[redacted]tta

in gIBM-PCorMultib us peripher alstoan1108 wi th Exte nded Processo rOption(C PE)Ini tiall yr

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HerringEdit:22Oct 19 84IB MPC- orMulti bus-com patible pe rip hera l

dev ice s(notbothat once!)canb eattachedt oan1108whichhas th eExten ded Pr ocessorO pt io n(CP E),us ing Xer ox'sBusM asterinte rfaceo ption. Thisd ocumentdescribes thefuncti onality
ofth eBusMast erhardwar e,a ndtheBUSMASTERSoft warepacka geforcont rol lin git.Itisd ividedin tosecti ons:thisintrod uct orysections ingl e-bytetra

nsfe rs-theBUSfunctionsm
icrocodedbl ocktransf e rs- the BUSBLTfun
ctionsdma- overv iewofdire c tme moryac cessdma-d
eta i leddiscu ss ionoft hedmap rocess
dma - register modeloftheBusMaste rdmacon
tro l lerdma-theBUSDMAfunctionsdm a-s ummaryofsi
mpl e use dma-te chnicalno
tes (Thisdoc umentand the
acc o mpanyingBUSMAS

TERsoftwarepa cka gea resomewhatpr eliminary :Whileth eyhaveb een usedwith IBMPC-compat iblep erip hera ls,t heMultib usa lternativehas notbeenfully int egrateda tthiswritin g.T hus some chang escanbeexpec tedbeforethe BusMaste rinterf ace op tionisre leased .In particula r,moreobscurede ta ilsmaycha ng e,themoretechni caldocu mentationm aybecomemoreex act,thedo cumentationwi llb ecomel essP Coriented ,and(perhapsm osti mporta ntly)w ell-packa ged diagnost icso ftwarewillbe included.Also hopefullyg lobalini tial iz ationwill bebe tterunder stooda ndbetterpackaged,a nd thepro blemofacce ssi ngnone xistentme mor yontheexte rn albuswill beproperlya ddress ed .No teinpart icu lart ha tmuchoft hisdocumen
tati oniswrittena stho ugho nl yIBMPCperipherals weresuppo rt ed,whi chis fal se .IBMPC,IPBP C-XT,Intel8237 -5A,a ndDataTr
ans lat ion DT2801 arepr oprietar yna mes.)Additional hardwa rei srequiredbe tweenth

eBusMasterandthepe ri pheralde vices:a nIB MPCorPC-XTex pan sionchassi stomount th epe ri ph erals 'controll ercards in ,andi nso mecasesaPCmemorycard,mounte dinthe ex pans ionch a ss is.The BusMa stercon ne cts thePCexpa nsionchassi s(the"ext ernalbus ")t ot heBusExte nderhigh-sp eedparall elpor to fth e1108.TheBU SMASTERlibrarypackagemak esu seoft
heB USEXTENDE Rlibrar ypackag e.Int erm so fth ehardwareen vironment,PCper

ip heral sf iti ntothisa ugmented1108sy steminjustt hesamewaytheywouldin toan IBMPCMostpr ogr ammi ngo fthe perip hera ls isd one inju stthesamewa yi twouldbedoneinBASICo na nIBMPC:"pee ksa nd pokes "- -tha ti s,exp li ci tly pro grammedtr ansfer sofind ivi dualbytesfromandtoin dividuali /o andmemoryaddres ses. The re aretworest ric tio nsaffe ctingmorea dvanc edi /op rogrammingtechniques: 1)In terrupts :In terruptsare notasyetsup
po rted.Morepr ecisely,wh ile the ha rdwaredoessup port interrupts ,exac tly asonanIB MPC,the1108 microcodedoesnotas ye ts up por tin ter rupt s.2)Direc tmemory ac ces s:PCper ipheralscan
*no tperfo rmdire ctmemory*a ccess(dma)t othein ternalm emoryofthe11 08.However, th epe ripheral canper fo rmdmato/ fromPCmemorymountedinthe PCexpan sio nchassi s, andthe 1108can si multa neouslyac cessthat memory ,eit her *withpeeks&pokes*orwit hmicrocoded high-s peed block t ransf er inst ructions.O urexperien ceist hatexamplei/oprograms

inB ASIC,notin volvin ginterr upt sordma,c an betran sla tedimmediatelytoInt er lisp -Dwit houtsubtle ty.Wehaveal so implementedseveral applicati
on stha tuse dmatechniqu es,with twodifferent peri phe ral devices,the Data Tra nslationD T2801Analog&DigitalI/ OSys temandaTecmar-lik e640x4 0 0x4-bit col orboar d.O n eofourappli cationshasthe dataa cquisi tio nb oar dsamplingacoust icd ataa t

thedata (incl udi ngFF Ts)andgra phs ther esults,con tinuo usl yinrea lti me.Thisapplicationus es quit esoph isti cateddmatechniq ues:t hedataacquisi tio nboarddmasc ont inuo uslyintoaci rcula rbuf ferinmemoryi nthe e xpansionchassi s, whilet he pro graminthe 1108continuou sly reads&p ro ces sesd atafromtheci rcula r buffer.Th isis poss ibl ebecause(1)theP C'sd macontroll er(whic his fun ctio nal lyduplicat edinth eB usMaster)canbeprogrammed towrapdmaarou nda ci rcularbuff er cont inu ouslyw i thoutsof twarei ntervention, (2)thed mapointe rscanbereadbythe sof twa reprogra m,a nd (3)d at atr ansferfr omthePCmemo ryt othe 1108doesnoti nte rf erewit hdmafromt hepe rip heraldevi ce.T his dmat ech niquetooko nlyacou pleo fda ystodesig n&impleme ntusin gt heBUSMASTERso ftware.Ou rinte rfa cefunctio nsfortheD ata Translati onboardar eavail able astheLISPLi brary PackagePCDAC;it is onee xampleofhowtou setheB USMASTERpackag e. Sin gl e-b yte transfers to/fromt

he

ionsNotethatwheneveryoupower-up orBUS.RESET,y out hen havetocal

lB

initi aliz ethememo ryr efreshap pa ratus,befo ret hememory ontheexternalbusc anbeexp ected to holddata.(BUSRESET)--acts likeapower -up:re set stheBu sMast erandass ert sth eR esetsign al onth eexte

rnalbus,the rebycausingev erydevice theret ore setitself asa tpower-up. BUSDMAINITwi llt henhavet obec alledag ainifth edmacontrol leror memoryrefreshap paratusisne eded.(BUS.I NPUT i/oa ddre ss)= >8bitv alue- -i nputab ytefromanext ernal- busi/oa ddress,re turningit

asasmallnon n*egativeint* e ge *r.(BUS.OUT*PUTi/o a ddre ss8b it value)--outp uta byte(the leastsign if ic a nt8bi tsoftheinte gerargum

ent)toanexte r *nal-busi/o address(B*US. READmemorya ddre ss)=>8bitvalue-- r eadaby tef romexternal-busm emor y,returningi tas asmalln

onnegative i *nteger.(BUS.R* EAD *HLmemaddr*himemaddrlo)=>8 bitvalue--re adabyte fromexter nal- b usmemory,returni ngitasas

mallnonnegat i *veinteger .memaddrl* o is *thelesssi* gnific a nt16 bits ofthememoryaddress; memaddrhiis th e moresignificantb itsofthe *address.(* BUS.WRITEmemoryaddress 8bit va lue)--wri teabyte(*theleasts* ig nif ican t8bitsofthe inte ge rar gument)t

oexternal-b u*smemory(BUS.WRITEHLmem*addrhimemaddr lo8b itval ue)--writea b yte(th ele astsign ificant8b it softheintege rargum

ent)toexterna l *-busmemor y.memaddr loisthele* s ss ignif i cant 16bi tsoft hememoryaddess; memad drhiist hemoresig ni ficantbitsof theaddr *ess.Micro* coded blocktranfersto /f romthe ext ernalb us--theB *USBLTfunc* ti ons Thes efunctionst ransfe rda tabetwee

n

anarrayinI nterl isp-Dvirtualmemory andaconsecu ti ver egioni nthememor

y

onthe externalb us.Notet hatB USDMA.INI Thast obecalledatle astonce,toini tia l izethememor yrefre sh app aratus ,b efo rethememoryo nthe exte rnalbuscanb eex pe ct edtohold data. (BUSBLT.BYTESarray st arting indexbusaddressne lement sto extern al memory?)--t ran sfe re verybyte of nele ments

elementsofthea r *rayin Interlisp-Dme mory,start ingwithth estartingindex'th* e le ment,toorfrom cons ec *utivebyte* addresse so nth *eexte* rn albus,start ingatbu saddress.arr aym*ustbeanarrayof*ei therBYTEs, WORDs(=SMALLPOSPs) or FIXPs.Ift he arr ayisofWORDsorFIXPsthen *themoresign ifica* ntby te of eachI nt erlisp -Dword istra ns ferredtothel oweraddr es son theex te rn albus .

t
ingindexbusaddressn e*lemen tstoexternalm emory?)--t ransferth elesssignificantb* y te ofeachwordo fnel ementselementso ft hear rayi nI *nterlisp-* Dmemory,st art *ingwi* th thestarting index't helement,too rfr *omconsecutive* byt eaddress es on thee xternalbus, star tingatbus ad dre ss.array mustbeanarrayo*feitherWORDs(=SMA*LLPOSPs)orFI XPs.(Not ethat ar raycannotbe of BYTEs.)Ontr ansf *ersto* Interl is p- Dvirtua lm emory,themo resignifica ntbyteofeachwo rdi szer oed.(BUSBLT.NYBBLESar rays ta rtingin

dexbusaddressnel e*ments)--transferev ery4-bitny bbleofnel* e mentselementsof thear rayinI nt *erlisp-Dm* emory,st ar tin *gwith* th estartingin dex'the lement,t ocon sec *utivebyteaddr*ess esonthee xt ernalbus,st arti ngatbusad dr ess .Each4-b itny bbleofInte *rlisp-Dvir* t ualm emory corres po ndstoabytei ntheext ernalb usmemory:th eI n terl is p-Dnybbleis rig ht-alig ned intheextern al-bus byte,withthelef t4 bit softheextern al-bu sbyt eun speci fied .T heb yteresulting from themoresigni fic antn ybbleofeachIn ter lisp -Dwordistransferr ed toth elowerbytea ddre ss ontheextern al bus .arra ymustbeanar ra yof eitherBYTEs, *WORDs*(=SMAL LP OSPs)or FIXPs.NOTEth atonl yt hetransferf ro mInter lisp -Dmemorytoe xternal- busm emoryisimplemente da tthiswriting .Aread formofBUSBLT.NYBBLESisexpec

t edto bead de dlater.AlsoBUS BLT.SWAPBYTES, which willdi ffer fromBUSBLT.BYTESo nlyin that themoresig nificantbyte ofth e1 108word will correspondtothe hi ghe radd ress onth eexternalb us .Dma--ove rviewof di rec tmemoryacces

sont heexternal busTheBusMaste rinclu de s,i nadditio nto

peekandpokeap paratus,a 3- channelDMAcont rol lera ndmemoryre reshcircu itr y.Memoryrefre shcirc uitryis necessaryf

ordyna micRAM(suchasthatu sedintheP C)t okeepit sda ta.As in theI BMPC,t heBusM as ter' smemoryr ef re shc irc uit ryi sintegrated withit sdmacontrolleran dt imer,andus esth efourt hdmachannel#0 .Memor yre fres his initia ted duringt heg lobali nitiali zationofthe dmacontro ller.T heseoperationswould bed oneautomatically onanIBMPC.Direc tm emor yaccess(dma)r ef er sto apr

ocesswhereby ani/od evice cantra ns f erdatat oorfrom mainmemorywith outdirec tint er ve ntio nbyt hecent ralproc essor. Thatis,altho ug hth ecentra lprocessor must helpinsetti ngupthedmaoperation andi ntid yi ngupafter it, man ybytesofd ata ca nbetran sf erred inasing ledmaop erat ion wi thoutthecen tr a lproce sso rhavingto beinvol ved aseachbyteistran sferre d. Th isinvolv es havi ngde di catedhardware(in thiscase theBus Master'sd macontro lle r)wi thmemory-addressan dtr ansfer-countreg istersandcontr olc ircuitry.Typic allyasing led maoperationtransf
ersaprede t erminednu mberofbyt esofdataf r omthei/odevic etoseq ue ntial ad dres sesi nmainm emory, or similarlyw iththedat ag oing frommem or ytothei/o devi ce. Thedmacir cuit ryhast oa llo wfo rtheope rat ion toterminatep re matur ely ;th eBusMastera llowstheo perationtobe ter minatedpr ematur ely eitherbyt he pr ogramorbyt hei/odevice (thoug hn ota lli/ode vi ce sar esmarteno ugh).Th eBusMaste rwillal soa llowd matotake
pla cetoorfro ma"circu larbu ffe r" inmemory. This isre f erredtoin thisdoc umentbyth enot -o bviously -a ppropr iatename "A uto initializationMode".Thena meco mesfromthefactthat, inAuto ini tial izati onMode, thedmacontr ollerdoesnottermin ateth edmaop erationwhenthe tra nsfercoun tru nso ut,butrat herr e-i nitializ esthe addr essa ndc ounter registerstotheiri nitialv alu es,thus "wrapping around"the"cir cularbu ffer ".Inthisc asetheB usMasterwill letthedm ag oonforev er: thei/odev iceo rth epr ogr amha stotermi nat eit .Thedi re ctm emoryac ces sd iscussedh ere

tak esplac eentir elyont heexterna lbus .Ther eisno directmemorya ccesspos sibl ebetw eeni /odevi cesont heexte rnalbusa ndthe11 08' smemory.A sim ilareffe ctc anb ego tbyusi ngdmabe t weenthei/odev ice an dth em emoryont heexter nal bus ,toget her wit hblock tr ans fersbetw eent heextern albu smemoryandthe1 108'sme mory(discus sed inthei row nse ctiona bove). AsontheIBMPC,thed mac ontroll erandit

ss up por tha rdw are are actuallyco ntr oll edviape eksandpo kes .However,theBUSMASTERpacka gei nclude sasetofB USDMAfunctio nsthati mplementa troller.Thisv iewo ft hed mac ontrolleris basi call ya sim pli fiedversio nofthatinth e specificat ionsfor th eInt el 8237-5A,onwhichthesy ste misbased.Dma- -d etail edd iscuss io nofthe

dmaprocessTypicaldmaoperat ion sus ingtheB

u

sMaster are quiteeasyt oprog ram--youareo nly deali ngwith onei/od evice and inon lyoneway.Ev enp lan ningth eus eo fone par ticu lari /odevice isn ott oo bad ifyou're no tgo ingtob eexot ic. Unf ortunately, i/ode vi ce sdiffer inmajor&minorways ,theBus Masteris desig n edtof itwel lwi thmostoft hem,andthi sd iscussi onha stoe na bleyo uto plantheuseof(a lmost)anyi/ ode vi cein (al most) anywayreaso nable.Sop le asebetol era nt. Myhopeistha ta fteryo ur eadthrought othe Summarysect ion belo w,yoush ouldh aveatmo stafewq uestio ns, whichc anli kelybe a nsw eredbyskimminga rou nd.(If yo uareplan ni ngexotic things, youmay nee dtoreadt hespecificati ons for thet he Inte l82 37-5Admacontroller rch ip, onwhichtheBu sma sterisbase d,and th eTech nic alNotesse ct ionbel ow.)Th edmacontr oller andmemoryrefre

shc irc uitryhavet obe initia lizedbe foreanydmacan ta ke placeandbeforethe memory int hePCexpan sio nchass isc anhold da tar el iably.Thi sisdone wit hthe BUSDMA.INITfuncti on(tho ughu nde rsomecircum stancesy oumayal sonee dthe BUS.RESETfunctio ndi scus seda bove).BUSDMA .INITcan becalleda gainata nytime,with the si deeffe ctofd is abl ing(maski ng) allt hreedmac hannels.T hedmacont rol lerha sth reesepara

ted mac hannels,numbered1t o3.(Ther eis actuallya lsoafour t hc ha nnel,n umbered0,dedic a tedtot hememoryrefresha pparatus.)E ac hi/ odevic ethatdo esdmahastoknowo rbe toldit sdmachan nel numbe r,as do es thes oftwar econtro llingth ed evic e.U suallyad evice'sinte rfa cecardh asswitc h esorjump erswhichdeter min ewhichdmac hanneli twill use.Onlyo nedev ice canbeus inganyoned

mach ann elatat ime .T husth ere can bea tmostth re e i/ode vice sdoin gdmaa ta nyti me.Theth reedmachanne lsa re con troll eds epara tel y.Wethin kin termsofdma"operations

". A"sin gl edmaope rat ion"is:thepro g ramgetsthe i/odevicea nditsc hannels etup for the operat ion ;manybytes are tr ans fer redoneatat imea tthei nst igationofth ei/ ode vice butun derthecontr ol oft hec hannel ;th etran sfe risterm in ate dsomehowbye itherthe channel,thei /odevic e, and/or the program; fin all ythepro gramti die supthei/ odevice&thechanne l.Also ,d uri ngt hetime w hen individu albyt esareb ein gtra nsfe rredbythei /odev ice andth echannel,th ep rog rammighti nte rve netotemp ora rily"su spend "andthen" re sume"thedmaoperation .It isim portantt onotic ethatthedm acontrollerit se lfdoes nota ctu all ydistingui shbetween" sus pended"and"terminat ed":ift heprogramre sum estheoperatio nthen itwas"s uspende d"; ifitsetsu pane woper ationthenthe oldonewas" t erm inated"!T hese tup oft hei /od evicedependso

nth edevi ce .Se tti ngupth edmacha nn elb asicall yinvolv es set tin gupaddr ess,trans fer-coun t,andmode register s.Itwouldbepremature reto discussthe se tupfu rt herhere,a swehavenotye tmoti vatedth eissu es .R athe rwe wil ldiscusse ver ythinge lse,in cl udingthefun ctionofthe channel'sregis ter s,thendi sc uss setupagai nintheSummarys ection. Durin gthee xt end ed"dmao peration

",indi vid ualbytet rans fersarerequ estedbythe i/od eviceinvolve d.Ifmoret ha non ede vicere questsdma at thes amet ime ,thedm acontrol ler se rvi cest helower- num beredchannelfirst. The directionofthe transfe r(toor fro mmemory)als toh avebeensetu pt hesa meinbot hth ei /ode vice andth edm acha nn el.T hememoryaddr ess to/ fro mwhichth

etr ansfer willtak eplacei sdete rmi nedentir elybythe dmachannel.Normal lyituses su cce ssi velyincr easingby te addr essesinmemory,butitisp ossi bletouses uc cessive lyd ecre asingadd re sse s,andin"Autoinitializa tionMode",the ch annelwillwraptheaddresses aro undacir cula rbuf fer (wrapping ineith e rdirecti on).Fo rexactlyh owaddres sesaregener ate d,seeth edi scussiono fth epage,curr ent -ad dress,andb as e-a ddres sregistersbelowi nth eRegisterModelsection .Dmao na par ticularc hanne lcanbesu

spe nd e dandresumedby"maskin g" and"unmas kin g"thech an nel.Amask edc hannelrefus est ohonoran y dmatra nsferre quests. If there isa dma transfer requestst il lpend in g whe nthechannelbeco mesun masked, thec han nelwill service thereques tth en.Obvi ousl y,datac anb elostby keepi ngthedmachanne lma sk edtool ongwhil eit si/ odevice isrequ est ingt ransf ers.It remain st odiscussho wadmaopera

ti onister minated.T his i spo tentially ra thercomplic ated .

ithe rofthreec onditions :thei /odevi ce cease storequestd matran sfers; thedmach annelmasks itselfbeca use its transfe rcoun terrunsout;or thedmachannelismas kedb ythe pr ogr am. Ineithe rc ase,th ed machannelit

se lfdoes notdi sti ngu ishbetw een"suspen ded "and"terminated".I willtrytosa ywh atitdoesdo:At a nygivenpo int ,adm achann eli

sa ski ngits elf"AmI mas ked?".I fs o,that 'sall. But i fitisnotm as ked,itthe nask

s"A mIreceivi ngarequ estfor admatra n sfer?".If n ot,that 'sa l l.B utifitisrec ei ving arequestfo

rad matr ansfer,then i tgetsth etr a nsf erdone,andthe nincre mentsordecr ement sit scur rent-addre ss register,a nddecrementsitscur rent-tran sfe r-countreg ist er.Ifitscurrent-transf er-countr egist erdoesnotgotozero,then that'sal l.Bu tif it sc urren t-tr ansfer-cou

ntr egist erdoesgotozero,thenthe channelasser ts th eexte rnal -bu ssignal namedTC,an dalsosetsits "TCbit"inth edm aco ntro ller 'sstat usre gi ste r.(TheTCsignalisalsor eferredtoasEOP, andisa vailab leforthe i/ odevic eto senseifitwa nts .)T hec hannel th enask si ts elf"AmI inA utoinit iali zati onMode?". I fi tisnotinAutoinitia lizatio nmode, the ni tmasksitself;ifiti sinAu toin it ializ ationmode,t heni treinitializesitsc urren t-ad dressandcurrent-tr ansfer-countreg ist ersfromthecorrespondin gbaseregister s,b utdoesnotmask itse lf.Inanycase, thed machann eldoesn

ot "te rminatet hed maopera tion "re ally:itmay maskit self,andit mayemittheTC sign alandsetit sT Cbi t,an dth ep rogramort hei /odev icemaya cto ntheset hi ngs .Bu tallth ech annel cares aboutth is, unt ili tisacte donbythepr ogram;isth at if itmas ke di tse lf,theni ts tays maskedunti ltheprogramunmasksit(pos sibly aft erchang ingitso therregiste rs!). Thei/ode vicemightceasetorequ

est dmatransf ersfo ranyo fs everalr eas ons,inclu din g:i th asitsow ntransfe rcountregi st er, whi chh asrunout;itha sdetectedanerr orc ond itio nandc hosentos to ptran sfer;itha sde tected th eTCsignalfrom it sdmachannel ont he extern albu s;i tha sdetect ed someotherte rmin ation conditio n;or ithas beendisable dbytheprog ra m.Anypart iculari/ od evi cemaywel lno tsupportal lth esecho ice s.Th edmachanne lca nnott elldirec tly tha tthedev icehas ceasedrequesting dmatransf ers ;itsim plyrespond sto themif&astheyarise .Typical ly thep rog ra mdet erminesthatthei /od eviceco nsidersthe dmaoper ati ondone.Theprogr ammight maskthec hanne

lte mporari ly,fo rsom eki ndofhou sekeepingrea son,ori tmay do soaspartofte rminati ng thedm ao pe ra tion .I tcanhaveany sor tof reasonford oi ngt his. The dmacha nneldo esn otcar e:ift hep rog ramchoo sest ore setso meoft hechann el'spar ameters whil ei tis masked,th at'sfine;o therw is ewhenthec hannelbecomesunmasked,it wil lkeepon fromwhe reitwas.C hangingadmac hann el'sp aramet erswhile i tis unmaskedisriskyandt obeav oided.Direct memoryacce ss -- register

modelofttheBus Masterdmacontrollerln ourmodelofthed mac ontroller,

t

he rea renog lo bal reg isters,ande achch ann el hasase tofsevenregis ters :Pagere gis t er- -S uppli esthemores

igni ficantbits

oftheext ern al-b usmemoryaddres ses gen eratedbythec hannel .Theconte ntsofthis re gis teraresi mpl yconcate na tedontothele fto ftheco ntentsofthec urre nt- addres sre gisterwh en ana ddressisgenerat ed.Unfortuna te ly,incr ementingorde

crementingacha nnel'scurren t- addressregis t erdoesnot affectitspagere gisters. (Thi sim pliest hat anyd maoperationmusttakepla ceentir ely withinone (64K B-al igned)64KBpagesinc eth ecurrent-addre ssre giste rsare 16bitswide.Further ,admabuffert ha tsee mstoo verlapa6 4 KB- pageboundarywil lr eallywr a paroundwi thinthe6 4KB-pageit star tsin.T hepage reg istersare setupbythep

rog ram, butcannotber eadby it .Cu rrent-ad dre ssregi st er-- Holds

thelesssignific antbitsoft

heext ern al-b usmemoryaddres ses gen eratedbythec hannel ,thatis,t he16-bita dd res s-within -pag e.T hec hannelgeneratesaddressesby con catenat ingitspag eregister on totheleftofit scurren t-addres sreg ist er.

annelincre mentsordecrement sthecur rent-addre ss registerby one .Thedirectionde pendsonabi tint hec hannel'smoderegi st e r.Unf ort unately,t hisi ncrementordecrementdoes notaffectthep ag eregister (asd isc ussedabov e).T hecurrent-a ddressreg isteris

set upbytheprogram,incremente dorde cr ementedbyth echannel,an d, in"Autoinit ia liz ationMod e",r el oadedbythechannelfromitsb ase-addr es sre gisterw heni tscurrent-trans fer-countreg ist errunsdown.Thecurrent-addressregis terca nbe readbytheprogra m,sothatthe pr ogra mcank eepitsac ce ssto the externa l-b usme morysynchro niz eedwithdmaontheext ernalbus.Base -add res sr egi ster--In Auto

initializati onMode,hol

ds thestartingaddress ofthe circu lar buffer.T hatis,i nAuto initiali zationMode, whena channel'scurrent-t ransf er-c o untregist errunsdown,thechannelreinitial izes itscu rre nt-addr essregisterfr omitsbase-addressr egister. Theb ase-addressregi sterisloa

ded automaticall ywhenevert heprog ramsetsupthec urrent-a ddr essregi ster .T her eisnoBUSDMAfunc tionforre ading th eb ase-ad dressreg ist er.Curr ent -transfer-co untregist

er--Controlsthelengtho fthedmaope

ration(o r,i nAutoi ni tia liz ationMode,the le ngthofthecircularb uffer).T hatis, af ter eachdata transfer ,the channeldecre mentsitscurre nt- transfe r-countreg ist er,andifitgoestozero,t henaTCsignal *is* as sert ed tothe *exte* r na lbusandt hechanneli smasked(ifn otA *uto* ini tializa ti onMode)orthe currentaddress&transfer -c ountregist ersarer e initializedfro mthebaseones (ifAutoinitia liza tio nMode).N otethatthecurrent-tra nsfer-

coun treg ist ercontainsthenumberofbytetrans fersrema ini ngtobe do ne,a sanunsigned16-bitn umbe r.Not ea ls othatwhi leacur rent-tr ansf er-c ount regis t ervalueofzero,viewedas afteradmatran sf er,me ans"do ne *",the* s ame zerovalueviewe dasbefo rea dmat rans fer,m eans64 K. *Thusth*e max imumtransfer(o rcir cula rbu ffersiz e)is64Kbyte s.(Youmayalson eedtoknowt hatthe

hard war ereg iste rk eeps itsv alu esoneles sthatwhatwe'v edescribe dhe re,modul o64K.TheB USDMAfunctions mainta inth etr anslat ion.)Thec urrent-t ran sfer-countreg

ist erissetupbytheprogram, decremente dbyth ec han nel,and, inAutoiniti al iza tionMode,rel oa dedbythechannelfromitsb ase-tran sf er- countre gist erwhenitrunsdown.Thecurrent-tr ansf er-cou ntreg ist ercanbereadbytheprogram,sothatthe pr ogra mcans ynchroni ze itse xte rnal-bu smemoryaccesse swi ththeexterna l-busd ma.Base-tran sfe r-countregis ter-

-InAutoinitializati onMode,hol

ds theinitialvalueoft hecur rent- tra nsfer-countr eg ist er.Thatis,inAutoinitia lizationMode, whena channel'scurrent-t ransf er-c o untregist errunsdown,thechannelreinitial izes itfro mit sbase-t ransfer-count re gist er. Thebase-transfer-co untregist

eri sloadedautomaticall ywhenevert heprog ramsetsupthec urrent-t ran sfer-co untr eg ist er.ThereisnoBUSDMAfunctionforre ading th eb ase-tr ansfer-c ountregist er. Moderegister--Conta inssomeco

ntro lbits.Them

oderegis teri ssetupb ytheprog ram, butcannotb ere ad by it. writemem ory ?--det er mine sw het

herdmatrans f er sarefromth ei/odev ice tomemory,orv icev ers a.a utoini t? --gover ns Autoinitia

lization Mode.Iffal se,thecurrent-tran sfer- countregist ershouldbesetupwiththe lengthofthetra ns fer ,a ndwheni trunsd ownth echannelmask sits el f.If true ,th ecurren t-tra nsfer-countreg ist ershouldbesetupwiththe lengthofthecir cu lar bu ffer ine xterna l- bus memory,and,wheni trunsdown,th echanne lrel oads thecur rent- add ressand current -tr ansfer-countreg ist ersfromthebase-address andbase-trans fer -countregist ers ,thuswrappingaroundthecircula rbuf fer.deca ddr?-- det erminesWhethert

hecurre n t- addressreg isteris tob eincrementedord ecrementedaf te reachbytetr an sferred.Mas kbit- -Whi leac hannel'smask

biti sset(

thech a nnelissai dtob e"masked"),d maonthe channeli ss uspendedin tha tt hec hannelw il lignorere qu ests for dmatran sfer sfromt hei/odev ice .No tethatifa ni/o dev ice request

sadm atra nsfe rwhileits channeli s mas ked,andi sstil lasserting th atreque stw henthechannelbecomes unmasked,th ech annelwi llservi cetherequ est atthatt ime.Thusdataca nbelost whilea chann elis maskedo nl yift hecha n neliske ptmasked fora si gni ficantt imerel ativet oth e speedofthei/ode vice.

henthedmacontroll eris (re)in itia liz ed, includinga tp ower-up.Theycanbesetorcle ar edbythepr ogra m.Ach annel setsits ma skb itwhenth e current -tra nsfer-c ounterr uns down,exceptinAutoinitial izat ionMo de.The pr ogramcannotreadthemaskb its .TCbit- -Wheth erth ech anne l'scu

rr ent-t

ransfer -co untregist erhasrundownsincethelasttimeei the rth edma contr oll erwas(re *)initi* ali zed ,including atp ower-uporBUSDMA.READTCBITwasexplici *tl* yusedtoresetthis bit .Directmemorya cc ess--theBUSDM

AfunctionsSee theRegis ter Models ectionabo

v

efo rex planatio nsoft heargumentso fth esefunctions an dof theregist er srefe rredtobyt hem .T hes efunctionsdonotchec kt heira

rgume ntsexcept as spe cific allyn oted.(BUS DMA.INIT)--(re)initi alizet

hedmacontroll erandmemoryrefresh cui try.Maskschan nels1, 2and3,andclearsth eirTC bits.(BU SDM A.S ETMODEchannelwri te memor

y?autoinit?decad d*r?)--se tthemoderegi sterfort* h *echanne*l. (BUSDMA.SETP AGEchannelh igh bitsofad

dress)--writetot h*epagere gisterforthechann*e l. Checkst hat chan nelisint her ang e1-3.(BU SDMA.S ETAD*DRESSch*anne llo w16bi tsof

address)--writetobo t *hthebas e&currentaddressre*g is tersf or thec han nel. T hechannelmustb emaskedwhent his function isc alled-- this is thecal ler' sres ponsibil it y.(BUSDMA.READ ADDRESSchannel)=>low16bits

ofaddress--readthecu r*rentadd* r es sregisterforthecha nnel.T hec hannelmustbema skedwhenthi sfu nctionis cal led--th isis th ecalle r'sr esponsibilit y. (BUSDMA.SETCOUNTERchannel nbytes)--writet

oboththebase&curren t*transfe r-coun*t re giste rs fort hec hann e l.Check sthatnbytesisi ntherange 1-6 553 6.Thecha nnelmu stbe *masked*when thi sfunc tionisca lle d--this isth ec aller' sres ponsibility. (BUSDMA.READCOUNTERchannel)=>nbytes--readt

hecurrenttransfer-co u*ntregis* t er *forthe* channe l.N otethat thevalue65536i sreturne das (th efunctio nall yind ist ingui shabl evalue)zer o. Thechannelmustbemaskedwhenthisfunctioni scall ed- -thisis thec al ler'sr espo nsib ility.(B USDMA.MASKchannel)- -setthem askbitforthecha

nnel,disablin g*dmaonth*e channel. (BUS DMA.UNMASKchannel)--cleart hem as kbi tforthec

hannel,enabling d*maonthe*c hannel. (BUSDMA.READTCBITchannel clearthe bit ?) =>t hechanne

l'sTCbit,asTorNIL. *Alsoclea rsthebitifr* eque ste d.Directm em oryacc e ss --su mmaryofsimple useGenerallyeac

hchannelcanbe dealtw it hsepara te ly.Pla nni

n

g--

cewilluse. Dete rminewhatc onditi onswillt erminatet hedmaoperation s,an dhowthedevic e,t heprogram,andt hed macontroll erwillfindo uta boutth em.Determinewhereret heb uffer (s)wi llbe,toth eexte ntt hattheyar enotdynamica llyall ocat ed.I fyo uar eusingcircu larbufferi
ng,or oth erexo ticstuff ,you'llkno witbyth ispoin t.Globalinit iali zati on--CallBU

S.RESETwheneveryouwant
tosi mulateapo wer-down ,po wer- upcyclefor t heBusMaster ,theexpa nsion chassi s,andthede vic esontheex pansionchas sis bus.Cal lB USDMA.INIT.Thishast obed
oneatleastoncebe fore doi ngdmaont heexternalb usorex pecti ngt he memoryontheext er nalbustok eep data.I tc anb ecalledr edu ndantl y,but hasth es ideeff ectofmasking cha nne ls1 -3.S inceth er eisnowa ytoreadt hemaskbit s,ify ouha vem ul tipl e,l ogic allyi ndepe nden ti/odevic esusingdmaonthesyste m,youwillh aveto coo rd ina teBUSDMAin itia liza ti oninyourownsoftw are.Thismaybefix edla ter .Admaoperatio n-- If thech anneli

s not masked(whic
hi tis afterBU SDMA.INIT), callBU SDMA.MASK),thencallBUSD MA.SETMODE,BUSDM A.SE TPAG E,BUSDMA.SETADD RESS,andBUSDMA. SETCOUNTERinanyord er. (Ifyourmodesettin gs orp agenumberfort hech annelareco nsta nt,you don'th avetose tth emeachtime,t houghit's ch eap.)Wh ilet hechannelis maskedisasa fetim eto setupth ei /odevi ce. NowcallB USDMA.U NMASK,then,wh
enr eady,startthei/ode vice. (Itc ouldbe start edwhil ethecha nnelisma sk edifdat awouldn' tbelost ,b utthis wayalw aysworks .) Thedmaop erat ion isnowh opefull
y"i npr ogress".Y ouwil lneedtote stt hingsdurin gth isti me,e sp eciallysin cewedon'th avein terrupts.I fyouare going tous eBUSDMA.READADDRESSorBUSDMA.READCOUNTER,orother wi seneedtosuspenddmao nt hechannel temp or arilyfo rso me rea son,cal lBUSDMA.MASKtosusp end,the ncallBUSDMA.UNM ASKtoresume.To stopthedmachannel ca llBUSDM
A. MASK.Di rec tmemoryaccess--technica

lnotes(1)Thec urrent -andbase-transfe

r
-co unt register sar ekept inthehardwareasthenumberof tran sf ers remainin gl ess one,an dt hechannel checksaft *ereachb*ytet ran sferfor thecur rent- tran sfer -counthavin gbe endecrementedfromzeroto-1.BU SDMA .SETCOUNTER*andB*USDMA.READCOUNTERperformth etr anslationtothemode ldescri bed above.(2)Thei /oa ddres sesofthed evices

des cri bedhereinare th esa measontheIBMPC.Theycan bedisc over ed by ins pec tin gthe Int er lisp-Dsour ce codeinthis BUSMASTERlibrarypack age. (3)Themainpoint ofthiss ectionis

tot ell tech nical ly advancedrea ders howtheBUSDMAmethod maproce ssr ela testot heTru th abo utt heBusMasterandth eIn tel82 37-5A dmacontrolle rch ip. Thisf orthose who havereadthespec ific ati onsfo rth eInt el82 37- 5Admacontrollerch ipo rlook edatthe Bus MasterorIBMPCsch ematic s. Asi debenefit ,p erh ap s,istogiveh i ntsf orthosewhoarethi nkin gaboutusi nganexot icd evi cethroug htheB usMaste r.This sectio nisnoti nte ndedtobein
tell igiblet oacas ualreade r. BusMasterfunctio n alityt hatishi

ddenbythe BUSDMAfunctions-- theInter ru pta ndInte rruptMaskbi ts, ParityErr or, andingene rala llthe BusMastersta tus an dcontro lre gis terbits(e xceptResetviaBUS.RESET).Notethatint errup tsf romtheexter
nal- busi /odevicest othe 1108aresupporte dbyBusMaster ,bu tthe 1108microcod ewillatprese ntb lowupif presented withsu chanint erru pt .SeealsoTec hnic alNo te (1)above.I
nte l8237-5Afunct iona lit ythatd

oesnotapplyi nthehardwarecontextof the BusMast er- -Channel 0isdedi ca ted tomemoryref resh.An d thereforebl oc kmemor y-to-memory transfera ndblo ckmemoryinitiali zationar eim possi ble.I/ odevicescannotass erttheTCsig nal tothedmacontr oller. Comma ndregi st er: the timingvaria tionsma yormaynotbep hysica llypossibl e,I do n't kno w; DREQ&DACKsenseareofc ourse fixed .Mod e regi ster: "ca sc ade"modeisof cour senotpossible.Note that th ep agereg ist ersarenot
onth e8237-5 A.

a
tishi ddenbec auseitiseithe rimpossiblei ntheBus Mast erhard warecontex to ron lyusefulw ithverye xoticha rd ware (Idon' tkno wwhich)--Moderegis te r:"bl ock" mode,"de mand "mode.Commandreg ister :rotatin gprio rity.In tel8237-5Afunctionalitytha

tishi ddeninB USDMAbecauseitwasju dgedno tu sefuli ncontex t- -Re ad&wri tet herequ es tbits,rea dtem p orary reg ister,c learmaskr egister,r eadbase-address reg ister,rea dbas e-transfer-c ountregister. Commandregisterbits:disablec ontroll er.Moderegist erbits: the"verify" tran sfertype .Inte l82 37-5Afun ctionali tytha

tispa rtially hiddeninBUSDMA.Mastercleari simbed de dinBUSDM A.INIT .Read&clearstat us registerTCbi tsis p resen ted,so mewhatmodi fied ,i nBUSDMA.READTCBIT.Clearbyte se lectflipflopishid denin thef ourfunctionsBUSDMA.READ/SETADDRESS/COUNTER.