign the priority on the first group of packets. Once this has been done, recognize all subsequent packets belonging to the same stream or flow, and send them out the same port with the same priority. In this way, a connectionless environment can behave like a connection-oriented environment.

Using CAM (Content Addressable Memory) and RCPs (Routing CoProcessor) to "remember" the traffic flow allows the network switch or router to identify packets belonging to that flow, at wire speed, and without processor intervention.

Identifying Traffic Flows - How Many Bits?

It takes more than just identifying the TCP or UDP port numbers to uniquely identify a flow of traffic. The more bits used, the more likely the traffic flow is uniquely identified. Unfortunately, the more bits used to identify a flow of traffic, the more difficult it becomes to recognize the flow on a packet by packet basis at wire speeds.

In most cases, the proper identification of a data flow can be achieved with 96 bits. These are (see Figure 1):

32 bits of IP Source Address
32 bits of IP Destination Address
16 bits of Source TCP or UDP Port Number
16 bits of Destination TCP or UDP Port Number

In some cases the protocol identification needs to be stored and identified on a per packet basis as well. Since the number of bits needed to identify the protocol is small, it is not necessary to store it in the device itself. This detection and discrimination could be done outside of the device.

Similarly, the ToS (Type of Service) field in the IP packet header is currently not used, but certain routing management software checks this field as part of the policy management per port. The ToS information need not be stored in the device, but can be stored in the associated data in external RAM pointed to by the CAM or RCP. This document will not address hardware firewalling. Providing a hardware firewall by using the source MAC address could be realized by sectioning the CAM or RCP, storing the source MAC addresses in this section, and performing an additional search of the CAM or RCP. This would effectively reduce the number of simultaneous connections a given CAM or RCP could support and reduce the throughput performance as a result of these additional searches. The simplicity, reduced part count, and deterministic nature of this approach may outweigh these penalties.

The Source and Destination IP Addresses identify a host-to-host connection. If several applications are communicating between the host pair, each will have its own unique pair of TCP or UDP port numbers. This will allow the same pair of hosts to have multiple types of

32-bit IP Source Address	32-bit IP Destination Address	16-bit TCP/UDP Source Port #	16-bit TCP/UDP Destination Port #

Figure 1: Data Flow Identification

connections, such as voice traffic, video traffic, and data traffic. The switch or router also can identify and treat each traffic flow separately. Each of these connections can then receive an adequate Quality of Service level.

The MUSIC MU9C1965A/L MP LANCAM is a 128-bit wide device. This device may be the obvious choice for a workgroup or small edge switch or router, but the following alternatives will allow the use of 64-bit wide, cost-effective, deeper MUSIC Devices.

Identifying Traffic Flows – How Many Flows?

It is not necessary to identify and prioritize every frame. The reason for this is simple: there is a fair amount of network traffic necessary for overhead, management, and exploration, which do not need to be handled at high priority. “Hello” messages used in routing protocols and “Ping” would not be considered as traffic flows. These, as well as other types of short-term traffic, have default time-outs in seconds and do not require higher priority than “Default.” Switching at Layer 4 assumes a continuous flow of traffic between two or more end points. “Hello” and “Ping” are very short; at most only a few packets long. Preventing the Layer 4 search engine from seeing this type of traffic minimizes the size of the Layer 4 table, and greatly reduces the required table maintenance. Storing and maintaining a smaller Layer 4 database reduces the cost and complexity of the Layer 4 engine, as well as reducing the number of host processor cycles required for overhead.

Multiple Search Approach

In this approach, the device database is searched twice; once for the IP source and destination pair, and once for the TCP/UDP source and destination port pair. The IP source and destination pair establishes the “Parent” of a two-level tree, and the TCP/UDP port pairs are the “Children” of the tree. As mentioned before, each IP source and destination pair may have many applications communicating, each with a different TCP or UDP port pair, so each “Parent” can have many “Children.”

A successful search of the device for the IP source and destination pair (64-bit compare) returns a unique address within the device where the match was found. This address identifies the “Parent,” and is used in the search for the TCP or UDP port pair (See Figure 2a).

A successful search for the “Child” returns the device address where it was found, which is used to index into external RAM for the associated data.

The leading zeros for the “Child” entry prevent any possibility that a “Child” could look like a “Parent.” The first eight most significant bits of an IP address cannot be all zeros. All zeros are reserved and therefore cannot be a source address. In this scheme, there are up to 24 bits available for the “Parent” address, 16 million entries. This example uses 16 bits, which supports 65,536 entries.

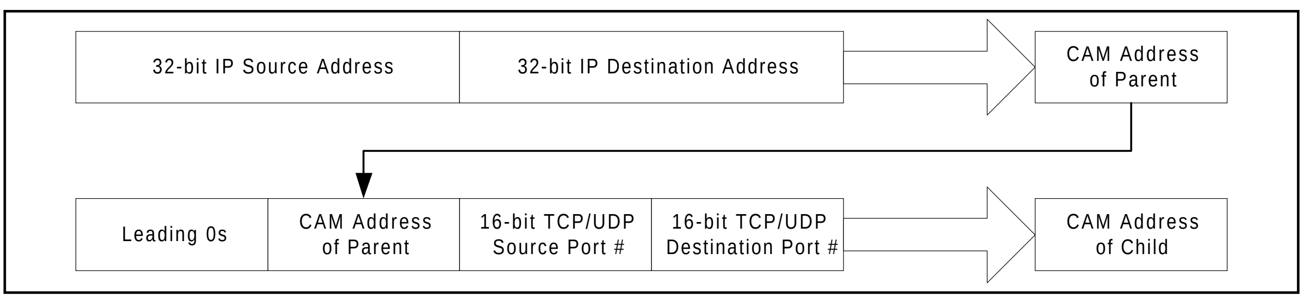

Figure 2a: Two-Search Method Without Timestamp

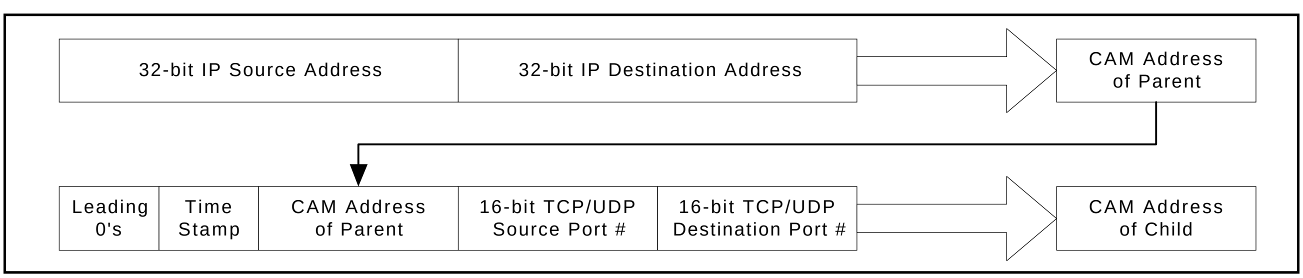

Figure 2b: Two-Search Method With Timestamp

In the example routines shown in this document, learning new flows is automatic. Once a flow is identified, the system software would then assign the proper priority to the newly identified flow. If aging is not used, the system software would need to keep track of the locations of every "Child" and "Parent." As each session ends, the "Child" is removed from the device database by the system software. When the last "Child" has been removed from the device database, the system software also removes the "Parent." This is not a real-time issue, so software can provide adequate performance.

Refer to the routine examples at the end of this document for each of the different MUSIC devices. For additional information on each of the device families refer to the individual data sheets.

Multiple-Search Device Routines

For the devices to perform searches properly, they must be initialized and configured correctly. The first routine shown for each device type is the Initialization and Configuration routine. Although this routine is not time critical and happens only after power-up and system reset, timing information and clock cycle count are given for reference.

The Search and Learn routine contains a couple of branches, depending on whether or not a match was found for each of the searches. If the "Parent" IP source and destination address pair is not found, it is automatically "Learned" by the device, along with the "Child" TCP/UDP source and destination port pair. (There cannot be a "Child" without a "Parent," so if a "Parent" is not found, a search for the "Child" is unnecessary.) If the "Parent" is found, then a search for the "Child" is initiated. If the "Child" is found, then the routine is finished. If the "Child" is not found, it is

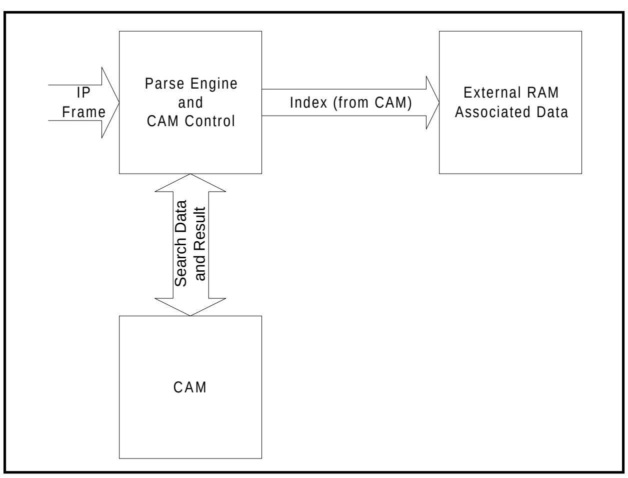

Figure 3: Simplified Block Diagram Two-Search Method

"Learned" by the device. In each of the cases where learning is necessary (adding a new connection), the Next Free address of the device is read out so the system software can keep track of where the new additions are being placed. This way, the system software can efficiently remove these entries when they are no longer active.

Flow Termination – Removing Inactive Flow Identifiers Using Device-Stored Timestamps

It is possible, even desirable to store timestamp information in the device to facilitate aging and purging of inactive flow identifiers. For the two-search method of identifying traffic flows, the routine to remove inactive flow identifiers contains several decision break points. The first decision is whether or not there are entries that need to be removed. If there are entries that need to be removed, is it one or more than one entry?

Since the two-search approach is a two-level tree, you need to determine if the "Child" entry getting removed has any siblings. If not, the "Parent" needs to be removed as well. If there is more than one entry that needs to be removed, the routine must be run again.

This process is repeated until all inactive flow identifiers have been removed. Because identifying traffic flows should have higher priority than table maintenance routines, it is not necessary to immediately initiate the aging routine back to back. It would be better to wait for lulls in the priority traffic to initiate the second or third (or more) purge routines.

Figure 2b is the modified version of Figure 2a that incorporates 8 bits of timestamp in the "Child" level of the tree-structured database. It is necessary to have the first 8 bit locations be set to 0 to assure that the "Child" level never looks like a "Parent" level entry. (An IP Source address cannot be an aggregate of a Class A address.) Each time the flow is touched, the timestamp field is updated to the current time. The purge time eventually "catches up" to the timestamp contained in the inactive flows, causing those locations to match during a search of the timestamp field. These flow identifiers are then deleted by the routine, causing them to be purged, freeing those locations.

An 8-bit field was chosen for the timestamp so that the number of flow identifiers aging out per interval is, on average, small. Additional bits could be "stolen" from the Parent Address field, provided the full 16 bits are not required for the Parent address. This would make the aging interval smaller, effectively reducing the number of times the purge routine is run per aging interval.

Single Search Approach

In this example, the (Layer 3) IP Addresses are stored in another table, and a pointer is used to identify where a particular IP address is stored. Limiting each pointer to 16 bits, the representation of the IP Source and IP Destination address pair would fit into a 32-bit field. As in the previous multiple search example, the source and destination TCP/UDP port numbers also fit into a 32-bit field. The IP Source and Destination pair plus the TCP/UDP port pair fit inside the 64-bit width of any of the MUSIC LANCAM devices or the MU9C RCP devices. Because hashing is not used to reduce the size of the IP addresses, the possibility of collisions does not exist. Upon a successful match, the device will return the match address, which is used to index into external RAM, where the associated data is stored.

Routines

The configuration of the device database is identical for both the single-search method and the two-search method without internal timestamp field. For this reason, the Initialization and Configuration routine has not been repeated for the following routine examples.

There are several reasons to always perform IP source and destination address searches, especially for policy implementation and management. Provided the Layer 3 search has already been performed, there is no need to do it again at Layer 4. Given this case, the single-search approach will work well. The main idea is to minimize the time it takes to make a decision for in-band activities. Remembering the locations of the Layer 3 addresses is easier than again searching for them for the Layer 4 flow recognition task. The result is a significant improvement in packet throughput and learning of new flows.

Use of the pipelined multi-port RCPs, such as the MU9C RCP, will greatly improve search times. This allows the first part of the next search to be written to the RCP while reading the match location of the previous compare (search) operation, eliminating several clock cycles.

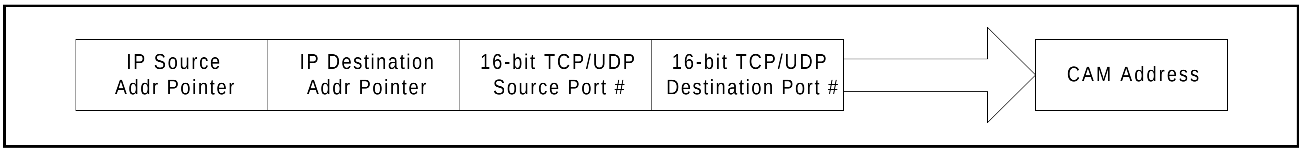

Figure 4: Single Search

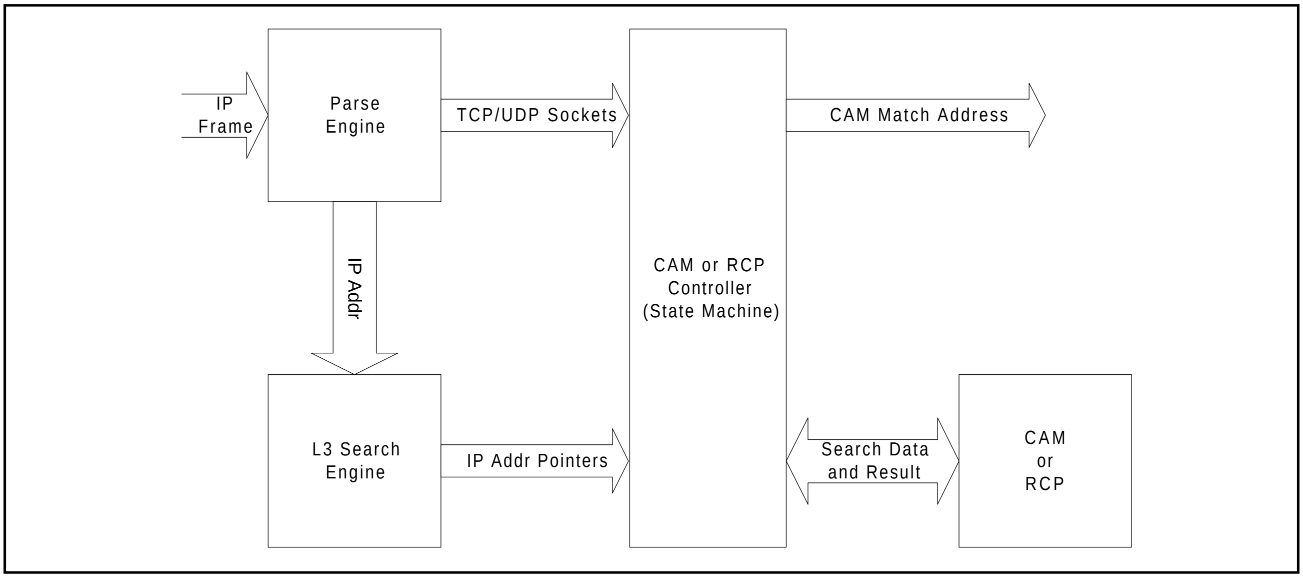

Figure 5: Simplified Block Diagram Single-Search Method

MULTIPLE-SEARCH Device ROUTINES

LANCAM 1ST

Initialization Routine

Two Search Method without Internal Timestamp and Single-Search Method

Cycle	Data	/E=L	/E=H	# 15 ns Clk
CRS	Dummy Read Cycle; Clears power-up anomalies	30	15	3
CWS	TCO_CT; Target Control Register	30	15	3
CWM	0x0000; Reset	60	15	5
CWS	TCO_CT; Target Control Register	30	15	3
CWM	0x8000; 64 CAM, 0 RAM, Increment Address Register	60	15	5
CWS	TCO_SC; Target Segment Control Register	30	15	3
CWM	0x18C0; Write to Segments 0:3, Read Segments 0:3	60	15	5
CWS	SPD_CR; Set Persistent Destination to Comparand Register	30	15	3
CWS	SPS_Mem@AR	30	15	3
Total		**495 ns**		**33**

Initialization Routine

Two Search Method with Internal Timestamp

Cycle	Data	/E=L	/E=H	# 15 ns Clk
CRS	Dummy Read Cycle; Clears power-up anomalies	30	15	3
CWS	TCO_CT; Target Control Register	30	15	3
CWM	0x0000; Reset	60	15	5
CWS	TCO_CT; Target Control Register	30	15	3
CWM	0x8000; 64 CAM, 0 RAM, Increment Address Register	60	15	5
CWS	TCO_SC; Target Segment Control Register	30	15	3
CWM	0x1A41; Write to Segments 0:3, Read Segment 1	60	15	5
CWS	SPD_MR1; Sibling Mask	30	15	3
DWS	0x00FF	30	15	3
DWS	0x0000	30	15	3
DWS	0xFFFF	30	15	3
DWS	0xFFFF	30	15	3
CWS	SPD_CR; Set Persistent Destination to Comparand Register	30	15	3
CWS	SBR; Set to Background Register Set	30	15	3
CWS	TCO_CT	30	15	3
CWM	0x80C0; 16 CAM, 48 RAM	60	15	5
CWS	TCO_SC	30	15	3
CWM	0x0141; Write to Segment 0, Read from Segment 1	60	15	5
CWS	SFR; Set to Foreground Register Set	30	15	3
CWS	SPS_Mem@AR	30	15	3
Total		**1455 ns**		**97**

Legend:

CRS: Command Read, Short Cycle
CRM: Command Read, Medium Cycle
CWS: Command Write, Short Cycle
CWL: Command Write, Long Cycle
DWS: Data Write, Short Cycle
DWL: Data Write, Long Cycle

Please refer to the individual device data sheets for the detail information.

MULTIPLE-SEARCH DEVICE ROUTINES *Continued*
LANCAM 1ST

Search and Learn Routine
Two-Search Method

Cycle	Data	/E=L	/E=H	# 15 ns Clk
DWS	Write IP Source Address bits 31:16	30	15	3
DWS	Write IP Source Address bits 15:0	30	15	3
DWS	Write IP Destination Address bits 31:16	30	15	3
DWL	Write IP Destination Address bits 15:0	75	15	6
CWM	Read Status Register - Address of "Parent"	60	15	5

If CAM Status Register bit 0 = 1 (No Match)
Then

Cycle	Data	/E=L	/E=H	# 15 ns Clk
CWS	TCO_NF - Select the Next Free Address Register	30	15	3
CRM	Read the Next Free Address Register - "Parent" Address	60	15	5
CWL	MOV_NF, CR, V - Add "Parent" to database	75	15	6
DWS	Dummy Write - All "0"	30	15	3
DWS	Write Address of "Parent"	30	15	3
DWS	Write TCP/UDP Source Port Number	30	15	3
DWL	Write TCP/UDP Destination Port Number	75	15	6
CRM	Read the Next Free Address Register - "Child" Address	60	15	5
CWL	MOV_NF, CR, V - Add "Child" to database	75	15	6
Total	**1.1 Million New Connections per Second**	**900 ns**		**60**

Else

Cycle	Data	/E=L	/E=H	# 15 ns Clk
DWS	Dummy Write - All "0"	30	15	3
DWS	Write Address of "Parent"	30	15	3
DWS	Write TCP/UDP Source Port Number	30	15	3
DWL	Write TCP/UDP Destination Port Number	75	15	6
CRM	Read Status Register - Address of "Child"	60	15	5
Total	**1.6 Million Existing Connections per Second**	**600 ns**		**40**

If Cam Status Register bit 0 = 0 (Match Found)
Then Done
Else

Cycle	Data	/E=L	/E=H	# 15 ns Clk
CWS	TCO_NF - Select the Next Free Address Register	30	15	3
CRM	Read the Next Free Address Register - "Child" Address	60	15	5
CWL	MOV_NF, CR, V - Add "Child" to database	75	15	6
Total	**1.2 Million New "Child" Connections per Second**	**810 ns**		**54**

Legend:
CRS: Command Read, Short Cycle
CRM: Command Read, Medium Cycle
CWS: Command Write, Short Cycle
CWL: Command Write, Long Cycle
DWS: Data Write, Short Cycle
DWL: Data Write, Long Cycle
Please refer to the individual device data sheets for the detail information.

MULTIPLE-SEARCH DEVICE ROUTINES *Continued*

LANCAM 1ST

Search and Learn Routine

Single-Search Method

Cycle	Data	/E=L	/E=H	# 15 ns Clk
DWS	Write IP Source Address Pointer	30	15	3
DWS	Write IP Destination Address Pointer	30	15	3
DWS	Write TCP/UDP Source Port Number	30	15	3
DWL	Write TCP/UDP Destination Port Number	75	15	6
CRM	Read Status Register - Match Address	60	15	5
Total	**3.3 Million Existing Connections per Second**	**300 ns**		**20**

If Status Register Bit 0 = 0 (Match Found)
Then Done
Else

CWL	MOV_NF, CR, V	75	15	6
Total	**2.56 Million New Connections per Second**	**390 ns**		**26**

Legend:

CRS: Command Read, Short Cycle
CRM: Command Read, Medium Cycle
CWS: Command Write, Short Cycle
CWL: Command Write, Long Cycle
DWS: Data Write, Short Cycle
DWL: Data Write, Long Cycle

Please refer to the individual device data sheets for the detail information.

MULTIPLE-SEARCH DEVICE ROUTINES *Continued*

LANCAM 1ST

Age Entry Routine

Two-Search Method

Cycle	Data	/E=L	/E=H	# 15 ns Clk
CWS	SBR	30	15	3
DWL	0x00tt; tt = 8 bit timestamp value; Initiate Compare	90	15	7
CRM	Read CAM address of “Child”; Valid address if bit 0 = “0”	60	15	5

If bit 0 = 1; No entries need to be deleted
Then

CWS	SFR	30	15	3
Total		**270 ns**		**18**

Else Read /MM (Multi-Match) Flag (If /MM = 0, then additional entries need to be purged.)

DRL	Read CAM address of “Parent” Entry	90	15	7
DWS	MOV_CR, HM; Copy “Child” entry to Comparand Register	90	15	7
DWS	VBC_HM, E; Delete “Child” at Highest Match location	60	15	5
DWL	SFR	30	15	3
CRM	TCO_CT	30	15	3
DWL	0x8090; 32 CAM, 32 RAM, MR1; Initiate Compare	90	15	7
CRM	Read Status Register	60	15	5

If bit 0 = 1; “Child” has no siblings
Then

CWM	VBC aaaH, E; Delete “Parent” entry	60	15	5
CWL	Write CAM Address of “Parent”	90	15	7
CWS	TCO_CT; Target Control Register	30	15	3
CWM	0x8000; 64 CAM, 0 RAM, Increment Address Register	60	15	5
Total		**1080 ns**		**72**

Else

CWS	TCO_CT; Target Control Register	30	15	3
CWM	0x8000; 64 CAM, 0 RAM, Increment Address Register	60	15	5
Total		**900 ns**		**60**

If the Multi-Match Flag was detected, run the Age Entry Routine again to delete the next expired entry.

Legend:

CRS: Command Read, Short Cycle
CRM: Command Read, Medium Cycle
CWS: Command Write, Short Cycle
CWL: Command Write, Long Cycle
DWS: Data Write, Short Cycle
DWL: Data Write, Long Cycle

Please refer to the individual device data sheets for the detail information.

MULTIPLE-SEARCH DEVICE ROUTINES

LANCAM (L-70)

Initialization Routine

Two-Search Method without Internal Timestamp and Single-Search Method

Cycle	Data	/E=L	/E=H	# 15 ns Clk
CRS	Dummy Read Cycle; Clears power-up anomalies	15	15	2
CWS	TCO_CT; Target Control Register	15	15	2
CWM	0x0000; Reset	45	15	4
CWS	TCO_CT; Target Control Register	15	15	2
CWM	0x8000; 64 CAM, 0 RAM, Increment Address Register	45	15	4
CWS	TCO_SC; Target Segment Control Register	15	15	2
CWM	0x18C0; Write to Segments 0:3, Read Segments 0:3	45	15	4
CWS	SPD_CR; Set Persistent Destination to Comparand Register	15	15	2
CWS	SPS_Mem@AR	15	15	2
Total				**24**

Initialization Routine

Two-Search Method with Internal Timestamp

Cycle	Data	/E=L	/E=H	# 15 ns Clk
CRS	Dummy Read Cycle; Clears power-up anomalies	15	15	2
CWS	TCO_CT; Target Control Register	15	15	2
CWM	0x0000; Reset	45	15	4
CWS	TCO_CT; Target Control Register	15	15	2
CWM	0x8000; 64 CAM, 0 RAM, Increment Address Register	45	15	4
CWS	TCO_SC; Target Segment Control Register	15	15	2
CWM	0x1A41; Write to Segments 0:3, Read Segment 1	45	15	4
CWS	SPD_MR1; Sibling Mask	15	15	2
DWS	0x00FF	15	15	2
DWS	0x0000	15	15	2
DWS	0xFFFF	15	15	2
DWS	0xFFFF	15	15	2
CWS	SPD_CR; Set Persistent Destination to Comparand Register	15	15	2
CWS	SBR; Set to Background Register Set	15	15	2
CWS	TCO_CT	15	15	2
CWM	0x80C0; 16 CAM, 48 RAM	45	15	4
CWS	TCO_SC	15	15	2
CWM	0x0141; Write to Segment 0, Read from Segment 1	45	15	4
CWS	SFR; Set to Foreground Register Set	15	15	2
CWS	SPS_Mem@AR	15	15	2
Total		**750 ns**		**50**

Legend:

CRS: Command Read, Short Cycle
CRM: Command Read, Medium Cycle
CWS: Command Write, Short Cycle
CWL: Command Write, Long Cycle
DWS: Data Write, Short Cycle
DWL: Data Write, Long Cycle

Please refer to the individual device data sheets for the detail information.

MULTIPLE-SEARCH DEVICE ROUTINES *Continued*
LANCAM (L-70)

Search and Learn Routine
Two-Search Method

Cycle	Data	/E=L	/E=H	# 15 ns Clk
DWS	Write IP Source Address bits 31:16	15	15	2
DWS	Write IP Source Address bits 15:0	15	15	2
DWS	Write IP Destination Address bits 31:16	15	15	2
DWL	Write IP Destination Address bits 15:0	60	15	5
CWM	Read Status Register - Address of “Parent”	45	15	4

If CAM Status Register bit 0 = 1 (No Match)
Then

Cycle	Data	/E=L	/E=H	# 15 ns Clk
CWS	TCO_NF - Select the Next Free Address Register	15	15	2
CRM	Read the Next Free Address Register - “Parent” Address	45	15	4
CWL	MOV_NF, CR, V - Add “Parent” to database	60	15	5
DWS	Dummy Write - All 0	15	15	2
DWS	Write Address of “Parent”	15	15	2
DWS	Write TCP/UDP Source Port Number	15	15	2
DWL	Write TCP/UDP Destination Port Number	60	15	5
CRM	Read the Next Free Address Register - “Child” Address	45	15	4
CWL	MOV_NF, CR, V - Add “Child” to database	60	15	5
Total	**1.4 Million New Connections per Second**	**690 ns**		**46**

Else

Cycle	Data	/E=L	/E=H	# 15 ns Clk
DWS	Dummy Write - All 0	15	15	2
DWS	Write Address of “Parent”	15	15	2
DWS	Write TCP/UDP Source Port Number	15	15	2
DWL	Write TCP/UDP Destination Port Number	60	15	5
CRM	Read Status Register - Address of “Child”	45	15	4
Total	**2.2 Million Existing Connections per Second**	**450 ns**		**30**

If Cam Status Register bit 0 = 0 (Match Found)
Then Done
Else

Cycle	Data	/E=L	/E=H	# 15 ns Clk
CWS	TCO_NF - Select the Next Free Address Register	15	15	2
CRM	Read the Next Free Address Register - “Child” Address	45	15	4
CWL	MOV_NF, CR, V - Add “Child” to database	60	15	5
Total	**1.6 Million New “Child” Connections per Second**	**615 ns**		**41**

Legend:

CRS: Command Read, Short Cycle
CRM: Command Read, Medium Cycle
CWS: Command Write, Short Cycle
CWL: Command Write, Long Cycle
DWS: Data Write, Short Cycle
DWL: Data Write, Long Cycle

Please refer to the individual device data sheets for the detail information.

MULTIPLE-SEARCH DEVICE ROUTINES *Continued*

LANCAM (L-70)

Search and Learn Routine

Single-Search Method

Cycle	Data	/E=L	/E=H	# 15 ns Clk
DWS	Write IP Source Address Pointer	15	15	2
DWS	Write IP Destination Address Pointer	15	15	2
DWS	Write TCP/UDP Source Port Number	15	15	2
DWL	Write TCP/UDP Destination Port Number	60	15	5
CRM	Read Status Register - Match Address	45	15	4
Total	**4.44 Million Existing Connections per Second**	**225 ns**		**15**

If Status Register Bit 0 = 0 (Match Found)
Then Done
Else

CWL	MOV_NF, CR, V	60	15	5
Total	**3.3 Million New Connections per Second**	**300 ns**		**20**

Legend:

CRS: Command Read, Short Cycle
CRM: Command Read, Medium Cycle
CWS: Command Write, Short Cycle
CWL: Command Write, Long Cycle
DWS: Data Write, Short Cycle
DWL: Data Write, Long Cycle

Please refer to the individual device data sheets for the detail information.

MULTIPLE-SEARCH DEVICE ROUTINES *Continued*

LANCAM (L-70)

Age Entry Routine

Two-Search Method

Cycle	Data	/E=L	/E=H	# 15 ns Clk
CWS	SBR	15	15	2
DWL	0x00tt; tt = 8 bit timestamp value; Initiate Compare	60	15	5
CRM	Read CAM address of “Child”; Valid address if bit 0 = 0	45	15	4

If bit 0 = 1; No entries need to be deleted
Then

CWS	SFR	15	15	2
Total		**195 ns**		**13**

Else Read /MM (Multi-Match) Flag (If /MM = 0, then additional entries need to be purged.)

DRL	Read CAM address of “Parent” Entry	60	15	5
CWL	MOV_CR, HM; Copy “Child” entry to Comparand Register	60	15	5
CWM	VBC_HM, E; Delete “Child” at Highest Match location	45	15	4
CWS	SFR	15	15	2
CWS	TCO_CT	15	15	2
CWL	0x8090; 32 CAM, 32 RAM, MR1; Initiate Compare	60	15	5
CRM	Read Status Register	45	15	4

If bit 0 = 1; “Child” has no siblings
Then

CWM	VBC aaaH, E; Delete “Parent” entry	45	15	4
CWL	Write CAM Address of “Parent”	60	15	5
CWS	TCO_CT; Target Control Register	15	15	2
CWM	0x8000; 64 CAM, 0 RAM, Increment Address Register	45	15	4
Total		**795 ns**		**53**

Else

CWS	TCO_CT; Target Control Register	30	15	3
CWM	0x8000; 64 CAM, 0 RAM, Increment Address Register	60	15	5
Total		**690 ns**		**46**

If the Multi-Match Flag was detected, run the Age Entry Routine again to delete the next expired entry.

Legend:

CRS: Command Read, Short Cycle
CRM: Command Read, Medium Cycle
CWS: Command Write, Short Cycle
CWL: Command Write, Long Cycle
DWS: Data Write, Short Cycle
DWL: Data Write, Long Cycle

Please refer to the individual device data sheets for the detail information.

MULTIPLE-SEARCH DEVICE ROUTINES

WidePort LANCAM (L-70)

Initialization Routine

Two-Search Method without Internal Timestamp and Single-Search Method

Cycle	Data	/E=L	/E=H	# 15 ns Clk
CRS	Dummy Read Cycle; Clears power-up anomalies	15	15	2
CWS	TCOW_CT, 0x0000; Target Control Register, Reset	45	15	4
CWM	TCOW_CT, 0x8000; 64 CAM, Increment Address Register	45	15	4
CWS	TCOW_SC, 0x18C0; Write Segment 0:3, Read Segment 0:3	45	15	4
CWS	SPD_CR; Set Persistent Destination to Comparand Register	15	15	2
CWS	SPS_Mem@AR	15	15	2
Total				**18**

Initialization Routine

Two-Search Method with Internal Timestamp

Cycle	Data	/E=L	/E=H	# 15 ns Clk
CRS	Dummy Read Cycle; Clears power-up anomalies	15	15	2
CWM	TCOW_CT, 0x0000; Target Control Register, Reset	45	15	4
CWM	TCOW_CT, 0x8000; 64 CAM, Increment Address Register	45	15	4
CWM	TCOW_SC, 0x18C0; Write Segment 0:1, Read Segment 0:1	45	15	4
CWS	SPD_MR1; Sibling Mask	15	15	2
DWS	0x00FF 0000	15	15	2
DWS	0xFFFF FFFF	15	15	2
CWS	SPD_CR; Set Persistent Destination to Comparand Register	15	15	2
CWS	SBR; Set to Background Register Set	15	15	2
CWM	TCOW_CT, 0x80C0; 16CAM, 48 RAM	45	15	4
CWM	TCOW_SC, 0x0000; Write Segment 0, Read Segment 0	45	15	4
CWS	SFR; Set to Foreground Register Set	15	15	2
CWS	SPS_Mem@AR	15	15	2
Total		**540 ns**		**36**

Legend:

CRS: Command Read, Short Cycle
CRM: Command Read, Medium Cycle
CWS: Command Write, Short Cycle
CWL: Command Write, Long Cycle
DWS: Data Write, Short Cycle
DWL: Data Write, Long Cycle

Please refer to the individual device data sheets for the detail information.

MULTIPLE-SEARCH DEVICE ROUTINES *Continued*
WidePort LANCAM (L-70)

Search and Learn Routine
Two-Search Method

Cycle	Data	/E=L	/E=H	# 15 ns Clk
DWS	Write IP Source Address bits 31:0	15	15	2
DWS	Write IP Destination Address bits 31:0	15	15	2
CWM	Read Status Register - Address of “Parent”	60	15	5

If CAM Status Register bit 0 = 1 (No Match)
Then

Cycle	Data	/E=L	/E=H	# 15 ns Clk
CWS	TCO_NF - Select the Next Free Address Register	15	15	2
CRM	Read the Next Free Address Register - “Parent” Address	45	15	4
CWL	MOV_NF, CR, V - Add “Parent” to database	60	15	5
DWS	Write Leading 0’s and Address of “Parent”	15	15	2
DWL	Write TCP/UDP Source and Destination Port Numbers	60	15	5
CRM	Read the Next Free Address Register - “Child” Address	45	15	4
CWL	MOV_NF, CR, V - Add “Child” to database	60	15	5
Total	**1.85 Million New Connections per Second**	**540 ns**		**36**

Else

Cycle	Data	/E=L	/E=H	# 15 ns Clk
DWS	Write Leading 0’s and Address of “Parent”	15	15	2
DWL	Write TCP/UDP Source and Destination Port Numbers	60	15	5
CRM	Read Status Register - Address of “Child”	45	15	4
Total	**3.3 Million Existing Connections per Second**	**300 ns**		**20**

If CAM Status Register bit 0 = 0 (Match Found)
Then Done
Else

Cycle	Data	/E=L	/E=H	# 15 ns Clk
CWS	TCO.NF - Select the Next Free Address Register	15	15	2
CRM	Read the Next Free Address Register- “Child” Address	45	15	4
CWL	MOV_NF, CR, V - Add “Child” to database	60	15	5
Total	**2.4 Million New “Child” Connections per Second**	**415 ns**		**31**

Legend:

CRS: Command Read, Short Cycle
CRM: Command Read, Medium Cycle
CWS: Command Write, Short Cycle
CWL: Command Write, Long Cycle
DWS: Data Write, Short Cycle
DWL: Data Write, Long Cycle

Please refer to the individual device data sheets for the detail information.

MULTIPLE-SEARCH DEVICE ROUTINES *Continued*

WidePort LANCAM (L-70)

Search and Learn Routine

Single-Search Method

Cycle	Data	/E=L	/E=H	# 15 ns Clk
DWS	Write IP Source and Destination Address Pointer	15	15	2
DWL	Write TCP/UDP Source and Destination Port Numbers	60	15	5
CRM	Read Status Register - Match Address	60	15	5
Total	**5.55 Million Existing Connections per Second**	**180 ns**		**12**

If Status Register Bit 0 = 0 (Match Found)
Then Done
Else

CWL	MOV_NF, CR, V	60	15	5
Total	**3.9 Million New Connections per Second**	**255 ns**		**17**

Legend:

CRS: Command Read, Short Cycle
CRM: Command Read, Medium Cycle
CWS: Command Write, Short Cycle
CWL: Command Write, Long Cycle
DWS: Data Write, Short Cycle
DWL: Data Write, Long Cycle

Please refer to the individual device data sheets for the detail information.

MULTIPLE-SEARCH DEVICE ROUTINES *Continued*

WidePort LANCAM (L-70)

Age Entry Routine

Two-Search Method

Cycle	Data	/E=L	/E=H	# 15 ns Clk
CWS	SBR	15	15	2
DWL	0x00tt XXXX; tt = 8 bit Timestamp value; Compare	60	15	5
CRM	Read CAM address of “Child”; Valid address if bit 0 = 0	45	15	4

If bit 0 = 1; No entries need to be deleted
Then

CWS	SFR	15	15	2
Total		**195 ns**		**13**

Else Read /MM (Multi-Match) Flag (If /MM = 0, then additional entries need to be purged.)

DRL	Read CAM address of “Parent” Entry	60	15	5
CWL	MOV_CR, HM; Copy “Child” entry to Comparand Register	60	15	5
CWM	VBC_HM, E; Delete “Child” at Highest Match location	45	15	4
CWS	SFR	15	15	2
CWL	TCO_CT; 0x8090; 32 CAM, 32 RAM, MR1; Compare	60	15	5
CRM	Read Status Register	45	15	4

If bit 0 = 1; “Child” has no siblings
Then

CWL	VBC aaaH, E; 0x0aaa (“Parent” entry); Delete “Parent”	60	15	5
CWM	TCO_CT; 0x8000; 64 CAM, 0 RAM, Increment AR	45	15	4
Total		**645 ns**		**43**

Else

CWM	TCO_CT; 0x8000; 64 CAM, 0 RAM, Increment AR	60	15	5
Total		**585 ns**		**39**

If the Multi-Match Flag was detected, run the Age Entry Routine again to delete the next expired entry.

Legend:

CRS: Command Read, Short Cycle
CRM: Command Read, Medium Cycle
CWS: Command Write, Short Cycle
CWL: Command Write, Long Cycle
DWS: Data Write, Short Cycle
DWL: Data Write, Long Cycle

Please refer to the individual device data sheets for the detail information.

MULTIPLE-SEARCH DEVICE ROUTINES

MU9C (L-90)

Initialization Routine

Two-Search Method without Internal Timestamp and Single-Search Method

Cycle	Data	/E=L	/E=H	# 15 ns Clk
	0xXXXX X006 (/AV=1, DQ12=0) Load Instruction Register	45	15	4
	0x200 0000 (/AV=0) Execute, Set to Hardware Mode	45	15	4
WR DS	0xXXXX X100 - Disable Device Select Register	45	15	4
Total		**180 ns**		**12**

Initialization Routine

Two-Search Method with Internal Timestamp

Cycle	Data	/E=L	/E=H	# 15 ns Clk
	0xXXXX X006 (/AV=1, DQ12=0) Load Instruction Register	45	15	4
	0200 0000 (/AV=0) Execute, Set to Hardware Mode	45	15	4
WR DS	0xXXXX X100 - Disable Device Select Register	45	15	4
WRH MR1	0xFFFF FFFF - Mask for Timestamp Field	45	15	4
WRL MR1	0x0000 FFFF - Mask for Timestamp Field	45	15	4
WRH MR2	0xFFFF FFFF - Mask for Parent Address Field	45	15	4
WRL MR2	0x00FF 0000 - Mask for Parent Address Field	45	15	4
Total		**420 ns**		**28**

Legend:

MR1: Mask Register 1
MR2: Mask Register 2
WRL: Write Register- Lower 32 bits
WRH: Write Register- Higher 32 bits
WR DS: Write Register- Device Select
X: "Don't Care"

Please refer to the individual device data sheets for the detail information.

MULTIPLE-SEARCH DEVICE ROUTINES *Continued*

MU9C (L-90)

Search and Learn Routine

Two-Search Method

Cycle	Data	/E=L	/E=H	# 15 ns Clk
WRL CR	Write IP Source Address bits 31:0	45	15	4
CMPWH DQ	Write IP Destination Address bits 31:0	75	15	6

If /MF = 1 (No Match)
Then

Cycle	Data	/E=L	/E=H	# 15 ns Clk
RD NFA	Read the Next Free Address Register - “Parent” Address	45	15	4
MOV [NFA], CR	Add “Parent” to database	45	15	4
RD NFA	Read the Next Free Address Register - “Child” Address	45	15	4
WRL NFA	Writing Leading 0’s and Address of “Parent”	45	15	4
WRH NFA	Write TCP/UDP Source and Destination Port Numbers	45	15	4
Total	**2.5 Million New Connections per Second**	**400 ns**		**30**

Else

Cycle	Data	/E=L	/E=H	# 15 ns Clk
WRL CR	Writing Leading 0’s and Address of “Parent” (/VB=1)	45	15	4
CMPWH DQ	Write TCP/UDP Source and Destination Port Numbers (/VB=0)	75	15	6
Total	**3.3 Million Existing Connections per Second**	**300 ns**		**20**

If /MF = 0 (Match Found)
Then Done
Else

Cycle	Data	/E=L	/E=H	# 15 ns Clk
RD NFA	Read the Next Free Address Register - “Child” Address	45	15	4
MOV [NFA], CR	Add “Child” to database	45	15	4
Total	**2.7 Million New “Child” Connections per Second**	**470 ns**		**38**

Legend:

WRL: Write Register- Lower 32-Bits
WRH: Write Register- Higher 32-Bits
CR: Command Register
CMPWH DQ: Write Register- Higher 32-Bits and Compare
RD: Read Data
NFA: Next Free Address
MOV: Move instruction
HPM: Highest-Priority Match
RST V@AR: Reset Validity Bit at the Location Contained in the Address Register

Please refer to the individual device data sheets for the detail information.

MULTIPLE-SEARCH DEVICE ROUTINES *Continued*
MU9C (L-90)

Search and Learn Routine
Single-Search Method

Cycle	Data	/E=L	/E=H	# 15 ns Clk
WRL CR	Write IP Source and Destination Address Pointers	45	15	4
CMPWH DQ	Write TCP/UDP Source and Destination Port Numbers	75	15	6
Total	**6.6 Million Existing Connections per Second**	**150 ns**		**10**

If /MF = 0 (No Match)
Then Done
Else

MOV [NFA], CR	Move to the Next Free Address	45	15	4
Total	**4.76 Million New Connections per Second**	**210 ns**		**14**

Age Entry Routine
Two-Search Method

Cycle	Data	/E=L	/E=H	# 15 ns Clk
WRL CR	0x00tt XXXX; tt = 8-bit Timestamp	45	15	4
CMPWH DQ	0x XXXX XXXX; Invoke MR1; Compare	75	15	6
Total		**150 ns**		**10**

If /MF = 1; No entries need to be deleted
Then Done
Else Read /MM (Multi-Match) Flag (If /MM = 0, then additional entries need to be purged.)

Cycle	Data	/E=L	/E=H	# 15 ns Clk
RDL [HPM]	Invoke MR2; Read CAM address of “Parent” Entry	45	15	4
MOV CR, [HPM]	Invoke MR2; Move to CR from Highest Priority Match	45	15	4
CMP CR	Invoke MR2; Compare	75	15	6
Total		**360 ns**		**24**

If /MF = 0; “Child” has siblings (no need to delete “Parent”)
Then
If the Multi-Match Flag was detected
Then run the Age Entry Routine again to delete the next expired entry.
Else Done
Else

RST V@AR	AC11-0 = x xxx xxx 100 001, PA:AA = aaa; aaa = “Parent” entry; Delete “Parent”	45	15	4
Total		**420 ns**		**28**

If the Multi-Match Flag was detected
Then run the Age Entry Routine again to delete the next expired entry.
Else Done

NOTES

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