

1 BUSpec specification of AMBA-AHB protocol

AHB is a new generation of AMBA bus which is intended to address the requirements of high-performance synthesizable designs. It is a high-performance bus that supports multiple bus masters and provide high-bandwidth operation.

AMBA AHB implements the features required for high-performance, high clock frequency systems including:

- burst transfers
- split transactions
- single cycle bus-handover
- single clock edge operation

In BUSpec we have successfully modeled this protocol. We have not considered all aspects of AHB protocol such as fixed length incrementing transfers, locked transfers. However modeling of AHB bus protocol in BUSpec clearly reveals the power of this language. The BUSpec specification of AHB bus protocol is given as follows (for clarity some comments are provided in the specification).

```
StartFSM
// This is the default state of the system. A1 is the initial phase
// A2 corresponds a requesting state
StartTransfer INITIAL
  StartPhase
    A1 {
      signal {
        hbusreq = 0, hsel = 1, hmaster = 0, hgrant = 0,
        hgrantd = 1, hresp = 0, hready = 1;
      }
      N:hgrant;
      N:hbusreq;
    }
    A2 {
      signal {
        hbusreq = 1, hgrant = 0, hsel = 1, hgrantd = 1,
        hresp = 0, hmaster = 0, hready = 1;
      }
      E:hbusreq;
      N:hgrant;
    }
  EndPhase

  StartPhTrans
    A1_A1 {
      A1 A1
    }
    A1_A2 {
      A1 A2
    }
    A2_A2 {
      A2 A2
    }
  EndPhTrans
EndTransfer

// Grant sequence of the system
StartTransfer GRNT
  StartPhase
    DGRANT {
      signal {
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        hbusreq = 1, hsel = 1, hgrant = 1, hmaster = 0,
        hresp = 0, hready = 0;
    }
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}

NGRANT {
    signal {
        hbusreq = 1, hsel = 1, hgrant = 1, hmaster = 1,
        hresp = 0, hready = 1;
    }
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
EndPhase

StartPhTrans
    DGRANT_NGRANT {
        DGRANT    NGRANT
    }
    DGRANT_DGRANT {
        DGRANT    DGRANT
    }
EndPhTrans
EndTransfer

// Encoding of IDLE transfer of AHB
StartTransfer    IDLE
    StartPhase
        A17 {
            signal {
                htrans = 0, hsel = 1, hready = 1, hresp = 0,
                hmaster = 1, hgrant = 1, hbusreq = 1;
            }
            E:hgrant;
            E:hbusreq;
            ONE(hgrant);
        }

        A34 {
            signal {
                htrans = 0, hsel = 1, hready = 0, hresp = 0,
                hmaster = 1, hgrant = 1, hbusreq=1;
            }
            E:hgrant;
            E:hbusreq;
            ONE(hgrant);
        }
    }
EndPhase

StartPhTrans
    A17_A17 {
        A17    A17
    }
    A34_A17 {
        A34    A17
    }
}

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        A34_A34 {
            A34    A34
        }
    EndPhTrans
EndTransfer

// Encoding of INCR Write transfer
StartTransfer    WINCR
    StartPhase
        A3 {
            signal {
                hbusreq = 1, hsel = 1, hgrant = 1, hwrite = 1,
                hrdata = 1, hresp = 0, htrans = 2, hmaster = 1,
                hburst = 1, hready = 1;
            }
            Valid(haddr);
            E:hgrant;
            E:hbusreq;
            ONE(hgrant);
        }
        A41 {
            signal {
                hbusreq = 1, hsel = 1, hgrant = 1, hwrite = 1,
                hrdata = 1, hresp = 0, htrans = 2, hmaster = 1,
                hburst = 1, hready = 1;
            }
            Valid(hwdata),
            Valid(haddr);
            E:hgrant;
            E:hbusreq;
            ONE(hgrant);
        }
        A4 {
            signal {
                hbusreq = 1, hsel = 1, hgrant = 1, hresp = 0,
                hwrite = 1, htrans = 2, hmaster = 1,
                hburst = 1, hready = 0;
            }
            Valid(haddr);
            E:hgrant;
            E:hbusreq;
            ONE(hgrant);
        }
        A39 {
            signal {
                hbusreq = 1, hsel = 1, hgrant = 1, hresp = 0,
                hwrite = 1, htrans = 2, hmaster = 1,
                hburst = 1, hready = 0;
            }
            Valid(haddr),
            Valid(hwdata);
            E:hgrant;
            E:hbusreq;
            ONE(hgrant);
        }
        A40 {
            signal {
                hbusreq = 1, hsel = 1, hgrant = 1, hresp = 0,
                hwrite = 1, htrans = 2, hmaster = 1,
                hburst = 1, hready = 0;
            }

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    }
    Valid(haddr),
    Equal(hwdata, past(hwdata)),
    Equal(haddr, past(haddr));
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A42 {
    signal {
        hbusreq = 1, hsel = 1, hgrant = 1, hresp = 0,
        hwrite = 1, htrans = 2, hmaster = 1,
        hburst = 1, hready = 1;
    }
    Valid(haddr),
    Valid(hrdata);
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A5 {
    signal {
        hbusreq = 1, hsel = 1, hgrant = 1, hresp = 0,
        hwrite = 1, htrans = 3, hmaster = 1,
        hburst = 1, hready = 1;
    }
    Valid(haddr),
    Equal(haddr, past(haddr)+hsize),
    Valid(hwdata);
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A6 {
    signal {
        hbusreq = 1, hsel = 1, hgrant = 1,
        hresp = 0, hwrite = 1, htrans = 3, hmaster = 1,
        hburst = 1, hready = 0;
    }
    Equal(haddr, past(haddr)+hsize),
    Valid(hwdata);
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A47 {
    signal {
        hbusreq = 1, hsel = 1, hgrant = 1,
        hresp = 0, hwrite = 1, htrans = 3, hmaster = 1,
        hburst = 1, hready = 0;
    }
    Equal(hwdata, past(hwdata)),
    Equal(haddr, past(haddr));
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A7 {
    signal {
        hbusreq = 1, hgrant = 1, hresp = 0, htrans = 1,

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        hwrite = 1, hsel = 1, hmaster = 1,
        hburst = 1, hready = 1;
    }
    Valid(haddr),
    Equal(haddr, past(haddr)+hsize),
    Valid(hwdata);
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A48 {
    signal {
        hbusreq = 1, hgrant = 1, hresp = 0, htrans = 1,
        hwrite = 1, hsel = 1, hmaster = 1,
        hburst = 1, hready = 1;
    }
    Valid(haddr),
    Valid(hwdata),
    Equal(hwdata, past(hwdata)),
    Equal(haddr, past(haddr));
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A18 {
    signal {
        hbusreq = 1, hgrant = 1, hresp = 0, hsel = 1,
        htrans = 1, hwrite = 1, hmaster = 1,
        hburst = 1, hready = 0;
    }
    Valid(haddr),
    Valid(hwdata);
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A8 {
    signal {
        hbusreq = 0, hsel = 1, hgrant = 1, hresp = 0,
        hmaster = 1, hwrite = 1, htrans = 3,
        hburst = 1, hready = 1;
    }
    Valid(haddr),
    Equal(haddr, past(haddr)+hsize),
    Valid(hwdata);
    E:hgrant;
    N:hbusreq;
    ONE(hgrant);
}
A9 {
    signal {
        hbusreq = 0, hgrant = 1, hresp = 0, hsel = 1,
        hwrite = 1, htrans = 3, hmaster = 1,
        hburst = 1, hready = 0;
    }
    Valid(haddr),
    Valid(hwdata);
    E:hgrant;
    N:hbusreq;
    ONE(hgrant);
}

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    }
EndPhase

StartPhTrans
  a4_a4 {
    A4    A4
  }
  a4_a3 {
    A4    A3
  }
  a3_a4 {
    A3    A4
  }
  a3_a5 {
    A3    A5
  }
  a3_a6 {
    A3    A6
  }
  a3_a7 {
    A3    A7
  }
  a3_a8 {
    A3    A8
  }
  a3_a18 {
    A3    A18
  }
  a3_a9 {
    A3    A9
  }
  a5_a5 {
    A5    A5
  }
  a5_a6 {
    A5    A6
  }
  a5_a7 {
    A5    A7
  }
  a5_a8 {
    A5    A8
  }
  a5_a18 {
    A5    A18
  }
  a5_a9 {
    A5    A9
  }
  a6_a5 {
    A6    A5
  }
  a6_a47 {
    A6    A47
  }
  a47_a47 {
    A47   A47
  }
  a6_a8 {
    A6    A8
  }

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    }
    a47_a8 {
        A47    A8
    }
    a7_a48 {
        A7     A48
    }
    A8_a48 {
        A8     A48
    }
    a48_a48 {
        A48    A48
    }
    a7_a5 {
        A7     A5
    }
    a7_a8 {
        A7     A8
    }
    a9_a8 {
        A9     A8
    }
    a9_a9 {
        A9     A9
    }
    a18_a7 {
        A18    A7
    }
    a18_a18 {
        A18    A18
    }
    a39_a40 {
        A39    A40
    }
    a40_a40 {
        A40    A40
    }
    a40_a41 {
        A40    A41
    }
    a39_a41 {
        A39    A41
    }
}
EndPhTrans
EndTransfer

// Encoding of INCR Read transfer
StartTransfer RINCR
StartPhase
A19 {
    signal {
        hbusreq = 1, hsel = 1, hgrant = 1,
        hwrite = 0, hresp = 0, htrans = 2,
        hmaster = 1, hburst = 1, hready = 1;
    }
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A20 {

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signal {
    hbusreq = 1, hsel = 1, hgrant = 1, hresp = 0,
    hwrite = 0, htrans = 2, hmaster = 1,
    hburst = 1, hready = 0;
}
E:hgrant;
E:hbusreq;
ONE(hgrant);
}
A46 {
    signal {
        hbusreq = 1, hsel = 1, hgrant = 1,
        hresp = 0, hwrite = 0, htrans = 2,
        hmaster = 1, hburst = 1, hready = 0;
    }
    Valid(hrdata);
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A43 {
    signal {
        hbusreq = 1, hsel = 1, hgrant = 1, hresp = 0,
        hwrite = 0, htrans = 2, hmaster = 1,
        hburst = 1, hready = 0;
    }
    Valid(hwdata);
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A44 {
    signal {
        hbusreq = 1, hsel = 1, hgrant = 1, hresp = 0,
        hwrite = 0, htrans = 2, hmaster = 1,
        hburst = 1, hready = 0;
    }
    Equal(hwdata, past(hwdata)),
    Equal(haddr, past(haddr));
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A45 {
    signal {
        hbusreq = 1, hsel = 1, hgrant = 1, hresp = 0,
        hwrite = 0, htrans = 2, hmaster = 1,
        hburst = 1, hready = 0;
    }
    Valid(hwdata);
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A21 {
    signal {
        hbusreq = 1, hsel = 1, hgrant = 1, hresp = 0,
        hwrite = 0, hrdata = 1, htrans = 3,
        hmaster = 1, hburst = 1, hready = 1;
    }
}

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Valid(hrdata),
Equal(haddr, past(haddr) + hsize);
E:hgrant;
E:hbusreq;
ONE(hgrant);
}
A22 {
  signal {
    hbusreq = 1, hsel = 1, hgrant = 1, hresp = 0,
    hwrite = 0, htrans = 3, hmaster = 1, hburst = 1,
    hready = 0;
  }
  Equal(haddr, past(haddr) + hsize);
  E:hgrant;
  E:hbusreq;
  ONE(hgrant);
}
A23 {
  signal {
    hbusreq = 1, hgrant = 1, hresp = 0, htrans = 1,
    hwrite = 0, hsel = 1, hrdata = 1, hmaster = 1,
    hburst = 1, hready = 1;
  }
  E:hgrant;
  E:hbusreq;
  ONE(hgrant);
}
A24 {
  signal {
    hbusreq = 1, hgrant = 1, hresp = 0, hsel = 1,
    htrans = 1, hwrite = 0, hmaster = 1, hburst = 1,
    hready = 0;
  }
  E:hgrant;
  E:hbusreq;
  ONE(hgrant);
}
A25 {
  signal {
    hbusreq = 0, hsel = 1, hgrant = 1, hresp = 0,
    hmaster = 1, hwrite = 0, htrans = 3,
    hburst = 1, hready = 1;
  }
  Valid(hrdata);
  E:hgrant;
  N:hbusreq;
  ONE(hgrant);
}
A26 {
  signal {
    hbusreq = 0, hgrant = 1, hresp = 0, hsel = 1,
    hwrite = 0, htrans = 3, hmaster = 1, hburst = 1,
    hready = 0;
  }
  Equal(haddr, past(haddr));
  E:hgrant;
  N:hbusreq;
  ONE(hgrant);
}
EndPhase

```

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StartPhTrans
  a19_a19 {
    A19    A19
  }
  a19_a20 {
    A19 A20
  }
  a20_a21 {
    A20 A21
  }
  a20_a22 {
    A20 A22
  }
  a20_a23 {
    A20 A23
  }
  a20_a24 {
    A20 A24
  }
  a20_a25 {
    A20 A25
  }
  a20_a26 {
    A20 A26
  }
  a21_21 {
    A21 A21
  }
  A21_A22 {
    A21 A22
  }
  A21_A26 {
    A21 A26
  }
  a21_a25 {
    A21 A25
  }
  a21_a24 {
    A21 A24
  }
  a22_a26 {
    A22 A26
  }
  a22_a21 {
    A22 A21
  }
  a22_a26 {
    A22 A26
  }
  a22_a25 {
    A22 A25
  }
  a23_a23 {
    A23 A23
  }
  a23_a21 {
    A23 A21
  }
  a23_a25 {

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        A23 A25
    }
    a24_a24 {
        A24 A24
    }
    a24_a23 {
        A24 A23
    }
    a26_a26 {
        A26 A26
    }
    a26_a25 {
        A26 A25
    }
    a43_a44 {
        A43 A44
    }
    a44_a44 {
        A44 A44
    }
    a44_a45 {
        A44 A45
    }
    a43_a45 {
        A43 A45
    }
}
EndPhTrans
EndTransfer

// Encoding of SINGLE Write transfer
StartTransfer WSINGLE
StartPhase
A10 {
    signal {
        hbusreq = 1, hgrant = 1, hresp = 0, hsel = 1,
        hwrite = 1, hmaster = 1, htrans = 2,
        hburst = 0, hready = 1;
    }
    Valid(haddr);
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A11 {
    signal {
        hbusreq = 1, hgrant = 1, hsel = 1, hresp = 0,
        htrans = 2, hburst = 0, hwrite = 1, hready = 0;
    }
    Valid(haddr);
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A12 {
    signal {
        hbusreq = 0, hgrant = 1, hresp = 0, hsel = 1,
        hwrite = 1, htrans = 2, hburst = 0,
        hready = 1;
    }
    Equal(haddr, past(haddr) + hsize),

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Valid(hwdata),
Valid(haddr);
E:hgrant;
N:hbusreq;
ONE(hgrant);
}
A50 {
  signal {
    hbusreq = 0, hgrant = 1, hresp = 0, hsel = 1,
    hwrite = 1, htrans = 2, hburst = 0,
    hready = 0;
  }
  Equal(haddr, past(haddr) + hsize),
  Valid(hwdata),
  Valid(haddr);
  E:hgrant;
  N:hbusreq;
  ONE(hgrant);
}
A51 {
  signal {
    hbusreq = 0, hgrant = 1, hresp = 0, hsel = 1,
    hwrite = 1, htrans = 2, hburst = 0,
    hready = 0;
  }
  Equal(haddr, past(haddr)),
  Valid(hwdata);
  E:hgrant;
  N:hbusreq;
  ONE(hgrant);
}
A52 {
  signal {
    hbusreq = 0, hgrant = 1, hresp = 0, hsel = 1,
    hwrite = 1, htrans = 2, hburst = 0,
    hready = 1;
  }
  Equal(haddr, past(haddr)),
  Valid(hwdata);
  E:hgrant;
  N:hbusreq;
  ONE(hgrant);
}
A53 {
  signal {
    hbusreq = 0, hgrant = 1, hresp = 0, hsel = 1,
    hwrite = 1, htrans = 2, hburst = 0,
    hready = 0;
  }
  Equal(haddr, past(haddr));
  E:hgrant;
  N:hbusreq;
  ONE(hgrant);
}
A54 {
  signal {
    hbusreq = 0, hgrant = 1, hresp = 0, hsel = 1,
    hwrite = 1, htrans = 2, hburst = 0,
    hready = 1;
  }
}

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        Equal(haddr, past(haddr)),
        Valid(hrdata);
        E:hgrant;
        N:hbusreq;
        ONE(hgrant);
    }

EndPhase

StartPhTrans
    a10_a11 {
        A10 A11
    }
    a11_a10 {
        A11 A10
    }
    a11_a12 {
        A11 A12
    }
    a11_a53 {
        A11 A53
    }
    a53_a53 {
        A53 A53
    }
    a53_a54 {
        A53 A54
    }
    a50_a51 {
        A50 A51
    }
    a51_a51 {
        A51 A51
    }
    a51_a52 {
        A51 A52
    }
    a12_a50 {
        A12 A50
    }
}

EndPhTrans
EndTransfer

// Encoding of SINGLE Read transfer
StartTransfer    RSINGLE
    StartPhase
        A27 {
            signal {
                hbusreq = 1, hgrant = 1, hresp = 0, hsel = 1,
                hwrite = 0, hwdata = 1, hmaster = 1, htrans = 2,
                hburst = 0, hready = 0;
            }
            Valid(hrdata);
            E:hgrant;
            E:hbusreq;
            ONE(hgrant);
        }
        A28 {
            signal {

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        hbusreq = 1, hgrant = 1, hsel = 1, hresp = 0,
        htrans = 2, hburst = 0, hwrite = 0,
        hready = 1;
    }
    Equal(haddr, past(haddr) + hsize),
    Valid(hrdata);
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A49 {
    signal {
        hbusreq = 1, hgrant = 1, hsel = 1, hresp = 0,
        htrans = 2, hburst = 0, hwrite = 0,
        hready = 1;
    }
    Equal(haddr, past(haddr)),
    Valid(hwdata);
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A55 {
    signal {
        hbusreq = 1, hgrant = 1, hsel = 1, hresp = 0,
        htrans = 2, hburst = 0, hwrite = 0,
        hready = 0;
    }
    Valid(haddr),
    Valid(hwdata);
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A56 {
    signal {
        hbusreq = 1, hgrant = 1, hsel = 1, hresp = 0,
        htrans = 2, hburst = 0, hwrite = 0,
        hready = 0;
    }
    Equal(haddr, past(haddr)),
    Equal(hwdata, past(hwdata));
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A58 {
    signal {
        hbusreq = 1, hgrant = 1, hsel = 1, hresp = 0,
        htrans = 2, hburst = 0, hwrite = 0,
        hready = 0;
    }
    Valid(haddr);
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A59 {
    signal {
        hbusreq = 1, hgrant = 1, hsel = 1, hresp = 0,

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        htrans = 2, hburst = 0, hwrite = 0,
        hready = 0;
    }
    Equal(haddr, past(haddr));
    E:hgrant;
    E:hbusreq;
    ONE(hgrant);
}
A29 {
    signal {
        hbusreq = 0, hgrant = 1, hresp = 0, hsel = 1,
        hwrite = 0, htrans = 2, hburst = 0,
        hready = 1;
    }
    Valid(hrdata);
    E:hgrant;
    N:hbusreq;
    ONE(hgrant);
}
EndPhase

StartPhTrans
    a27_a27 {
        A27 A27
    }
    a27_a28 {
        A27 A28
    }
    a27_a29 {
        A27 A29
    }
    a28_a28 {
        A28 A28
    }
    a28_a29 {
        A28 A29
    }
    a28_a27 {
        A28 A27
    }
    a55_a56 {
        A55 A56
    }
    a56_a56 {
        A56 A56
    }
    a56_a49 {
        A56 A49
    }
    a58_a49 {
        A58 A49
    }
    a59_a49 {
        A59 A49
    }
}
EndPhTrans
EndTransfer

//Encoding of SPLIT sequence
StartTransfer    SPLIT

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StartPhase
  A13 {
    signal {
      hgrant = 1, hmaster = 1, hresp = 3, hsel = 1,
      hwrite = 1, htrans = 2, hready = 0;
    }
    E:hgrant;
    ONE(hgrant);
  }
  A35 {
    signal {
      hgrant = 1, hmaster = 1, hresp = 3, hsel = 1,
      hwrite = 1, htrans = 3, hready = 0;
    }
    E:hgrant;
    ONE(hgrant);
  }
  A36 {
    signal {
      hgrant = 1, hmaster = 1, hresp = 3, hsel = 1,
      hwrite = 1, htrans = 1, hready = 0;
    }
    E:hgrant;
    ONE(hgrant);
  }
  A30 {
    signal {
      hgrant = 1, hmaster = 1, hresp = 3, hsel = 1,
      hwrite = 0, htrans = 2, hready = 0;
    }
    E:hgrant;
    ONE(hgrant);
  }
  A37 {
    signal {
      hgrant = 1, hmaster = 1, hresp = 3, hsel = 1,
      hwrite = 0, htrans = 3, hready = 0;
    }
    E:hgrant;
    ONE(hgrant);
  }
  A38 {
    signal {
      hgrant = 1, hmaster = 1, hresp = 3, hsel = 1,
      hwrite = 0, htrans = 1, hready = 0;
    }
    E:hgrant;
    ONE(hgrant);
  }
  A14 {
    signal {
      hgrant = 0, hgrantd = 1, hresp = 3, hsel = 1,
      htrans = 0, hbusreq = 1, hready = 1;
    }
    N:hgrant;
    E:hbusreq;
  }
EndPhase
StartPhTrans
  a13_a14 {

```

```

        A13 A14
    }
    a30_a14 {
        A30 A14
    }
    a35_a14 {
        A35 A14
    }
    a36_a14 {
        A36 A14
    }
    a37_a14 {
        A37 A14
    }
    a38_a14 {
        A38 A14
    }
    }
    EndPhTrans
EndTransfer

//Encoding of RETRY sequence
StartTransfer    RETRY
    StartPhase
        A31 {
            signal {
                hgrant = 1, hmaster = 1, hresp = 2, hsel = 1,
                hwrite = 1, htrans = 2, hready = 0;
            }
            E:hgrant;
            ONE(hgrant);
        }
        A32 {
            signal {
                hgrant = 1, hmaster = 1, hresp = 2,
                hsel = 1, hwrite = 0, htrans = 2, hready = 0;
            }
            E:hgrant;
            ONE(hgrant);
        }
        A33 {
            signal {
                hgrant = 0, hgrantd = 1, hresp = 2,
                hsel = 1, htrans = 0, hbusreq = 1, hready = 1;
            }
            E:hbusreq;
            N:hgrant;
        }
    }
EndPhase
StartPhTrans
    a31_a33 {
        A31 A33
    }
    a32_a33 {
        A32 A33
    }
}
EndPhTrans
EndTransfer

// Encoding of SPLIT sequence (req)
StartTransfer    RSPLIT

```

```

StartPhase
  A15 {
    signal {
      hbusreq = 1, hgrant = 0, hgrantd = 1,
      hresp = 0, hsel = 1, split = 1;
    }
    E:hbusreq;
    N:hgrant;
  }
  A16 {
    signal {
      hbusreq = 1, hgrant = 0, hsel = 1,
      hgrantd = 1, hresp = 0, hsplit = 1,
      split = 1;
    }
    E:hbusreq;
    N:hgrant;
  }
EndPhase
StartPhTrans
  a15_a16 {
    A15 A16
  }
EndPhTrans
EndTransfer

// Encoding of inter-transfer transitions
StartSmTrans
  a2_DGRANT {
    A2 DGRANT
  }
  a2_NGRANT {
    A2 NGRANT
  }
  a33_DGRANT {
    A33 DGRANT
  }
  a33_NGRANT {
    A33 NGRANT
  }
  a33_a2 {
    A33 A2
  }
  NGRANT_a3 {
    NGRANT A3
  }
  NGRANT_a4 {
    NGRANT A4
  }
  NGRANT_a10 {
    NGRANT A10
  }
  NGRANT_a11 {
    NGRANT A11
  }
  NGRANT_a17 {
    NGRANT A17
  }
  NGRANT_a31 {
    NGRANT A34
  }

```

```

}
NGRANT_a19 {
  NGRANT A19
}
NGRANT_a20 {
  NGRANT A20
}
NGRANT_a27 {
  NGRANT A27
}
NGRANT_a28 {
  NGRANT A28
}
a28_20 {
  A28 A20
}
a28_a19 {
  A28 A19
}
a28_a3 {
  A28 A3
}
a28_a4 {
  A28 A4
}
a28_a10 {
  A28 A10
}
a28_a11 {
  A28 A11
}
a28_a30 {
  A28 A30
}
a28_a28 {
  A28 A28
}
a27_a28 {
  A27 A28
}
a28_a32 {
  A28 A32
}
a28_a54 {
  A28 A54
}
a49_a54 {
  A49 A54
}
a49_a11 {
  A49 A11
}
a27_a30 {
  A27 A30
}
a27_a32 {
  A27 A32
}
a29_a30 {
  A29 A30
}
}

```

```
a29_a32 {
  A29 A32
}
a29_a1 {
  A29 A1
}
a29_a2 {
  A29 A2
}
a29_a11 {
  A29 A11
}
a25_a30 {
  A25 A30
}
a25_a32 {
  A25 A32
}
a25_a1 {
  A25 A1
}
a25_a2 {
  A25 A2
}
a26_a30 {
  A26 A30
}
a26_a32 {
  A26 A32
}
a21_a27 {
  A21 A27
}
a22_a27 {
  A22 A27
}
a8_a1 {
  A8 A1
}
a8_a2 {
  A8 A2
}
a8_a13 {
  A8 A13
}
a8_a31 {
  A8 A31
}
a12_a1 {
  A12 A1
}
a12_a2 {
  A12 A2
}
a12_a13 {
  A12 A13
}
a12_a31 {
  A12 A31
}
}
```

```
a10_a13 {
    A10 A13
}
a10_a31 {
    A10 A31
}
a10_a1 {
    A10 A1
}
a10_a2 {
    A10 A2
}
a10_a3 {
    A10 A3
}
a10_a4 {
    A10 A4
}
a10_a27 {
    A10 A27
}
a10_a28 {
    A10 A28
}
a10_a19 {
    A10 A19
}
a10_a20 {
    A10 A20
}
a14_a15 {
    A14 A15
}
a16_a2 {
    A16 A2
}
a16_a1 {
    A16 A1
}
a16_NGRANT {
    A16 NGRANT
}
a16_DGRANT {
    A16 DGRANT
}
a17_a3 {
    A17 A3
}
a17_a4 {
    A17 A4
}
a17_a10 {
    A17 A10
}
a17_a11 {
    A17 A11
}
a21_a46 {
    A21 A46
}
}
```

```
a5_a43 {
    A5    A43
}
a5_a41 {
    A5    A41
}
a21_a42 {
    A21    A42
}
a10_a49 {
    A10    A49
}
a12_a49 {
    A12    A49
}
a5_a49 {
    A5    A49
}
a12_a12 {
    A12 A12
}
a52_a12 {
    A52 A12
}
a10_a12 {
    A10 A12
}
a52_a50 {
    A52 A50
}
a54_a12 {
    A54 A12
}
a49_a11 {
    A49 A11
}
}
```

```
EndSmTrans
EndFSM
```